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

PRUDENCE

Contract No. EVK2-2001-00156

Event: 4th PRUDENCE project meeting
Palacio Lorenzana
ES-45071 Toledo
Spain
6 September – 10 September, 2004

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Content list

Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects – 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 12 institutions from several European countries, Israel, Australia, the USA and Canada have expressed their interest in the projects and some have 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 work plan 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. The kick-off meeting took place during 3 – 5 December, 2001 in Snekkersten, Denmark. 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, while a third meeting 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*, held at Hotel Regina in Wengen, Switzerland.

The present document presents the minutes of the fourth and final project meeting attended by the entire PRUDENCE consortium and several of the afore mentioned additional groups. The meeting took place at

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Synopsis

The 4th 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 finish 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 work package leaders, the coordinators of the EU-project STARTDEX and MICE and one additional invited speaker using Prudence output within the EU-project SWURVE during the conference. As the project is coming to its end, many results have already been achieved and reported upon elsewhere. This work shop gave a unique opportunity to communicate new results to an expert audience – the PRUDENCE consortium. The scientific presentations by the partners were given approximately 30 minutes each. This allowed enough time for questions and initial discussions. On days 4 - 5, the work package (WP) participants met in various constellations to monitor in detail the progress of the work, defined by deliverables and milestones. A plenary session for planning of the last phase of the project was 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. Also at the present meeting, a number of external participants were accepted 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 Thursday evening of the meeting as well as during plenary sessions. 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 were taken and that most of the remaining tasks are concentrated within WP7 and particularly issues related to non-technical outreach of the project has high priority.

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 was formed by:

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

4th SSG and EAG meetings

On the evening of the 9 September, the members of the PRUDENCE SSG and EAG met for the fourth 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 was 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)
Martina Jung for Axel Michaelowa; for Hamburg Institute of Intern. 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)
÷ Georgios Armanatidis; for DG-R

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

The proposed agenda for the meeting was as follows:

1. Accept of agenda
2. PRUDENCE management reports
3. WP progress
4. Update on PRUDENCE Special Issue of *Climatic Change*
5. Issues missed so far/AOB

1) Accept of agenda JHC welcomes. This is for interaction with other projects like MICE and STARDEX. JHC points out where reports are located. Asks for reports of any irregularities re. deliverables. An important point to keep in mind during this meeting: how to reach out Glossy? Brochure? Clare Goodess raised the point of the role of the project cluster, and any relations to ENSEMBLES.

2) PRUDENCE management report. Last management report was briefly discussed. Publication list handed out illustrates that scientifically we are very successful. We have almost 2 papers per participant and the bulk of material is still to be published. Regarding management, very few milestones/deliverables have looked problematic. Some groups have been delayed by lack of data from other groups. One problem has been HC data required by DLR, but ways around have been found. Only deliverables left are those supposed to be finished during last 6 months. An important next step is to complete the Technical implementation plan. A draft should have been handed in with first 6-month report, but no complaints have been heard. TIP is a Brussels tool to check that practical details are on track. More relevant for bridges than for scientific work.

Management reports have been minimalist. The final management report needs extra items: Annual report plus TIP plus cost statements. WP leaders must assist on WP report, around 5 pages per WP. Fixed report format exists for ease of work. Apart from this we need a detailed report up to 50 pages for entire project. All partners need to participate in this. Also steering group will be called upon. Deadline is 2 months after end of project, *i.e.*, 1/1/05. Armanatidis has furthermore requested an assessment of our project, in particular policy relevance. This should be possible.

We need to follow the form in cost statements. STARDEX has had bad experiences with mismatch between cost statements and PM allocation. Kirsten Halsnæs posed the question: When are we going to spend remaining travel budget? There is no doubt to this, it must be done before 1/11 (end of project). In general, we should finish the reports in good time, as it is hard to do when nobody gets any money anymore.

3) WP progress Concept of merged deliverables explained by JHC.

WP1+2 (Dave Rowell): i) Uncertainties in models. Written by Michel Deque. ii)Assessment of current climate. Jens H Christensen responsible. Work is done, report still to be written. Iii) Uncertainty among RCMs. Michel Deque is working on paper. Lots of geographical analyses. We will have enough fulfil the contract. Trond Iversen asked to the uncertainty assessments (MD3), if there has been analyses for whole of Europe? Dave Rowell answered: Yes.

WP3 (Phil Graham): We have all under control, except D3B3, hi-res RCM fed hydrological modelling. It appears as no real improvement is seen in using the double resolution. This deliverable therefore will not be completed. This was decided in Lund; that ETH and MPI would not deliver hi-res HadCM3-SST-based runs due to Baltic error. But now we are at only 2, not 4 hi-res runs as promised. Instead, MPI delivers an alternative B2 high resolution run. This has been finished, but not yet delivered to the server. Also UCM offers to deliver a high resolution run only covering the Iberian Peninsula. The point is that the high resolution runs mostly are used for feasibility studies – leaving the real work for ENSEMBLES. In finishing the project argumentation will be important as plain ignorance will be a violation of the contract!

Deliverables to other WPs: D3A4, comprehensive report, to WP6-7 (dissemination and economy). Has been done. Final paper is on its way.

WP4 (Jørgen Olesen): Also here, final paper has been planned at this meeting. Had obligations month 30-34. But not all, though most, model runs have been finished at this time. It is estimated that within n a month or so, all should be ready for reporting. So, some deliverables will be delayed to the very end of the project. This is not a major issue. We have all data etc., so no unexpected problems should occur.

Though WP4 earlier had not been on schedule, it has caught up in general. Some interpolation problems remain, but nothing serious. More analyses will be performed. In any case, deliverable deadlines will be met.

WP5 (Chris Ferro): Several notes have been produced, and other WPs have received assistance. 2nd deliverable has been done, being used for wider analyses. 3rd (Brigitte Koffi) had been delayed, but progress has been made lately; should be OK. 4th, heat waves, on track. Also Jean has worked on that. Should be there in time by the end of project. Hydropower: Fribourg. Has been discussed with the coordinator. Although the relevance of climate change for hydropower production is high, this deliverable is better suited for WP6. Here the paper summarizing WP6 is addressing this issue already. Along with this Fribourg has delivered other relevant analysis, e.g. with respect to snow. Kirsten Halsnæs noted that the promised deliverable was discussed in Ch. D'Oex and could not be done. The coordinator will make sure this information will be brought forward in the context of the final report. Next one, CRU, is OK. Resource risk (Kirsti and Tim) some work has been done, and is almost finished. 5B on storms is GKSS (Katja) is in preparation for a joint paper. Stefan Hagemann, in this context raised the question: Has WP5 discussed where to put validation on extremes? Has been discussed, but no conclusions. It will most likely be dealt with in the special issue paper on model validation. Besides, there are plenty of STARDEX indices to investigate and some has been done within STARDEX and MICE. This is all a little late, since it requires some work. Also in SWURVE some hydrological work will be done. There is in general little data available for validation. So, in conclusion, there would not be a centralised extreme validation in the WP1+2 paper.

WP6 (Kirsten Halsnæs): First two have been met. Then one in month 33. Trying to link indices of precipitation to economy. Here focus has mostly been on urban areas. Some discussions in WP6: How to move from micro-level to aggregated economical models. It has been worth the effort to try! The IIASA study (2 months of Risø effort subcontracted) has given interesting results. CIRED will still have to make more detailed report on how to cover last deliverables. Detailed plan in three weeks. The scheduled workshop is not possible since there is no budget for this! Still, we can be active in participating in existing meetings. May be results can still be presented to EU representatives in minor meeting – or possible final press release. Too bad that Amanatidis not present. He expressed strong interest in PRUDENCE assessing itself. This would be promoted by him, so money might be there. Then he said that this funding from Brussels could also be used for press conferences and brochures. The coordinator will possibly have the chance to discuss at the ENSEMBLES kick-off meeting a week from now. The ACACIA project some years ago had a small meeting with EU representatives like the one suggested here. For that PRUDENCE still has a bit of money. This is all up to EU. Tim Carter noted on the IIASA contribution, that some stuff was similar to WP4. If we had known, WP4 might not have done this. What does WP6 require from IIASA? The IIASA was a stand-in due to sickness. So, there were personal interest reasons for overlap of themes. It does not appear to be a serious problem, but the coordinator should have ensured that no duplications of work occurs.

WP7 (Jens H Christensen): Dissemination. 1st, accessibility of boundary and output data. We realized that no specific need within the project to put boundary data up. New data are becoming available. Instead tapes were used. RCM output data are available on the web site.

2nd: web site. This does exist (http://prudence.dmi.dk) We will put up a front page with information, user registration and general information on PRUDENCE now that the data archive has been made public. Next: presentation of major findings (due end of project). Could be put on web site. Then one on impacts as obtained in PRUDENCE. We already have the material and it will be put together.

4) Update on special issue (PSICC) There will be a synthesis paper, the coordinator is in charge. Then, one paper from each WP. These should be outlined ASAP to make the synthesis paper possible. In WP1+2 meeting some bullet points were collected about major findings that should be communicated in synthesis paper. E.g. existence of mesoscale phenomena in RCMs and possible prediction of their future behaviour. We know already that a lot of studies, like WP5, requires RCMs. Filippo Giorgi: Are hydrology models improved by higher resolution? Phil Graham: We see differences - I think there is an improvement. For example, when scaling precipitation that is better in RCMs than GCMs. Thus, snow is better. Less calibration of seasonality. Tim Carter iterated on this by stating that in WP4 we are not so sure about added value. But, when running impact models we prefer delta-change to direct model input. Then, it is possibly a matter of faith whether change in RCMs is believable. Examples are furthermore provided analysing extreme events.
Manfred Lange argued: Two-way interaction re. model improvement between impact groups and modellers would be important. Normally this is a one-way thing. PRUDENCE is a possibility for something new. Phil Graham noted that at SMHI this has been going on for a while. In the last several years RCA has been improved due to dialog with hydrologists. Trond Iversen reminded that PRUDENCE aught to remember that there are still issues for ENSEMBLES. Tim Carter added that we have learned under which circumstances models can be used. We can provide guidance! We are advancing in leaps and bounds. Hence, PRUDENCE as a guidance point is essential.

Then there are WP papers. We have seen some of the relevant work already. These are in very different stages of development. A second volume of solicited papers will come, more than 30 titles have been offered, which is too much. Only 200 pages in a small format are available. Tim Carter and Markku Rummukainen will assist the coordinator in selecting papers in order to find a balance between papers with the goal of selecting 10 papers spanning the spectrum. Papers not to be in this issue are not disqualified, but would simply not be feasible. Also focus: All PSICC papers must be PRUDENCE-relevant. Other papers can be sent to other journals. More than 30 abstracts have been forwarded. Timeline: Is informal. We wish to meet IPCC requirement, in press end of 2005. Thus, papers need to be accepted summer '05. 1/11/04 is deadline, but will be delayed somewhat. Effectively, 1/1/05 will be the deadline.

Acronyms, references, figures need to be synchronized. Model descriptions etc. are already in WP5 paper but should be removed if in WP1/2 paper. Within this month names of models, experiments should be agreed upon. Phil Graham: In the final SWECLIM report this kind of work was done already. Syntax should be agreed upon. Some reference table will also be necessary. Phil Graham will send a mail with SWECLIM the syntax. This happens in STARDEX now as well. There is also a STARDEX paper in PSICC. We are not competing! The different applicability of statistical and dynamical downscaling is stressed there. There is a MICE special issue in some impacts journal. STARDEX publishes on an individual basis.

5) Issues missed so far Brochure? Manfred Lange: PRUDENCE has served as a model for other projects like the US one. State Europe's leading role in this field. May be we could accelerate making the reference from the IPCC-DDC. Tim Carter will take this up in the IPCC task group. Trond Iversen reminded about the importance of identifying what format/audience a brochure would have? An option that will pursued is policymakers like

MPs, and media. But also a non-scientific version; 5-6 pages, perhaps like ECMWF ERA-40 folder? For a glossy brochure we need professional layout!

The 3 projects: Brochure could be postponed until STARDEX finish (10 months from now). CG: Amanatidis eager about joint publication. But, PRUDENCE should go ahead. What about EGU visibility? There should be plenty of papers.

Notes on PRUDENCE

Martina Jung
Hamburg Institute of International Economics, Germany

My following judgements as an external advisor to the PRUDENCE project are based on reading the project summary, the information on the PRUDENCE homepage as well participating in the PRUDENCE workshop and Business Meeting in Toledo.

I am quite impressed by the overall achievements of the PRUDENCE project. Its innovative approach to analyze impacts of climate change and their uncertainties due to the use of different climate and impact models (as well as different emissions scenarios) has proven successful.

One ambitious goal of the project was the linking of the climate and impact modelling community. For achieving this goal, problems regarding different data formats, types of data and research concepts had to be solved. In the course of the project, most of these issues have been addressed successfully. It would be interesting for future research projects to get insights into which problems in linking the different areas have come up and how they have been addressed. Furthermore, PRUDENCE should report on how the magnitude of uncertainties found in the climate and impact models relates to the uncertainties connected with the translation of those physical impacts into economic ones.

While the dissemination of outputs at the most detailed level (data set) seems to be almost completed, dissemination of results on a non-technical level (part of WP 7) are still less developed. The project management is aware of the importance of dissemination of results to the general public and policy-makers, though. For accomplishing this challenging task, it would, therefore, be important to get a clearer picture of which results are especially policy-relevant, and to which level of policy-makers as well as which results are interesting to the general public. This will determine which dissemination approaches (some of them proposed in the workshop, e.g. brochures, national workshops…) are most appropriate. General questions regarding the existence of anthropogenic climate change and its uncertainty levels might be more interesting at the international level (UN climate negotiations, EU), while at the national and sub national level information on ranges of impacts to be expected, their importance for particular sectors and possible adaptation measures might be more relevant for the formulation of climate policy strategies.

Furthermore, it should be considered to establish contacts to other projects focussing on impacts and adaptation, which could take advantage from the knowledge gained in the PRUDENCE project. Since the subject of adaptation has gained political importance in the last years, the PRUDENCE outputs regarding impacts could be highly relevant for future adaptation policies.

Münster, 20. September 2004

Westfälische Wilhelms -Universität Münster
Institut für Geophysik
Prof. Dr. Manfred A. Lange

Comments on PRUDENCE

Prof. Dr. Manfred A. Lange

PRUDENCE is a major EU-funded project that is getting close to its completion. The project aims at a number of objectives including:

- a series of high resolution climate change scenarios for Europe for 2071-2100,
- an assessment of uncertainties of European regional climate models (RCMs),
- an assessment of risks caused by climate change for Europe,
- the application of RCM results to a number of clima te impact studies,
- an assessment of implications of climate change for socio-economic and political decision making and
- a broad dissemination of PRUDENCE results.

PRUDENCE has been carried out by 20 partners over three years. Thus, managing, steering and integrating the project and individual results have been substantial challenges. The coordinator and the project steering group should be commended on succeeding in navigating the project smoothly and effectively. As a measure of productivity within the project, the recent list of publication includes some 60 papers and reports, some in high ranking journals such as NATURE or Geophysical Research Letters. The publication record and other means of communication have resulted in a high profile within the international scientific community. PRUDENCE has thus significantly underlined the leading position of European climate modelling on an international level. This is also reflected by attempts of a number of research groups in North- and South America to use the PRUDENCE approach and major methodologies in similar national projects.

PRUDENCE has resulted in a wealth of data, scenarios and information. There have been a fairly large number of individual RCMs developed and implemented under PRUDENCE. One of the major results from the modelling work to be highlighted is the conclusion that RCMs are indeed capable of resolving meso-scale features that the global models that serve as boundary conditions are incapable of showing. Furthermore, there has been a fruitful dialogue between the modelling community and the impact scientists within PRUDENCE. This should still be enlarged and intensified in the future and will undoubtedly contribute towards progress in both communities.

Looking at the results of the RCMs presented at the meeting, the fairly large spread in the scenarios obtained for a common region and a common time slice is still striking. This spread is then also translated into the results of some of the impact studies leading to sometimes quite confusing conclusions.

A commonly applied practice to deal with differing RCM results has been to look at the ensemble of all results, employing suitable statistical techniques to come up with an aggregate outcome. In the simplest case, mean values and standard deviations may be computed. However, this raises the issue to what extent an aggregation of different model results represents an appropriate or even an acceptable way of pursuing the derivation of ensemble results. One issue to note here is the question to what extent such a process does justice to the

"good" models on the expense of the "bad" models or vice versa. However, these issues are apparently subject to new projects such as the EU-funded ENSEMBLE.

This withstanding and in summary, PRUDENCE has successfully assessed uncertainties in detailed climate scenarios for Europe based on RCM runs. The uncertainly due to the underlying GCM data seem to be constrained by the way sea surface temperatures are represented. Despite considerable efforts to improve RCM performances within PRUDENCE, the inter-model differences and the individual model uncertainties remain significantly. This notwithstanding, PRUDENCE, over only a three-year period has produced impressive and important results and has significantly enhanced our insight into the future development of European climate.

Notes on PRUDENCE **Oslo Oct. 5th 2004**

Trond Iversen
Professor,
Dep. Of Geosciences,
University of Oslo, Norway;
(Project leader of RegClim)

The following points of view from an external advisor is based on reading the work description, and participating in the third and fourth PRUDENCE workshops including the internal "Business Meeting". 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.

A unique feature of PRUDENCE is the systematic use of several AGCMs and RCMs which 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. Another important feature is the interdisciplinary structure of the project. PRUDENCE has been designed to study changes in the occurrence of different types of adverse weather events under changing anthropogenic forcing, and to estimate their environmental and socio-economic impacts.

An important aspect of these features concerns 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 able to meet the requirements according to its plans. There are some delays of deliverables, but none seems to be crucial. 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.

Scientific contributions
PRUDENCE has had significant scientific impacts through an impressive list of published papers. More papers, including a special issue, are also underway. Two major articles concerning extreme events have been published in Nature.

I am, in particular, happy for recent results from careful investigations of uncertainties in downscaled scenarios allocating their sources. Parts of this discussion include data from global climate models with considerably different characteristics for Atlantic-European climates (the model of the Hadley Centre, and that of MPI-Hamburg). Work along these lines will be necessary to pursue in further research.

Even though there is a considerable amount of results produced, I have an impression that further synthesis of the results should be made in order to extract the information on important uncertainty issues. I presume some resources will be allocated for this towards the end of the project and with the special issue for publication.

Finally, I need to mention that I am not able to judge the significant importance of results in impact-related and socio-economic parts of the project. That should be commented by other advisors to PRUDENCE. Nevertheless, it still is a challenge for the scientific community dealing with anthropogenic climate change issues to communicate between wide scientific disciplines.

All in all, I judge PRUDENCE to be a considerable success scientifically as well as for the assistance of decision makers. Perhaps some active popularization of the findings is needed, for example by producing a brochure.

Workshop Agenda

Monday 6 September

PRUDENCE general science session 1

9:00 Welcome and opening of PRUDENCE meeting
Manuel Castro/Jens Hesselbjerg Christensen

9:15 PRUDENCE, lessons learned
Jens Hesselbjerg Christensen

10:00 STARDEX, lessons learned
Clare Goodess

10:45 Coffee break

11:00 MICE, lessons learned
Jean Palutikof

11:45 Uncertainties in RCM projections for European Rivers catchments *(Invited)*
Marie Ekström (CRU)

12:30 Lunch

14:00 WP6 (Kirsten Halsnæs)
14:45 WP2 (Michel Déqué)

15:30 Coffee break

16:00 WP5 (David Stephenson)
16:45 WP7 (Jens Hesselbjerg Christensen)

17.30 *Meeting adjourn*

Tuesday 7 September

PRUDENCE general science session 2

9:00 WP1 (Daniela Jacob)
9:45 WP4 (Jørgen Olesen)

10:30 Coffee break

11:00 WP3 (Phil Graham)

11:45 General discussion on common WP issues actions needed (lead by Tim Carter)

12:30 Lunch

PRUDENCE individual partner contributions

14:00 P1 (DMI)
1. DMI analyses for PRUDENCE: High temporal resolution
2. The potential future change in extreme precipitation episodes in Europe as simulated by the HIRHAM regional climate model

14:30 P21 (FMI)
1. Regional temperature and precipitation change estimates for Europe under four SRES scenarios
2. Projected changes in indices related to low air temperatures and extreme precipitation

15:00 P3 (MétéoFrance)
Mediterranean Cyclogenesis : Model Validation and Regional Climate Change Scenario

15:30 Coffee break

16:00 P4: (DLR)
Evaluation of RCM control/scenario runs based on circulation patterns

16:30 P5: (HC)
1. Precipitation simulated by HadRM2 and HadRM3 driven By HadCM2
2. An initial estimate of the uncertainty in UK climate change due to RCM formulation

17:00 P16 (FEI)
Assessing uncertainties in climate change impacts on resource potential for Europe based on projections from RCMs and GCMs

17.30 *Meeting adjourn*

21:00 PRUDENCE dinner

Wednesday 8 September

9:00 P9 (SMHI)
PRUDENCE-related work at SMHI
9:30 P8 (MPI)
European Discharge under climate change conditions simulated by a multi-model ensemble
10:00 P10: (UCM)
1. Contributions to WP2
2. Country-by-country uncertainty and variability assessment from ensemble RCM-PRUDENCE simulations: preliminary results

10:30 Coffee break

11:00 P17 (UniRea)
Attributing variation in regional climate change model experiments
11:30 PB (Uni Oslo)
Optimal atmospheric sensitivity in Europe to forcing perturbations
12:00 P11 (UPM)
Impact studies in areas with complex orography. The need for high-resolution climate models in the Iberian Peninsula

12:30 Lunch

14:00 P2+P12 (ICTP/CINECA)
Summary of ICTP/CINECA activities and results for the PRUDENCE project
14:45 PA: (KNMI)
1. Circulation statistics and climate change in Central Europe; PRUDENCE simulations and observations.
2. Summertime inter-annual temperature variability in an ensemble of regional model simulations: impacts of the physics
3. Soil atmosphere-feedback under changing climate conditions

15:30 Coffee break

16:00 P14 (RISØ)
The Relevance of Climate Model Resolution on the Analysis of European Agricultural Policy Scenarios under Climatic Change.
16:30 P15 (UniFri)
Heat waves and extreme wind speeds over Europe by the end of the 21st century: Analysis of multi regional climate simulations
17:00 P6: (ETH)
1. Precipitation statistics in PRUDENCE models: Model evaluation, response uncertainties, extremes and runoff.
2. Variability of European climate in a heterogeneous multi-model ensemble

17.30 *Meeting adjourn*

Thursday 9 September

PRUDENCE individual contributions

9:00 P7 (GKSS)
1. Possible future changes in near surface wind speed over Europe from an ensemble of regional models
2. An assessment of possible changes in North Sea storm surges in a future climate and of the uncertainty due to the model formulation

9:30 P18 (UniLund)
Assessing Prudence RCMs using the LPJ-GUESS process-based vegetation dynamics model
10:00 P19 (CIRED)
Value-added for decision-making of finer spatial and temporal scale climate change projections

10:30 Coffee break

11:00 P20 highlights
11:30 P13 (DIAS)
Crop production and nitrogen cycling in arable crop rotations under climate change
12:00 PC (Uni Bergen)
Results related to northern latitudes from an ensemble of CMIP2-eksperiments and implications for dynamical downscaling

12:30 Lunch

Business sessions

14:00 WP coordinators joined meeting for cross fertilization

15:00 WP meetings as necessary

16:00 Coffee break

16:30 WP meetings as necessary

18:00 *Meeting adjourn*

19:00 Steering group and advisory board meeting followed by dinner at 21:30

Friday 10 September

Business sessions continued (plenary)

9:00 Discussions regarding *PRUDENCE Special Issue of Climatic Change*

10:30 Coffee break

11:00 Meeting wrap up

11:30 From here to the final report

13:00 End of meeting

Meeting summary

Rapporteur's report: General science sessions 1 and 2

The general science opening session began with a general presentation on the progress and status of **PRUDENCE** by the co-ordinator, Jens Hesselbjerg Christensen. He reminded Partners of the objectives outlined in the original PRUDENCE description of work (DoW) and outlined his impression of how completely these goals had been achieved. He emphasised how influential PRUDENCE has been internationally in stimulating similar projects in different parts of the world. He also encouraged Partners to begin to identify the key findings of the project and to think of effective methods of communicating these to the Commission, to other researchers, to policy makers and to the public. One idea might be to produce country-specific information about future climate change based on the PRUDENCE work.

Two presentations followed on the STARDEX and MICE projects, which form a cluster of FP5 projects with PRUDENCE on related themes. Progress in **STARDEX** was described by the co-ordinator, Clare Goodess. She reported that the project has dual aims: first, to evaluate statistical and dynamical downscaling methods, and second, to develop reliable and plausible scenarios using such methods. STARDEX has compiled daily temperature and precipitation data for over 40 years from 500 stations across Europe and PRUDENCE members have access to this (except where there are specific data restrictions). The project has also defined 10 core indices of interest for impact assessment, and is applying different downscaling methods to calculate these indices. Methods are applied by Partners over at least two regions. STARDEX is currently developing guidance material with recommendations for how to select the best downscaling methods for specific needs, discriminating between robustness criteria, application criteria and performance criteria for statistical and dynamical downscaling. STARDEX runs to July 2005..

The **MICE** project was described by Jean Palutikof, the co-ordinator. This focuses on impacts of extreme events, and has an end-user emphasis. 4 mini-workshops have already been conducted on Alpine sports, Central Europe floods, forest damage in Scandinavia, and excess temperatures and summer Mediterranean tourism. There will be a trans-European workshop in October. Jean then showed some examples of research work analysing higher moments of daily AOGCM outputs, discovering an unrealistically high frequency of temperature values close to 0°C.

Marie Ekström of the Climatic Research Unit, University of East Anglia, reported some recent work as part of the **FP5 SWURVE** project on uncertainties in RCM projections for European river catchments (Special Issue in press). She has carried out an uncertainty analysis using GCMs and the PRUDENCE RCMs to obtain probability distributions of temperature and precipitation change using a technique developed by Roger Jones in Australia. She assumed a linear relationship between global temperature and regional changes in T and P, obtaining a range of 2.28 to 3.56ºC mean annual warming by the 2080s for the bounding GCMs used in PRUDENCE, compared to 1.4 to 5.8ºC warming by 2100 as described by the IPCC.

Work Package presentations

WP 6: Economic concepts applied to the evaluation of regional climate impacts

Kirsten Halsnæs reported a lack of clarity in concepts to be used in assessing climate impacts in PRUDENCE. The project is generating a lot of detail on climate changes and their potential impacts for specific sectors and at different spatial scales. However, there has been little overview of the implications of such results. She emphasised that economic decisions are commonly made over, at most, a 20 year time frame and climate change is only one of many factors affecting decisions. In assessing the economic impacts of climate change, three types of assets can be identified, each requiring analysis:

1. Natural assets – input to production processes, ecosystems, biodiversity
2. Human assets – quality of life, health education
3. Social assets – social networks, risk management, markets

The impacts of climate change cannot all be judged in monetary terms, and there are advantages in evaluating impacts based on sustainability indicators. Moreover, it is important to note that extreme economic impacts do not necessarily follow from extreme climate events.

WP 6 is using a number of case studies at different scales and in different regions (based on work conducted in other Work Packages) to illustrate how impacts of climate variability and change can be interpreted from an economic viewpoint (e.g. hydropower supply in Scandinavia as a short term, economic optimisation problem).

WP 2: Uncertainty assessment of European regional climate model responses to common forcing, model formulation, and resolution

Michel Déqué reported that PRUDENCE Partners have looked at a wide range of uncertainties in model responses, including those associated with the driving models, emissions, and SST in the Baltic. There have also been attempts to create probability density functions of output data from different RCMs.

Météo-France has studied how GCMs compare to RCMs in PRUDENCE, concluding over 8 sub-domains in Europe that:

The greatest uncertainties in seasonal temperature changes are attributable to the forcing model and the emissions scenario, and less so to individual RCMs and ensemble members.

Uncertainties in seasonal precipitation changes are best explained by differences between RCMs, followed by the forcing models, emissions scenario and ensemble members.

Note that these conclusions only pertain to changes in the mean and may not be accurate in the case of extremes.

WP 5: Will European extremes become the norm?

David Stephenson described some of the methods adopted in WP 5 to describe extreme climate events. Examples include percentiles, maximum values and indices of exceedance/spell length. Some general conclusions from the work conducted to date include:

- The variance of daily temperatures increases in many models as well as the average
- 5-day precipitation events increase in winter over much of Europe
- 1-day precipitation events in summer decrease in southern Europe but increase in parts of northern Europe
- Windspeed direction is as important as windspeed for storm surges in the North Sea.

WP 7: Management, data, reporting and dissemination

Jens Christensen reminded Partners that towards the end of the project WP 7 was now assuming an important role in PRUDENCE. The project web site is widely accessed, and the PRUDENCE Data Distribution Center is now making RCM data available to the wider research community along with interfaces to boundary data, reliability assessments and other project findings. However, other aspects of the project results still need to be reported, summarised and disseminated. Aside from the Special Issue of Climatic Change, to be used for reporting the scientific results, other methods of communication will also be pursued. One idea is to produce a glossy brochure (maximum 10 pages, possibly shorter) setting out the main goals, methods and achievements of the project. This could be produced in the main European languages. Another intention is to produce briefing sheets, perhaps in the form of powerpoint presentations. Two presentations are described in the proposal, one summarising the climate scenarios, their uncertainties and example applications and the other

summarising the impacts of climate change, their uncertainties, and economic, social and policy making aspects of the PRUDENCE results. Mailing lists need to be compiled for targeting the brochure and presentations, and the idea of press conferences and/or workshops in Brussels and perhaps also in Partner countries was also aired.

WP 1: European regional climate simulations for 2071-2100 and their analysis

Stefan Hagemann raised the question of what should be included in the WP 1 paper for the Special Issue of Climatic Change. Here, the validation of model simulations should be presented, and one question concerned the appropriate resolution for presenting the runs. It was concluded that these should be presented at the standard 50 km resolution, and that higher resolution experiments could be described but detailed analysis of these should be deferred to another paper.

WP 4: Impacts on agriculture, forestry and ecosystems

Jørgen Olesen reported on progress with impact studies using RCM results. Partners within this work package have almost completed model simulations using the RCM projections, but there has been little time so far to analyse and intercompare results. Partners have explored different methods of applying RCM-based scenarios in impact studies, comparing the use of delta change estimates applied to observed 1961-1990 climate as inputs to impact models as opposed to using direct RCM outputs. Detailed models have been run at national scale (for wheat in Spain and Denmark and for maize in Spain). A dynamic vegetation model has been applied over the whole of Europe, requiring techniques to be developed to substitute information for the period between the reference and the end of the century (1990 to 2070) for which information provided from RCM simulations. Simple indices have been applied at regional or pan-European scale (e.g. of crop suitability, energy demand, Baltic Sea Ice; Mediterranean water balance). A simple regression model of wheat yield and N-leaching has been developed for application at European scale based on a more detailed, site model applied in Denmark.

WP 3: Impacts of future climate scenarios on hydrology

Phil Graham summarised progress in modelling hydrological impacts in the Baltic Sea region and in the Rhine basin. Like WP 4, Partners in WP 3 are also comparing methods of applying RCM information - whether directly or using the delta change approach. Some high resolution RCM outputs have also been applied in these studies (at 25 km resolution)The effect of scale is also being analysed in comparisons of responses over large basins to those over small watersheds (e.g. the entire Baltic Sea versus a river basin in northern Scandinavia important for hydroelectric power generation). Some lessons learned include:

- we can show the range of hydrological impacts from a range of different RCMs
- different forcings & different resolutions have an impact
- different hydrological approaches also give us different signal

General discussion

In the general discussion led by Tim Carter, issues were grouped into four main objectives of PRUDENCE, with a focus on the first, since little attention has been paid to this to date.

1. Disseminate the results of PRUDENCE widely – policy-makers and non-technical parties

    - PPT presentations; brochure in different languages; press releases; national meetings; thematic workshops for end-users cf. MICE; final EU decision maker meeting (WP6)
    - Role of joint MICE, STARDEX and PRUDENCE activities
    - Can we bridge the gap between scientists and decision makers?
    - What is needed from WPs?

2. Demonstrate value of scenarios for impact modelling focusing on adaptation and mitigation strategies and socio-economic and policy related decisions

- Further needs of impact assessors from other WPs
- Time horizon issue
- Selection of scenarios in impact assessment – guidance document on use of RCMs versus other downscaling methods (cf. STARDEX)?

3. Assess uncertainties in regional climate scenarios and risks arising from changes in climate; changes in extreme events

   - Work still to be completed
   - Presentation and interpretation of results
   - Links between extreme changes/impacts and mean changes/impacts
   - Relating impacts of extremes to socio-economic assessments

4. Provide series of high resolution scenarios and characterise the level of confidence in these scenarios and the variability in them related to model formulation and climate natural/internal variability

   - Runs still to be completed
   - Intercomparison studies
   - AOGCM suitability in providing boundary conditions
   - Guidance on model performance/reliability
   - Documenting PRUDENCE data for outside users

Tim Carter, 14 September 2004

Chairmen's report

Monday 6 September (Morning session)

Rapporteur: Manuel Castro

Session was opened with some few words for welcome the attendants (M. Castro) and opening the Final project meeting (J. Christensen).

First talk was given by J. Christensen (DMI) with the title of "Lessons learned in PRUDENCE". He reviewed the project's objectives with a look-back to the state-of-the-art of climate modelling by the time the project started 3 years ago. Afterward, the outmost results from the RCM simulations were showed, highlighting some of the results referred to climate extremes (heat waves and floods) in Europe. Also a brief analysis on AGCM and RCM formulation uncertainties was presented. Finally similar projects in the wake of PRUDENCE that are about to be accomplished in other regions of the globe (i.e. North America and South America) were commented.

Second talk was given by C. Goodess (CRU-EAU) with the title "STARDEX lessons learned". It was devoted to overview such European project which main goal deals with an analysis of climate extremes along the last 40 years in Europe from several statistical downscaling techniques applied to GCM simulations. The most consistent methodologies are tested and its results compared to observations.

Third talk was given by J. Palutikov (CRU-EAU) with the title "MICE lessons learned". It deals with definition and occurrence in terms of intensity and frequency of observed and GCM simulated climate extremes in Europe, including an analysis of their impacts on diverse climate related threatens (forest fires, insect forest damage, floods, etc) in some European regions. In results obtained so far, a locking phenomenon was identified in some GCM output; possibly due to the way freeze and thaw are handled in the models.

The last talk of the morning session was given by M. Ekström (CRU-EAU) with the title "Uncertainties in RCM projections for European river catchments". It is one of the issues addressed in SWURWE European project devoted to the study of impact of climate variability and change on the sustainable use of water and its related activities in Europe. The main objectives of the project were showed, consisting of the following four items: (a) Assessment risks to hydrologic and hydraulic systems posed by climate variability and change; (b) assessment of vulnerability in terms of operation as well as economic, ecological and social costs; (c) analysis methods of mitigating possible effects of climate change on system vulnerability; and (d) accounting for uncertainty due to natural variability and error due to incomplete knowledge of future conditions.

Monday 6 September (Afternoon session)

Rapporteur: Stefan Hagemann

WP6 presentation by Kirsten Halsnæs

Certain problems in the communication between the climate community and the policymakers were considered. Spatially there is the mismatch of climate gridboxes and economic units, such as farms, markets, etc. With regard to the timeframe, climate research in PRUDENCE focuses on the climate in the end of this century, i.e. the climate in 100 years from now. But

the only a few economic decisions have a time horizon of more than 20 years. Many decisions are based on a much shorter timeframe. Extreme economic events do not automatically follow from extreme climate events.

WP2 presentation by Michel Deque

3 papers will summarize the results of WP2. 1) A technical report describing the methods and first results, 2) a reviewed publication including the projection of the A2 / Hadley-SST simulations dealing with both GCMs and RCMs, and 3) the CC Special Issue paper about the variance partitioning of all RCM simulations
Paper 2 will handle the question "How do GCMs compare to RCMs within PRUDENCE?". It will include 2d projections based on EOFs, and will quantify both model biases and model responses. For temperature, GCMs agree quite well with the RCMs so that there is no problem with the climate change signal and the bias. For precipitation, the GCMs are only similar to the RCMs, as there is a better agreement between their signals than between their biases.

Paper 3 has two central questions: What are the main sources of uncertainty? Do they blur the mean signal?
The following ensembles were considered separately: R = 10 RCMs at 50 km, S = 2 scenarios (A2, B2), F = 3 forcings (HC, MPI, CRMF), M = 3 members. The total variance is equal to: R + F + S + M + RS + RF + ... + RFSM. But not everything was simulated with all models so that methods for filling missing data gaps have to be applied. 8 European sub-domains are considered. Major results are: There is a dominant role of the forcing in the uncertainty. The sampling from different members plays only a negligible role. The A2 mean impact features are robust, even for precipitation.

WP5 presentation by David Stephenson

Work conducted on extreme events and there possible future changes according to the RCM A2 scenarios were presented. One major topic is the heat waves, especially the predicted increase in frequency, intensity, and duration of summer heat waves over Europe. Another important topic is the heavy precipitation events and their general increase, except for Southern Europe in the summer.

WP7 presentation by Jens H. Christensen

The content of WP7 was presented and Certain management issues were discussed, especially with regard to the dissemination of results. A major issue will be a PRUDENCE brochure of 5-6 pages which was later discussed in the WP meetings on Thursday.

Tuesday 7 September (Afternoon Session)

Rapporteur: Burkhardt Rockel

P1 (DMI)
Ole B. Christensen presented DMI analyses for high temporal resolution simulation in PRUDENCE. He showed results from 50km, 25km, and 12km simulations with the HIRHAM. He examined the tail of wet day pdf for summer JAS. In Denmark extreme hourly precipitation could more than double in amount within hundred years: thirty year return values become five year values. Increasing horizontal resolution adds to the agreement on the daily time scale.

Willi May presented results from a study on the potential future change in extreme precipitation episodes in Europe as simulated by the HIRHAM regional climate model. He found that HIRHAM generally overestimates the frequency of wet spells but underestimates the intensity. HIRHAM predicts a future increase in the frequency of wet spells only in a few areas but an increase in the intensity in a major part Europe. HIRHAM underestimates the intensity of extreme wet spells in several areas, i.e., Spain, Romania, and southern Norway. HIRHAM predicts a future increase in the intensity of wet spells in a major part of Europe

P21 (FMI)
Heikki Tuomenvirta showed regional temperature and precipitation change estimates for Europe under four SRES scenarios. A super-ensemble pattern-scaling method was developed to obtain B1 and A1FI changes. The range of uncertainty for ? T and ? P in Europe is large due to AOGCM differences and uncertainty in emission scenarios. PRUDENCE RCM simulations cover only a small fraction of the AOGCM uncertainty range.
Kirsti Jylhä reported on projected changes in indices related to low air temperatures and extreme precipitation. She assessed the uncertainties in the estimated changes due to differences in RCM formulation, GCM boundary conditions and future emissions. She found that changes in dry spells and precipitation are between (+20%dry spell / -60%precip and 5%/-20%) for the Iberian Peninsula. Changes in number of snow days and mean snow depth are between (-40%/-70% and -23%/45%) She pointed out that at least in some cases, downscaling of additional GCM simulations might widen the range of projected changes in extreme weather events.

P3 (MétéoFrance)
Michel Déqué presented uncertainties in the temperature and precipitation response of PRUDENCE global models. He included the global models from CNRM, Hadley Centre, ICTP, and MPI in his study. The differences in the RMS response over Europe for temperature are for both winter and summer higher in the A2 scenario then in the B2. The differences between the models are small in winter but large in summer. For precipitation there are only small differences between all simulations.
Samuel Somot showed results from studies regarding Mediterranean cyclones. There is a general good agreement between ERA40 and ARPEGE results. In future change studies he found a decrease of Mediterranean cyclones number (except in summer). However, the cyclones characteristics do not change. Winter drying leads to a decrease in cyclone number. Summer drying leads to decrease in cyclone associated precipitation. In spring in autumn there will be probably more intense precipitation events.

P4 (DLR)
Maria Costa Zemsch presented a study on the evaluation of RCM control/scenario runs based on circulation patterns. She found that circulation classes are associated with distinct regional anomaly patterns. Regional anomaly patterns are persistent (robust) except JJA precipitation in western Mediterranean. Regional climate change due to shift in circulation pattern frequency only explains a small part of total regional climate change except JJA precipitation in Central Europe and Scandinavia.

P5 (HC)
Erasmo Buonomo presented results of precipitation simulated by HadRM2 and HadRM3 driven By HadCM2.
Dave Rowell reported on an initial estimate of the uncertainty in UK climate change due to RCM formulation. For UK average surface air temperature and precipitation, the uncertainty due to RCM formulation is fairly small. It is of comparable magnitude to the uncertainty due to large-scale internal variations of the climate system. Uncertainty due to formulation of the driving GCM dominates. Uncertainty due to RCM formulation is strongest in summer. At

sub-national scales, uncertainty due to RCM formulation is reduced for T(1.5m), but increases for precipitation. Projections of small-scale precipitation anomalies are particularly sensitive to large-scale internal anomalies of the climate system.

P16 (FEI)
Stefan Fronzek showed results from investigations to assess uncertainties in climate change impacts on resource potential for Europe based on projections from RCMs and GCMs. He found that climate change by the 2080s has impact on agriculture, energy, transport, and natural ecosystem. Areas suitable for crop cultivation expand northwards. Yield in winter wheat increases in Northern Europe and decreases in Southern Europe. Patterns of changes in nitrate leaching are more diverse but mostly decrease in Northern Europe and increases in Southern Europe. There is a demand for indoor cooling increase more strongly in Southern Europe and a decrease in heating demand stronger in N Europe. Transport on the Baltic Sea is affected by a considerable reduction of ice extent due to very mild ice conditions.

Wednesday 8 September (Morning Session)

Rapporteur: Heikki Tuomenvirta

Erik Kjellström and **Lars Bärring** (SMHI) gave a presentation on *PRUDENCE-related work at SMHI* covering three topics. Firstly EK showed that hydrological cycle change in the Baltic sea region depends critically on the Baltic sea surface temperature. Secondly using long-term observations from Stockholm EK presented evidence that observed temperature distribution changes connected with warming are similar to those simulated by RCAO. In Northern Europe asymmetric changes in projected temperature distributions take place in winter, while in Southern Europe the largest changes in temperature dispersion happen during summer. Thirdly, LB presented preliminary results on study of wind-storms. RCMs are being compared with storm indicators derived from observed sea-level pressure data.

Stefan Hagemann (MPI) presented paper titled *European Discharge under climate change conditions simulated by a multi-model ensemble.* Hydrological Discharge (HD) model driven with PRUDENCE RCMs was run on Baltic Sea, Elbe, Rhine, and Danube catchments. SH showed results on precipitation, temperature, evapo-transpiration and discharge. Multi-model ensemble mean proved to be closer to observations than any individual model.

Miguel Angel Gaertner (UCM) gave a summary on *UCM contributions to WP2*. He covered the following topics:

- The use of a modified Köppen climate-type classification for assessing climate change effects in Europe from an ensemble of nine regional climate models
- Quantification of projected displacements and changes in the length of seasons for a future climate scenario in Europe with an ensemble of RCMs
- Impact of a change in vegetation parameters on summer precipitation in Europe with RCM used at UCM (PROMES)
- Influence of spatial resolution on precipitation extremes in Iberian Peninsula
- Late summer cyclones over the Mediterranean sea. A lively discussion was inspired especially by the possibility of “tropical cyclones” over the Mediterranean sea.

Enrique Sánchez (UCM) gave presentation titled *Country-by-country uncertainty and variability assessment from ensemble RCM simulations: preliminary results*. Using all PRUDENCE RCM simulations preliminary results on temperature and precipitation (simple statistics) changes were presented on country-by-country basis. Possibility of input to WP7 was discussed.

Chris Ferro (Uni. Reading) presented paper titled *Attributing Variation in Regional Climate Change Model Experiments.* CF presented a method to decompose temperature change signal into effects by GCMs, RCMs CO_2 response and combined effects. Results can be used to assess their relative importance.

Trond Iversen (Uni. Oslo) introduced the use of Forcing Singular Vectors (FSVs) in presentation: *Optimal atmospheric sensitivity in Europe to forcing perturbations*. FSVs can be used to find what causes maximum perturbation of atmospheric flow in a selected target area. European sector seems to be sensitive to SST anomalies in the Northern North Atlantic and to mid-tropospheric forcing.

Inés Mínguez (UPM) gave presentation titled *Impact studies in areas of complex orography. The need for high resolution models in the Iberian Peninsula.* Using soil information (specific profiles) various crop models had been driven with multiple RCMs focussing on Iberian Peninsula. Sensitivity of irrigated and rain-fed systems was studied. Comparison of model results showed similar trends in many regions.

Thursday 9 September (Afternoon Session)

Rapporteur: Bart van den Hurk

The last session with individual contributions contained a diverse but without exception very interesting collection of talks.

Burkhardt Rockel (GKSS) presented an evaluation of the modelled wind speed over land. He first concluded that only (two) models carrying a gust parameterization were able to catch up with observed *maximum* winds to some extend, and that all other models had a systematically lower maximum wind speed of 1 – 2 Bft. The (daily) average wind speed at 10m was not sensitive to the presence of this gust parameterization. As expected, models running at a higher spatial resolution (25m) gave higher maximum wind speed. High percentiles in the wind speed distribution seem to increase by 30% when an A2 scenario is imposed, but the mean wind is not changed a lot.

Katja Wohl (GKSS) evaluated a number of simulations of storm surges driven by a range of RCM winds. Systematic increases of the maximum surge level were found particularly in the German Bight area, but also along the Danish and Dutch coasts increases were simulated.

A nice presentation on the impact of a changing GHG scenario on Net Ecosystem Exchange (NEE) and Net Primary Productivity (NPP) was presented by Morales. Pretty large increases of NPP (up to 0.5 kg C/m^2 yr) were simulated with LPJ-GUESS when driven by a range of RCM-outputs. The use of time slice experiments is a problem of this kind of analyses. The carbon stocks need long spin-up periods, and subtle variations in the way in which the absent time period between 1990 and 2070 was interpolated had large impact on the simulated changes in NEE. In fact, transient climate simulations are necessary for this application.

Two presentations by CIRED paid attention to the human dimension of (anticipating or coping with) climate change impacts. Stephane Hallegate caused laughter in the audience by showing a new European map of major cities, obtained by comparing future climate conditions for cities to locations that have similar climate characteristics in present day climate conditions. Although the true problem of climate change is more complex, it is a powerfull means to communicate the impacts of climate change to a wide audience. The move of Paris to Mallorca is a very simple to understand notion of climate change.

His colleague Philippe Ambrosi revealed plans to investigate how the (financial) damage of climate change could be expressed in terms of a necessary premium to cover this damage, and how income, adaptation capacity, and means of spreading the risk (per capita or per income unit) affect these adaptation strategies. The calculations are marked by quite a bit of uncertainty, and it would be interesting to compare this uncertainty to the spread of possible climate predictions.

Also the last talk in the session, given by Clare Goodess but in fact authored by Tom Holt, was interesting. They analysed the changes in a number of extremes indicators (number of days with high rains, number of consecutive dry days, etc). Using advanced statistical bootstrapping techniques they could show a map of change of these extremes indicators, which otherwise are particularly noisy and difficult to comprehend. As expected, a large North-South gradient in both dry and wet extremes is simulated by the analysed RCM's, but larger changes are associated with larger uncertainties.

Jørgen Olesen analysed nitrogen leaching and crop yield changes for Denmark using a range of RCM-results. His main conclusion is that the choice of applying climate perturbation via the so-called "Delta-approach" results in a smaller change of the interannual variability of crop yield and nitrogen leaching than via the "Direct Model output" approach, since changes in the (interannual) variability are not inherited. For farming decisions which are driven by risks of crop failure interannual variability may be an important feature to properly represent.

The final talk by the University of Bergen reminded us of the "crap in, crap out" principle. It was clearly demonstrated that strong biases in the GCM-pressure fields (too strong pressure gradients near Greenland) had large impacts on the precipitation simulations over the Northern European domain. Higher resolution simulations increased this bias even, which may be caused by misrepresentation of (stable) boundary layer dynamics.

WP1&2 meeting on the 9th of September 2004 in Toledo.

Rapporteur: Erik Kjellström

Present
Jens, Ole, Dave, Erik, Bart, Michel, Samuel, Stefan, Heikki, Manuel, Enrique, Burkhardt, Christoph S., Pier-Luigi.

Agenda:

1. Merged Deliverable Talks (Scientific highlights, Problems, Completion Plans, Publication Plans)
    i. MD1: Uncertainty assessment using high-resolution global model scenarios
    ii. MD2: Assessment of RCM current climate simulations
    iii. MD3: Uncertainty assessment using regional model scenarios
    iv. MD4: Upper/lower estimates of regional temperature change using pattern scaling
    v. MD5: Multi-member ensemble of the A2 scenario, using 20km RCMs
2. Data Issues
3. General Discussion / Other Issues

1) Report on the five MDs (merged deliverables).

i.) MD1. Michel reported on "Uncertainties in the temperature and precipitation response of PRUDENCE global models". 4 different high resolution AGCMs have been used. In all there are 9 simulations with the A2 SRES emission scenario and 2 with B2 emissions. Michel presented comparisons of the AGCMs both globally and regionally for Europe. He showed that no model was more sensitive to climate change (in terms of temperature and precipitation change) over the globe but that the Hadley Centre model was more sensitive wrt to temperature response over Europe in summer.

Publication plans: a) a PRUDENCE report is finished (available on the PRUDENCE web page). b) One paper on GCMs versus limited area models is to be submitted to Climate Dynamics. c) One paper on NAO in the CNRM regional scenarios is in press in J. Climate. d) One paper on "sources of uncertainties in RCMs" is to be submitted to the PRUDENCE special issue of Climatic Change.

ii.) MD2. Jens showed the "stamp maps". As an addition from what he showed in Wengen, now also the ensemble mean was included. He concluded that the ensemble mean biases are small and smaller than biases in the individual models. Further, the ensemble mean bias could possibly say something about deficiencies in the CRU climatology.

Publication plans: As outline for a publication a previous MPI report (Machenhauer *et el.1998, MPI report No. 275*) is to be used. One item of validation is the relation to the large scale flow. In addition biases in precipitation and 2m-temperature (mean, min, max) are to be included. Jens will write an outline and send it around for input from other groups.

At this point a suggestion was put forward by Christoph S. to submit a condensed version of this report to Bull. Am. Met. Soc. to advertise the PRUDENCE findings in the US.

iii.) MD3. Dave reported.

MD3a - Statistical analysis of sources of uncertainty:

Europe-wide: DMI (Ole+Jens), UCM (Enrique), and Met-Fr (Michel)

DMI/UCM: Uncertainty of climate change at the country level for temperature and precipitation. Publication plan: Possible paper in 2005. Other papers: one for the special issue of Climatic Change (see MD2 above), and one on the validation work in early 2005.

Met-Fr: The analysis of systematic errors using multidimensional scaling is complete. A further study, based on a quantitative rather than visual approach is in progress. Publication plan: A PRUDENCE report has been produced. A paper will be submitted to J. Climate in Oct 2004. A paper will be submitted to the special issue of Climatic Change. (compare with MD1 above)

UK only: MO/HC (Dave R)
Compared uncertainty sources for UK average climate change and north-south UK gradient of climate change, focusing on the uncertainty due to RCM formulation. Publication Plan: Submit a paper to Int. J. Climatol. in Oct 2004.

Data provision and advice: All Partners. Work is complete

MD3b - Analysis of the uncertainty of climate impacts (cross-cuts with other WPs):

Koeppen climate classification: FMI (Kirsti) and UCM (Manuel) Produced maps of projected changes of climate zones for selected SRES emissions (B1, B2, A2 and A1FI) to illustrate the uncertainty range. Publication plan: A joint UCM/FMI publication will be submitted in late 2004/early 2005.

Intense summer rainfall events: DMI (Jens+Ole) The total summer time precipitation amounts will be substantially reduced, but intensive rain events will become more frequent and even more intensive. Publication plan: Paper published in Nature in 2003.

MD3c - Analysis of climate change mechanisms and their reliability:

Baltic Summer Precip: SMHI (Erik) Additional experiments to investigate the role of SSTs in the increase in Baltic summer precipitation. Publication plan: One paper submitted to Nordic Hydrology in the of end August 2004. Submit a paper to the special issue of Climatic Change.

Norwegian Winter Precipitation: DNMI (Dag) Progress and publication plan: Unknown

Blocking: KNMI (Aad) Analysed the circulation statistics over central Europe from 9 RCM's, HadAM3H and ECHAM4, and compared them with long records of geostrophic winds. Publication plan: Submit a paper to the special issue of Climatic Change.

Summer drying: MO/HC (Dave R) Continued to work on sensitivity experiments that will roughly quantify the relative importance of 4 mechanisms of future summer drying over mid and southern Europe. Publication plan: Submit papers in Winter 2004/5 and Spring 2005.

Near-surf wind over N.Sea, Baltic and Europe: GKSS (Burkhardt+Katja) Continued to investigate mean and maximum daily wind speed for 11 RCM runs, for both control and scenario simulations. Publication plan: Submit a paper to the special issue of Climatic Change.

Late Summer Cyclogenesis over the Mediterranean: UCM (Miguel) The behaviour of several RCMs regarding the development of cyclones over the Mediterranean is being analysed for late summer /early autumn. Publication plan: One paper to be submitted now. A further paper will be submitted in early 2005.

Rhine catchment: KNMI (Bart) Analysed the role of terrestrial water storage on the simulated runoff from the Rhine basin. Compared 7 RCMs with observations and ERA40 analyses, and analysed the change in runoff under the A2 scenario using HadAM3H.Publication plan: A paper has been submitted to J.Climate.

Circulation types: DLR (Maria) Progress at March 2004: Deadline of April 30 delayed by 1-2 month caused by the delayed delivery of synchronous CGM/RCM results from Hadley Centre. Publication plan: A publication is planned for submission by the end of 2004.
Impact of vegetation parameters: UCM (Enrique) Control and A2 runs have been analysed with two vegetation descriptions, which mainly change the proportion of grassland into grass with trees over many parts of continental Europe. Publication plan: A paper will be submitted to Climate Dynamics by the end of 2004.

Seasonality changes over Europe: UCM (Clemente) Quantifying the expected changes in length and displacements of the meteorological seasons. Publication plan: A paper will be submitted to the special issue of Climatic Change, and/or a further paper is planned for the first half of 2005.

Interannual Variability of Summer Temperature: KNMI (Geert) Analysed the interannual variability of monthly mean summertime temperature from 9 RCMs, with the aim of diagnosing the origin of the range in modelled summertime temperature anomalies. Publication plan: A paper will be submitted to the special issue of Climatic Change.

The following two contributions by ETH were not addressed at the meeting but added afterwards:

Change of interannual variability: ETH (Pier-Luigi) Intercomparison of changes in variability in PRUDENCE RCMs and GCMs. Publication plan: A paper will be submitted to the PRUDENCE special issue of Climatic Change.

Diagnosed terrestrial water storage. ETH (Martin H) Use diagnosed values of terrestrial storage to evaluate PRUDENCE simulations, based on the use of ERA-40 water vapour convergence data and observed runoff data (Seneviratne et al., 2004)). Publication plan: Submit a paper in the first half of 2005.

MD3d - Analysis that is specifically of scales below that of the GCMs:

Europe-wide elevation dependence: MO/HC (Dave) No recent progress. Analysed the elevation-dependency of the climate change response for surface air temperature and precipitation, at sub-GCM spatial scales. Mechanisms are to be investigated. Publication plan: Submit a paper in 2005.

Alpine elevation dependence: MPI (was Tido) and ETH (who?) Progress and publication plan: unknown.

iv.) MD4. Heikki reported on the work at FMI putting the PRUDENCE simulations into perspective by the use of a pattern scaling method. He noted that a scaling method was also being used by the group at ETH (see the presentation in the Toledo meeting by Christoph F.). The issue of policy relevance was touched upon – sometimes the RCMs represent only a small subset of the uncertainty from the GCMs. Publication plan: A first draft is almost ready.

v.) MD5. Stefan reported on the status of data delivery. All 50 km runs have been submitted (Norwegian data to be submitted I the next month). In terms of the 25 km runs, DMI and SMHI have delivered the data, HC, ETH and MPI have not. The HC will not deliver these data since the runs have been made with the H-version of their RCM. MPI will not deliver but has promised an additional 50-km B2-simulation. ETH will not deliver a 25 km run but may deliver the ECHAM5 run instead. UCM offered to submit a 25 km run for the Iberian peninsula with PROMES.

It was discussed that there will be a subsection in the validation paper that will deal with the high resolution runs.

2.) Ole reported on data issues. The majority of the discussion was related to the public dissemination of the PRUDENCE data set. Norwegian and Italian (global model) data are not yet on the server. Ole will handle this via e-mail with the two groups.

He also raised the question on what we would like to require from users of the data. The following things were discussed:

- A list of studies having been performed on the data should be compiled and further on updated. This list should contain both scientific and other reports.
- There should be a contact person at each centre.
- Proper acknowledgements to the data should be made by the users.
- Users should fill in some kind of form when getting the data (similar to ECMWF form for ERA data).

It was noted that the HC H-data are not to be used by others than the PRUDENCE community as agreed upon previously. Ole to check on this with Richard Jones. Also it was noted that there are differences between the ECHAM4/OPYC3-runs that were used to force the RCMs at DMI and SMHI and that this difference must be made clear at the DDC.

3.) General discussion

i.) A list of variables that could be submitted on a voluntary basis was decided upon. Ole took notes of which variables and levels it was decided upon (basically monthly means for all 360

months in each run of sensible and latent heat fluxes, momentum flux, gust corrected maximum wind speed, and T,q,u,v,z at 850, 500 and 300 hPa)

ii.) A list of bullet points summarizing some of the most important findings in PRUDENCE that could be presented in a final brochure was compiled. These bullets are:

- Uncertainty due to RCM formulation smaller than that due to GCM formulation
- Ensemble mean of RCMs is a good representation of observed surface climate
- RCMs add information on summertime precipitation variability
- Increased temperature in A2 (range). Changed precipitation in A2 (range). Seasons? Whole Europe? N-S Europe contrasts
- Large matrix of RCM data
- Extreme events. Future climate mimics rare events of present climate? (Summer 2003 could become regular at the end of the century)
- Uncertainty due to RCM formulation smaller than that due to emission scenario for surface air temperature
- "Tropical" cyclones in the Mediterranean Sea is a possibility?
- Extreme events: Increased temperature in A2 (range). Changed precipitation in A2 (range). Seasons? Whole Europe? N-S Europe contrasts
- Climatic zones in Europe to move in the future

iii.) Finally the overview paper in WP1 was discussed. Possible contributions to that paper from the partners were:

DMI (Jens/Ole) summarize mean and spread of RCMs (Temperature and precipitation)
SMHI (Erik/Lars) comparison of daily data (Tmin/Tmax) with station data from ECA.
GKSS (Burkhardt/Katja) wind speed
UCM (Manuel/Miguel) Köppen climatology
KNMI (Bart/Aad/Geert) Geostrophic winds, summertime temperature variability
ETH (Christoph Frei/Pier-Luigi/Martin H.)
CNRM – ensuring consistency with WP2 paper
FMI and HC – no contributions

It was decided that Daniela should send out an outline within two weeks (Stefan to inform Daniela). Contributions (including text parts and figures) from the different groups should be sent to Daniela by the end of October. Daniela will compile these and send out a first draft after that for commenting.

Michel suggested that we could use the 8 regions defined by Burkhardt in this paper. Burkhardt to inform everyone on the definitions.

End of meeting.

Toledo discussions for 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 three modelling groups within WP3 are now concentrating on completing the final hydrological model simulations before the end of the project. The WP discussions at the Toledo meeting focused on appropriate comparisons to be done and the content of the WP3 paper to be submitted to the PRUDENCE special issue of Climate Change. In addition, reflections on the major outcomes from the WP were discussed, as well as conclusions from the hydrological perspective that could be included in the final project-wide brochure.

Comparison of results between groups will be made between MPI and SMHI for the Bothnian Bay basin and between MPI and ETH for the Rhine River basin. An important point is that it is difficult to compare the model results directly as they are all based on different approaches conducted with different inputs at different scales. Thus, comparisons will focus on *change* values for river discharge between control and scenarios from the different hydrological approaches. ETH will also compare their modelled snow results with the empirically based snow studies done by U. Fribourg.

Details of the common paper were agreed upon, together with a schedule for writing. Both SMHI and MPI plan to submit solicited papers in addition to the common paper. The common paper will refer to these two publications for some of the detailed modelling description. There will be some minor overlap, but this should not be a major concern.

All of the WP3 deliverables are expected to be completed by the close of the project with the exception of deliverable D3B3. This was discussed at the Lund meeting in March, 2004. At that time, it was decided that the high resolution scenarios would not be performed by ETH and thus this deliverable cannot be completed.

Summary of discussions of PRUDENCE WP4 meeting in Toledo

(Jørgen Olesen, DIAS)

The objective of WP4 is 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. ISAg-UPM studies impacts on agricultural production in Spain with a focus on effects of changes in water availability on production. DIAS studies impacts on agricultural production in Denmark with a focus on the relationship with nitrogen cycling and effects on nitrate leaching. University of Lund studies the effects of climate change on productivity of natural ecosystems and forests across Europe. FEI uses simple climate indices to study uncertainties in estimating resource potential under climate change across Europe. UEA-CRU performs analyses of uncertainty in the Mediterranean Basin focusing on heat waves, cold spells, droughts and high-intensity rainfall.

All modelling groups are now concentrated on completing their model runs and analysing the results. The discussions at the Toledo meeting concentrated on the structure of the joint paper for Climate Change and on deriving some overall conclusions. All WP3 deliverables are expected to be completed by the end of the project period.

Structure of joint paper for a special issue Climate Change

The joint paper will focus on certainties and uncertainties in impacts of climate change on managed and un-managed ecosystems in Europe. The following topics will be covered by paper:

- Effects of uncertainties associated with emissions scenario, driving GCM, RCM and spatial resolution of RCM
- Effect of downscaling methodology (Observed + Delta, Direct RCM, RCM + Delta, ERA-15 + Delta).
- Indicator values will be presented primarily as changes in mean, variability and in spatial extent.
- The indicators presented are: NEE; NPP; P/Ep; Yields of winter wheat, spring wheat and maize; Suitability of grain maize; Irrigation demand for maize; Nitrate leaching.
- The spatial scope will be: Europe (5 regions); Mediterranean; National (Denmark and Spain)
- The main issues to be discussed will concern downscaling, spatial resolution of RCM and uncertainties in estimated impacts.

It was pointed out that it is very important that all papers in the special issue of Climate Change use a common system for referencing the different GCM and RCM runs. WP1 should come up with such a list of acronyms.

Main conclusions

- Increased pressures on irrigation systems in Southern Europe
- Northward shift of ecosystems and cropping zones
- Increased plant productivity in Northern Europe and reduction for rainfed systems in large parts of Southern Europe
- Possibilities for winter agriculture should be reassessed in Southern Europe
- Direct RCM output may be used as input to impact models, but this needs to be analysed in each case.

Abstracts of meeting presentations

WP3

On interpreting hydrological change from regional climate models

L. Phil Graham, Stefan Hagemann, Simon Jaun and Martin Beniston

Evaluating changes to hydrological regimes due to climate change can be carried out in different ways. Although representation of hydrology is included in all regional climate models (RCM), the utility of hydrological results from RCMs can vary considerably from model to model. Studies to evaluate and compare the hydrological components of a suite of RCMs over Europe were therefore carried out. This included different methods to transfer RCM runoff to river discharge. Additional methods were used to further analyze climate change impacts on hydrology from the different RCMs. These included offline coupling to hydrological models of varying scale and detail ranging from regional scale to finer basin scales. Different methods to transfer the climate change signal between models were also employed. The work focused on drainage areas to the Baltic Basin, the Lule River Basin and the Rhine River Basin.

WP5

Future Extreme Events in European Climate: An Exploration of Regional Climate Model Projections

David Stephenson et al.

This paper presents an overview of changes in the extreme events that are most likely to affect Europe in forthcoming decades. A variety of diagnostic methods are used to determine how heat waves, heavy precipitation, drought, wind storms, and storm surges change between present (1961-90) and future (2071-2100) regional climate model simulations produced by the PRUDENCE project. A summary of the main results follows.

Heat waves - Regional surface warming causes the frequency, intensity and duration of heat waves to increase over Europe. By the end of the 21st century, countries in central Europe will experience the same number of hot days as are currently experienced in southern Europe. The intensity of extreme temperatures increases more rapidly than the intensity of more moderate temperatures over the continental interior due to increases in temperature variability.

Precipitation - Heavy winter precipitation increases in central and northern Europe and decreases in the south; heavy summer precipitation increases in north-eastern Europe and decrease in the south. These changes reflect changes in mean precipitation. Mediterranean droughts start earlier in the year and last longer.

Winter storms - Extreme wind speeds increase between 45N and 55N, except over and south of the Alps, and become more north-westerly. These changes are associated with reductions in mean sea-level pressure and generate more North Sea storms, leading to increases in storm surge along the North Sea coast, especially in Holland, Germany and Denmark.

Partner 1 (DMI)

DMI analyses for PRUDENCE: High temporal resolution

O.B. Christensen et al.

An investigation of RCM performance on sub-daily time scales has been done with output from the HIRHAM 25km PRUDENCE experiment. Hourly precipitation has been compared to observations from a rain-gauge network in the Copenhagen metropolitan area. Based on observational relations between point values and area averaged values of hourly precipitation and on the HIRHAM climate change calculations, an estimate can be made of future hourly precipitation extremes.

The potential future change in extreme precipitation episodes in Europe as simulated by the HIRHAM regional climate model

Wilhelm May

In my presentation the characteristics of extended episodes with precipitation in Europe as simulated by the HIRHAM regional climate model are investigated. This includes an assessment of the quality of the simulation under recent conditions and of the potential future changes associated with the anticipated greenhouse warming. Of particular interest are extreme (with respect to the amount) precipitation episodes, which are described via the Generalized Pareto distribution.
Here, ensembles of 30-year simulations with HIRHAM, which have been performed at a horizontal resolution of 50 km, are considered. More precisely, three simulations for the period 1961-1990 and four simulations for the period 2071-2100. As for the future climate, one of the simulations has been forced by different (more realistic) sea surface temperatures in the Baltic Sea. As observations, daily precipitation data from the European Climate Assessment and Dataset project (ECA&D) are used.

Partner 3 (MétéoFrance)

Mediterranean Cyclogenesis : Model Validation and Regional Climate Change Scenario

Samuel SOMOT, Cécile BARLAN, Eric CAILLAUD, Bruno JOLY

A study of Mediterranean cyclogenesis has been performed with present-day and future climate PRUDENCE simulations. Mediterranean cyclones are known to be sub-synoptic systems, mainly influenced by local complex orography, land-sea contrasts and important air-sea fluxes. So, using Regional Climate Models is well adapted for studying this particular cyclogenesis and its possible change during the 21st century.

ARPEGE-Climat is a global spectral AGCM with a stretched grid over the Mediterranean Sea. This stretching ability allows a 50 km horizontal resolution over the area of interest. A 140-year simulation has been performed with this model from 1960 to 2099. The first part of the simulation (1960-1998) is used to validate the present-day climate and the 2070-2099 period is studied as a representation of the end of the 21st century. The IPCC-A2 scenario has been chosen. The study of the Mediterranean cyclogenesis has been done by an objective tracking of individual cyclones. The algorithm was developed at CNRM (Ayrault and Joly, 2000). It detects and combines relative vorticity maxima at 850 hPa (1 field every 6h). A filtering is applied to only keep tracks longer than 600 km and 24 h.

As a validating step, we compare the 1960-1998 period of the ARPEGE-Climat simulation with the same period of ERA40 reanalysis. We obtain a very good agreement between the two datasets.

In the scenario, we obtain a small and significant decrease of the number of Mediterranean cyclogenesis except for July and August for which an increase is observed. Relationships between Mediterranean drying and precipitation associated to Mediterranean cyclones are investigated by the mean of composites.

Partner 4 (DLR)

Evaluation of RCM control/scenario runs based on circulation patterns

Maria José Costa Zemsch, Dietrich Heimann

It was investigated to what extent regional climate changes can be explained by changing circulation pattern frequency distribution.

The 500 hPa geopotential height of the two climate periods together (1961-1990 and 2071-2100) was used to find the circulation patterns. The continuous 60- year time-series, was disaggregated into distinct episodes of 2-5 days length. The resulting episodes were aggregated into 22 circulation classes. For each class, it was investigated the associated RCM data (in particular, temperature and precipitation) and how its statistics changes between control and scenario.

It could be concluded:
different circulation classes are associated with distinct regional anomaly patterns.
for DJF and JJA, the regional anomaly patterns are persistent (robust), with exception of JJA precipitation in western Mediterranean
the regional climate change due to shift in circulation pattern frequency, only explains a small part of the total regional climate change, with exception of JJA precipitation in Central Europe and Scandinavia.

Partner 5 (HC)

Uncertainty in UK Climate Change Resulting from RCM Formulation

Dave Rowell

Regional climate models (RCMs) are now commonly used to downscale climate change projections provided by global coupled models to resolutions that can be utilised at national and finer scales. Although this extra tier of complexity is necessary, it inevitably contributes a further source of uncertainty, due to the regional modelling uncertainties involved. Here, an initial attempt is made to estimate the uncertainty that arises from typical variations in RCM formulation, focussing on changes in UK surface air temperature (SAT) and precipitation projected for the late twenty-first century. Data is provided by a relatively large suite of RCM and global model integrations with widely varying formulations.

It is found that uncertainty in the formulation of the RCM has a relatively small, but non-negligible, impact on the range of possible outcomes of future UK seasonal mean climate. This uncertainty is largest in the summer season when flow from the model boundaries is weakest. It is also similar in magnitude to that deriving from random internal variations of the coupled climate system, and for SAT, it is less than the uncertainty due to the emissions scenario, whereas for precipitation it is probably larger. The largest source of uncertainty, for both variables and in all seasons, is the formulation of the global coupled model. The scale-dependency of uncertainty is also explored by considering its impact on projections of the gradient of climate change from the north to the south of the UK. Finally, the implications for the reliability of UK seasonal mean climate change projections are discussed.

Precipitation simulated by HadRM2 and HadRM3 driven By HadCM2

Erasmo Buonomo et al.

Present and GHG forced future climate over Europe have been simulated at the Hadley Centre by using the regional models HadRM2 and HadRM3 driven by the global model HadCM2. This presentation will focus on the comparison of the precipitation and changes described by the two sets of simulations, as a first step to assess the uncertainty due to RCM formulation.

Partner 6 (ETH)

Precipitation statistics in PRUDENCE models: Model evaluation, response uncertainties, extremes and runoff.

Christoph Frei, Jan Kleinn, Simon Jaun, Jürg Schmidli, Regina Schöll, Pier-Luigi Vidale, Christoph Schär

This presentation summarizes analyses of precipitation from PRUDENCE regional climate models with regard to their performance under present climate and their responses in a changing climate. The model evaluation focuses on the Alpine region, where dense observations are used to test the mesoscale distribution and annual cycle in precipitation statistics, including extremes. Diagnoses of model responses encompass the quantification of scenario uncertainties for regions of the Alps, and an analysis for extremes using extreme value statistics. Results will also be presented from an application of a distributed runoff model for the Rhine basin, forced with RCM data.

Variability of European climate in a heterogeneous multi-model ensemble

P.L. Vidale, R. Wegmann, D. Lüthi, C. Frei, C. Schär

Recent work on climate change for Europe (Schär et al. 2004) has once again stressed the need to consider both changes in climate and changes in its variability. Given our knowledge of variability in current climate (based on current CRU and ERA analyses), we turn to an analysis of variability in projected climate change from a heterogeneous ensemble of global and regional simulations.
We show how the summer change in T2m (30 year mean and standard deviation) bears a spatial signature common to the simulations in the PRUDENCE ensemble. We also present results which compare scenario and control simulations, indicating a clear correlation in the increase in the variability of surface temperature, soil moisture and precipitation, which suggest a potential for modulation at the land surface.

Partner 7 (GKSS)

Possible future changes in near surface wind speed over Europe from an ensemble of regional models

Burkhardt Rockel and Katja Woth

GKSS contributed to WP1 by two 50 km runs with the regional climate model CLM.
In WP2 we assess the uncertainty in future change of near surface wind predicted by an ensemble of regional model simulations. The basic data sets are the daily maximum and mean wind speed fields from the PRUDENCE data archive at DMI. The results of this study will be presented at the final PRUDENCE meeting.
Main focus is on the results from the standard 50km runs of eight regional models driven by the Hadley Centre global model results.
From the given data sets the optimal parameter for determining future changes in extreme wind speeds and the change in number of storm events is the maximum daily wind speed. It turns out that the way maximum daily wind speed is calculated differs among the regional models. The calculation is done in three different ways: 1) maximum from three hourly instantaneous values, 2) maximum values of each time step, 3) as the latter plus a gust parameterization. The effect of the different ways to determine the maximum wind speed on the storm prediction is investigated.
In order to get a homogeneous ensemble we also look at the 99-percentile of the daily mean wind speed. We divide Europe into eight sub-regions (e.g. British Isles, Iberian Peninsula, and Scandinavia) and investigate the monthly variation of wind over these regions.

An assessment of possible changes in North Sea storm surges in a future climate and of the uncertainty due to the model formulation

Katja Woth and Burkhardt Rockel

The intention of the talk is to summarize the final results and to give an overview over the performance of the task: “An assessment of possible changes in North sea storm surges in a future climate and of the uncertainty due to the model formulation”.
Results for possible changes in North Sea storm surge climate, obtained by using regional model output from four different RCMs are presented, driven all with global conditions, representative for 1961-1990 and 2071-2100 (IPCC A2 SRES) coming from HadAM3. The effect on windiness of the enhanced greenhouse gas conditions, projected by these four regional climate models was in al cases similar, yielding a moderate increase of high wind speeds in most parts of the North Sea during winter.
These simulated surface wind and pressure data have been used to run a storm surge model. We show the expected storm-related changes in different storm surge parameters. For instance, the largest increase of high water levels, defined as the 99.5%ile during winter sampled every half an hour would have to be expected along the southern and eastern North Sea coast, with maximum values of around 30 cm, which is beyond the range of normal year-to-year variations. Similar results can be found for all four experiments. Together with the expected rise of mean water levels of 40 cm by IPCC (2001), the total increase is 70 cm at the end of the 21st century under the assumptions of the rather severe A2 scenario.

Partner 8 (MPI)

European Discharge under climate change conditions simulated by a multi-model ensemble

Stefan Hagemann and Daniela Jacob

Ten regional climate models (RCMs) participated in the European project PRUDENCE, which was aimed to predict uncertainties in RCM simulations over Europe. Within PRUDENCE two major climate simulations were performed by each participating RCM. A control simulation representing current climate conditions for the period 1961-1990, and a scenario simulation representing climate change conditions according to the IPCC scenario A2 for the period 2071-2100. For both simulations, lateral boundary conditions and SST were provided by the coupled atmosphere-ocean general circulation model HadCM3. In order to perform hydrological studies on these RCM simulations, a special focus was put on the discharge from large river catchments located in northern and central Europe. The discharge was simulated with a simplified land surface (SL) scheme and the Hydrological Discharge (HD) Model by using daily fields of precipitation, 2m temperature and evapotranspiration from the RCM simulations. Therefore the total catchment water balances are constrained by the hydrological cycle of the different RCMs, The validation of the simulated hydrological cycle from the control simulations shows that the multi-model ensemble mean is closer to the observations than each of the models, especially if different catchments and hydrological means are considered. This provides some confidence in the future projections for the multi-model ensemble means. The scenario simulations predict a gradient in the climate change signal over Northern and Central Europe. Common features are the future warming and a general increase of evapotranspiration. But while in the northern parts the warming will enhance the hydrological cycle leading to an increased discharge, the large warming, especially in the summer, will slow down the hydrological cycle caused by a drying in the central parts which is accompanied by a reduction of discharge.

Partner 9 (SMHI)

PRUDENCE-related work at SMHI

Kjellström et al.

The SMHI presentation will consist of three parts

1) Precipitation in the Baltic Sea region.

Present-day and future precipitation over the Baltic Sea and surrounding land areas in the PRUDENCE RCMs will be described. Differences in the climate change signal between different driving global models and different regional models will be presented. We show that the influence of sea surface temperature has a profound impact on the simulated hydrological cycle over the Baltic Sea.

2) Variability in daily maximum and minimum temperature.

Present-day daily variability in the PRUDENE RCMs is compared to observed variability. Changes in daily variability in the future climate are discussed. Also, different future climate change responses between different RCMs are related to historical climate change in Europe. We focus on the winter climate in northern and eastern Europe and the summer climate in the southern half of Europe. During these seasons, these regions are projected to experience large changes not just in the average temperatures but especially in the tails of the probability distributions.

3) Storminess.

Storminess indicators derived from observed sea-level pressure have been used for assessing historical wind-storms. How well do the Prudence RCMs capture observed variability, and are there any systematic biases? We present some preliminary results from ongoing analyses of a subset of models.

Partner 10 (UCM)

Contributions to WP2

Miguel Anguel Gaertner et al.

We will present briefly the main results of several studies performed by our group (partner 10) during the last year. These studies are contributions to WP2, and partly to WP5. The studies are:
- The use of a climate type classification for assessing climate change effects in Europe from an ensemble of nine RCMs
- Seasonality changes for a future climate scenario in Europe from an ensemble of RCMs
- Impact of a change in vegetation parameters on summer precipitation in an RCM
- Late summer cyclones over the Mediterranean Sea

Country-by-country uncertainty and variability assessment from ensemble RCM-PRUDENCE simulations: preliminary results

Enrique Sanchez Sanchez et al.

Partner 11 (UPM)

Impact studies in areas with complex orography. The need for high-resolution climate models in the Iberian Peninsula.

Mínguez, M.I., Ruiz-Ramos, M., Díaz-Ambrona, C. H., Quemada M. and Sau, F.(*)
Universidad Politécnica de Madrid and Universidad de Santiago de Compostela(*)

The utility of high resolution climate models linked to crop simulation models is assessed for agricultural impact analysis in areas of complex orography. We evaluate and compare predictions on agricultural impacts generated by linking several high-resolution climate models to crop simulation models (CropSyst and CERES-DSSAT). New uncertainties are added in this process, derived from the simulation models *per se*, and from the extrapolation of crop models, tested within a limited sample of real conditions to a much larger domain. To standardise procedures, while maintaining balance between spatial scale and accuracy of the field data, crop model calibration and validation concentrated on the main processes involved at crop and cropping systems level, viz. yield, biomass, phenology, and, crop evapotranspiration (ET) and net irrigation requirements. Results will be structured according to the climate experiments that provided the raw data for climate scenarios. Impact mMaps will be generated to show direct or relative (future/current) changes in biomass, grain yield, evapotranspiration or irrigation requirements, for the reference crops, wheat, barley and maize, under current and future climate scenarios, so comparisons can also be assessed visually. Agronomic practices, species and types of cultivar, will be used to obtain information for comparisons and for changing uncertainties associated to soil and rainfall data, and to some crop processes.

Partner 2+12 (CINECA/ICTP)

Summary of ICTP/CINECA activities and results for the PRUDENCE project

F. Giorgi, X. Bi, J. Pal, F. Kucharski, E. Coppola

The ICTP regional climate model RegCM was run for reference (1961-1990) and A2/B2 (2071-2100) scenario simulations driven by HadAM3H fields. A thorough validation of the reference run was conducted, including mean, variability and trends. This analysis showed that the RegCM captured the main features of the observed climatology over Europe and that this was one of the most skilful simulations performed to date by the RegCM. Both in the A2 and B2 scenario simulations the European region is characterized by warming, maximum over eastern Europe in DJF and over southern Europe in JJA. The warming is 1-2 C lower in the B2 than the A2 simulations. The precipitation change signals in the B2 and A2 scenarios show similar characteristics. In DJF, precipitation increases over most of western and central Europe due to increased storm activity over the region and decreases over the southern Mediterranean. In JJA, precipitation decreases over most of western and southern Europe due to increased anticyclonic circulation over the northeastern Atlantic which deflects summer storms northward. The intensity of precipitation events and the interannual variability mostly increases in the scenario simulations across seasons and regions. Some features of the summer precipitation change signal are consistent with obervations of trends over the region during the last decades.

In addition to the RegCM simulations, time slice simulations for (1961-1990) and (2071-2100) under A2 forcing were completed with the FVGCM global model at a resolution of 1x1.25 degrees. The SST and GHG forcing is the same as that used in the other GCM simulations of the PRUDENCE project. Two realizations of each run were completed, which showed general similar features in the change signal over Europe. The temperature and precipitation change signals over Europe shown by the FVGCM have consistent dominant characteristics as those shown by other global models in PRUDENCE, namely wetter winter conditions over central and northern Europe and strong summer drying over western Europe and the Mediterranean Basin. This adds robustness to the findings.

Output from all simulations has been provided to the PRUDENCE users community.

Partner 13 (DIAS)

Crop production and nitrogen cycling in arable crop rotations under climate change

Jørgen E. Olesen, Tove Heidmann & Gitte Rubæk

The increasing crop yields that results from increased CO2 concentration and climate change will increase the optimal nitrogen fertiliser rates. This effect was estimated for continuous winter wheat cultivation using the DAISY model for different greenhouse gas emissions scenarios. The estimated increase in optimal nitrogen fertiliser rates for 2100 varied from 20 to 69 kg N ha-1 for one of the scenario. There was an increase in nitrate leaching for a climate from Western Denmark, whereas there was a tendency for a reduction for loamy soils for a climate in Eastern Denmark. The environmental effects of climate change in Denmark may therefore vary regionally. The effects can mainly be attributed to changes in temperature and CO2 concentration, because the effect of lower rainfall during the growing season is compensated by an increase in water use efficiency at higher CO2 concentration. The model calculations showed a clear tendency towards higher increases in nitrogen leaching under climate change for the sandy soils compared with the loamy soils. This is an effect of an increase in soil organic matter turnover rates at higher temperatures and an increase in the duration of bare soil during autumn. This increase in nitrogen leaching is counteracted by an increase in carbon content in the plant residues as an effect of increased photosynthesis at higher atmospheric CO2 concentrations. Model calculations showed that an increase in use of spring cereals with cover crops could effectively reduce the increase in nitrogen leaching.

Partner 14 (RISØ)

The Relevance of Climate Model Resolution on the Analysis of European Agricultural Policy Scenarios under Climatic Change.

Molly Hellmuth (UNEP Risoe) and David Wiberg (IIASA)

We investigated the impacts on agricultural production and trade flows for two different climate model spatial resolutions. The climate change scenarios for Europe are based on the Hadley Center's medium resolution (~300 km) HadAM3H model, applying three regional models, the high resolution (50 km) HadRM3H model, SMHI's RCAO model, and DMI's HIRHAM model, using the IPCC SRES A2 and B2 Scenarios. The agricultural yield assessments for Europe were based on data with 1 km resolution and for ROW on data with 5' resolution.

The trade flows within the EU, and between the EU and the rest of the World (ROW), were assessed. Two broad policy options were considered, a market-oriented and an environment-oriented scenario. The results indicate the importance of the spatial resolution of climate change scenarios in terms of the uncertainty in magnitude of climate change impacts; as well as, the agro-ecological and economic impacts of different scenarios on the agricultural sector development.

Partner 15 (UniFri)

Heat waves and extreme wind speeds over Europe by the end of the 21st century: Analysis of multi regional climate simulations

Brigitte Koffi

Changes in Heat Waves (HW) and wind storms indicators between the 20th (1961-90) and the 21st (2071-2100) centuries are investigated over Europe. In order to assess the uncertainties due to model formulation, natural climate variability, and radiation forcing, regional simulations for 2 different emission scenarios and four different model chains, consisting of 3 Regional Climate Models, driven by 2 Global Climate Models are considered. Based on calendar day thresholds of the daily maximum temperature, the HW indices allow a consistent analysis over the European continent and throughout the year. Heat wave events are shown to become very commonplace at the end of this century, with highly differing patterns according to season and location. First results of future changes in winter extreme wind speeds as deduced from the simulated daily maximum wind speed over Europe are also briefly discussed.

Partner 16 (FEI)

Assessing uncertainties in climate change impacts on resource potential for Europe based on projections from RCMs and GCMs

Stefan Fronzek[1], Timothy R. Carter[1] and Kirsti Jylhä[2]

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We present analyses of the estimated impacts of climate change on different aspects of the natural environment, agriculture and energy demand in Europe under a wide range of RCM- and AOGCM-based climate scenarios. A suite of simple models and indices are used to assess impacts on the growing season, potential biomass, and thermal suitability for the cultivation of crops, nitrate leaching from winter wheat, and potential energy demand for indoor cooling and heating.
Impacts have been estimated for observed climate in the 1961-1990 baseline period and projected climate during 2070-2099 based on outputs from a range of RCMs using SRES emission scenarios A2 and B2 and from seven GCMs using a wider range of emission scenarios. All analyses are conducted on a regular 0.5 x 0.5° grid across Europe.
Uncertainties in the projected impacts of climate change are assessed with respect to: 1) the direct model output vs. delta change approach, 2) differences in the driving GCMs and the RCM runs, 3) the model range vs. a range of emission scenarios, 4) changes in long-term mean climate, and 5) changes in inter-annual climate variability.

Partner 17 (UniReading)

Attributing variation in regional climate change model experiments

Christopher Ferro

An `analysis of variance' quantifies the uncertainty arising from different components of the PRUDENCE experiments. This systematic exploration of experiment results helps to identify the relative importance of the different components, to construct simplifying syntheses of simulation output, and to make inferences about climate change and model differences. The presented analysis quantifies the effects of emissions forcing, global models (GCMs), regional models (RCMs) and combinations of these factors for annual mean two-metre air temperatures.

Partner 18 (LU)

Assessing Prudence RCM scenarios using the LPJ-GUESS ecosystem model

Pablo Morales, Martin T.Sykes, Ben Smith, Thomas Hickler

Lund University, Centre for GeoBiosphere Science, Department of Physical Geography & Ecosystems Analysis

The LPJ-GUESS ecosystem model has been used to assess impacts of climate change on Net Primary Productivity (NPP) using a wide range of RCM and GCM based climate scenarios. Impacts have been estimated as the changes in NPP (anomalies) for different climatic zones and the entire Europe under the projected climate during 2070-2099 in comparison to the baseline period (1961-1990). All analyses were conducted on a CRU 0.5 x 0.5° grid cell across Europe.

Additionally, we present preliminary results comparing two approaches we have been developing to fill the time gap of climate data from 1991 to 2070.

Partner 19 (CIRED)

Value-added for decision-making of finer spatial and temporal scale climate change projections

Stéphane HALLEGATTE & Philippe AMBROSI

How to derive information regarding climate change risks from climate scenarios? What are the interest and value-added to produce climate change projections on a finer spatial and temporal scale ?

In the first case, we propose to derive some indicators of climate risks, based on data obtained from GCMs experiments which have been undertook in PRUDENCE project. These indicators will help to quantify and communicate between the integrated assessment community and between science and decision. One example of climate analogue mapping is given as an illustration of a better way to convey climate change information to a wider audience than the climate change community.

The second part focuses on regional/sectoral disaggregation and their potential masking effect. Two cases are explored: (i) the multiplicative effects of sectoral interactions on climate change impacts and; (ii) local non-linearities in CC damages valuation and the potential masking effects of aggregation to a more global level. These cases demonstrate which meaningful information PRUDENCE could provide for a more appropriate assessment of climate change risks.

Partner 21 (FMI)

Projected changes in indices related to low air temperatures and extreme precipitation

Jylhä K.(1), Fronzek S.(2), Ruosteenoja K.(1), Tuomenvirta H.(1) and Carter T.R.(2)
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We present analyses of projected changes in indices related to low temperatures and extreme precipitation, including the annual number of frost days, first and last dates of the frost season, number of days crossing the 0ºC threshold, number of days with snow cover, annual maximum ice cover over the Baltic Sea, maximum 1- and 5-day precipitation, and maximum length of dry spells. To assess the maximum ice cover we used a modified regression method based on monthly mean temperature. Seasonal and annual means of the remaining indices were calculated using daily data from an extensive suite of RCM runs. Interpolation of the indices onto a common grid across Europe enabled us to assess the uncertainties in the estimated changes due to differences in RCM formulation, GCM boundary conditions and future emissions. The results are presented as maps and domain-averages.

Regional temperature and precipitation change estimates for Europe under four SRES scenarios

Kimmo Ruosteenoja, Heikki Tuomenvirta and Kirsti Jylhä

The discourse gives 95% probability intervals of temperature and precipitation change for five regions covering Europe west of 35°E. Intervals are based on data derived from the output of six coupled GCMs, and the GCM-based projections are compared with those based on RCM simulations. Projections are given for four SRES scenarios. Responses to A2 and B2 scenarios are mainly based directly on model output, while the extreme A1FI and B1 responses are calculated applying a super-ensemble pattern-scaling method. The idea and applicability of that method were discussed in our poster presentation in the Lund meeting in March 2004.

Contributor A (KNMI)

Circulation statistics and climate change in Central Europe; PRUDENCE simulations and observations.

Aad van Ulden, Geert Lenderink, Bart van der Hurk and Erik van Meijgaard

PRUDENCE simulations of monthly mean pressure and geostrophic wind over Central Europe are analysed. Model simulations are compared with observations over the period 1780–1995. This long record provides information on the mean circulation and on natural variability on interannual and interdecadal timescales. The control simulations by the global models HadAM3H and ECHAM4/OPYC show biases, which fall outside the range of natural variability. In winter, both models have a pronounced positive bias in the west-component of the geostrophic wind (Gw too strong). In summer, HadAM3H has a pronounced negative bias in Gw (Gw too weak), while ECHAM shows no significant bias in this variable. Both models show a negative pressure bias in summer. In the A2 scenario simulations the circulation statistics move further away from the observed statistics. The biases in Gw have a strong impact on the frequency distributions of this variable. For winter months, the percentage of months with a mean easterly flow is 14% in the observations. In the control simulations this percentage is reduced to about 7%, while such easterly circulations are virtually absent in the scenario runs. Thus the simulated winter climate is far more maritime that the observed winter climate. For summer months, the HadAM3H simulation of the frequency distribution of Gw differs dramatically from the observations. In the observations about 8% of the summer months is characterised by a mean easterly flow. In the HadAM3H control run this percentage is 45% and in the HadAM3H scenario run even 75%. Thus the summer climate is far too continental in the HadAM3H simulations. The ECHAM simulations show fairly realistic circulation statistics for summer months.
We analyse nine regional climate models, which use lateral boundary conditions and SST's from HadAM3H. The correlations between monthly mean pressure and geostrophic wind components simulated by the regional models and those simulated by the driving model HadAM3H are quite high in winter (for DJF r = 0.95-0.99). Thus large scale dynamics effectively control the circulation statistics in the domain of the regional models. In other months the situation is different, especially in summer. Some models show correlations around 0.7, while other models show correlations around 0.95 even in summer. Thus differences in boundary relaxation procedures are important when large scale dynamical forcings are weaker. The regional models show also important differences with HadAM3H and between each other in the simulated mean flow characteristics. Also the variability in the circulation components shows a wide range between the models. An interesting feature is that most regional models tend to reduce the easterly bias present in the HadAM3H simulations for the summer. This reduction is more pronounced for models which have a low sensitivity to summer drying. This points at a positive feedback between summer drying and the easterly flow bias. Also temperatures are involved in this feedback. This makes the models rather sensitive to the treatment of the soil moisture budget, leading to very warm extremes in the scenario simulations by some models. Also the impact of the westerly bias in winter is important. There is a lack of very cold months, due to a lack of easterly circulations. In general there is a warm circulation bias which increases in the scenario simulations for winter. The conclusion is that biases in the frequency distributions of the atmospheric circulation have to be taken into account when comparing model simulations of e.g. temperature and precipitation with observations. In the assessment of regional climate change, the role of changes in circulation statistics should also be included in the analysis.

Soil atmosphere-feedback under changing climate conditions

Bart van den Hurk

For 7 RCM's using both the control and A2 scenario HadAM3H simulations as boundary conditions an analysis of the hydrological budget over the Rhine river has been carried out. Particular attention was paid to the way the land surface modules of the models treat anomalous moisture convergence over the area. From a combination of ERA40 data and discharge observations an 'optimal'; partitioning of the P-E anomalies over soil storage and runoff could be derived. All but one RCM's appeared to attribute a too small role of the soil storage capacity to absorb anomalies, and result in a too large interannual variability of the predicted runoff. The behaviour in the present-day simulation is to some extent transferable to the future: all models give a strong reduction of summertime P-E over the Rhine basin when changing from present-day to future climate simulations, and the response of the river runoff (strong increase of the annual cycle) roughly followed the response observed in the current climate simulations.

Summertime inter-annual temperature variability in an ensemble of regional model simulations: impacts of the physics

Geert Lenderink and Aad van Ulden

The inter-annual variability in monthly mean summer temperatures in nine different regional climate model (RCM) integrations, performed in the PRUDENCE project, is investigated for both the control climate (1961-1990) and the future climate (2071-2100). All models are driven by the same simulation of the HadAM3 global atmospheric model. Compared to the CRU TS 2.0 observational data set most RCMs most models over predict the temperature range between the 80% and 20% quantiles by 30% to 100% in large parts of Europe in their control simulation. In all models the temperature variability increases when imposing future climate boundary conditions, with particularly high values in central Europe. The behaviour of the different regional climate models is analysed in terms of the surface energy budget, and the individual contributions of long wave and short wave radiation and evaporation to the temperature variability are estimated for each model. In particular for the climate response, it appears that despite that the increase in temperature variability is rather uniform in the model ensemble, the way it is achieved is varies widely. Some models are very vulnerable to soil drying, whereas others are rather insensitive to drying. Variability in shortwave radiation and the land sea temperature contrast also play an important role.

Contributor B (University of Oslo)

Optimal atmospheric sensitivity in Europe to forcing perturbations.

Trond Iversen (1), Inger-Lise Frogner (2), Jan Barkmeijer (3)

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The concept of Singular Vectors have been generalized to forcing, so-called Forcing Singular Vectors (FSVs). These are spatial structures for the forcing-terms of the equations for atmospheric flows that lead to a maximum perturbation of the atmospheric state in a selected target area after an optimization time interval. We have calculated FSVs targeted to Europe for a range of basic atmospheric flow situations with variable NAO-phases. The sensitivity varies sharply, and the cases with high leading forcing singular values indicate high sensitivity w.r.t. SST-perturbations in the Northern North Atlantic Ocean, as well as to mid-tropospheric forcing. This has implications for the quality that can be expected from pure atmospheric downscaling of climate scenarioes in Europe.

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