WENGEN-2003 Workshop

ESF Exploratory Workshop

PRUDENCE 3rd Annual Meeting

Regional Climate Change in Europe: Processes and Impacts

Synthesis Report

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

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

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

- exchange views on the scientific and technical issues related to high resolution climate modeling;
- discuss the results of the simulations of regional climate futures in Europe under conditions of enhanced atmospheric greenhouse gas concentrations using a range of Regional Climate Models (RCMs);
- discuss approaches to regional-scale estimates of climate and the sensitivity of different regions to shifts in mean and extreme climates;

- evaluate the needs of the modeling community in terms of observational data for the calibration and validation of climate model results;
- foster discussion between climate modelers and impacts specialists.

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

Session 1: Modeling Activities I

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

- observational limitations (creating multiple means of validation)
- future GHG concentration (SRES emission scenarios affected by societal, demography and technology factors); uncertainties in carbon cycle make it difficult to relate anticipated emissions to ensuing concentrations
- natural variability (30-year climatology is just a convention)
- uncertainty in the response of the climate system (justifying the use a wide range of climate modelling systems)

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

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

The process of dynamical downscaling from global coupled simulations at 300 km grid mesh down to 50 km (and even to 10 km in some cases) increases the “weather” realism of climate simulations and generates more information; but the question of how to validate these simulations remains. While 50-km meshes appear to be required for realistic weather simulations, there still appears to be some orographic precipitation problem at this resolution. With 25-km meshes, the orographic precipitation problem is lessened, and it almost disappears at 10 km. The question of how to compare model simulations with observations, and at which scales, remains mainly open, in part due to factors of resolution and of observational constraints. It is clear that the computational mesh does not represent the

physical resolution of the simulation: once filtered to remove shorter than about 3 or 4 grid-point information, the resulting fields appear to be rather realistic. Similarly a lateral buffer around the perimeter of nested RCM exhibit non-physical behaviour; this zone includes the nesting / sponge zone, plus some (imprecisely defined) extra internal region where fields undergo adjustment.

In summary:

- Uncertainties can and should be addressed using the PRUDENCE data set
- There is a trend towards using even higher resolution; this will allow for more details
- The uncertainties addressed in PRUDENCE are still apparent at higher resolutions
- There is a need to identify aspects, where resolution is essential and provides robust results across model formulations etc.
- An RCM is a valuable tool for detailed investigations of climate change, providing quite realistic simulations

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

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

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

A study of uncertainty in the climate-change signal in the PRUDENCE runs for the 2-m temperature and precipitation over Europe in the winter (DJF) and summer (JJA) seasons

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

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

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

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

Session 2: Modeling Activities II

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

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

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

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

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

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

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

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

Session 3: Modeling Activities III

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

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

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

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

Session 4: Modeling Activities IV

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

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

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

Virginie Lorant investigated the fraction of convective precipitation compared to total precipitation with the Canadian CRCM over the Baltic drainage basin during the PIDCAP period. There seems to be an underestimation of the number of dry days as well as days with

extreme precipitation as a result of the very small contribution of convective precipitation (about 10%) to overall rainfall in the region. Sensitivity tests using a prognostic closure instead of the diagnostic closure within the convection scheme show an increase in days without convective precipitation, more convection during the day (afternoon) and a stable boundary layer at night. The results do not appear to be dependent on the chosen resolution or region.

Session 5: Extreme Events and Impacts I

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

As pointed out in the very beginning of this session, there is still some uncertainty related to the definition of an “extreme” event, which include the many qualitative and quantitative degrees of perception of the phenomenon. In particular, at the economic end, one should be careful to not always relate extreme loss to the severity of the weather. The key question concerning extremes is the following: how are they currently behaving under today’s climate and how are they going to respond to climatic change? To study them, a statistical approach of extremes is indeed required; however, to understand their origin, a meteorological study is also desirable. Some highlights of the talks include winter (December-January-February of DJF) observed extreme rainfall behaviour that has been analysed; results seem to suggest that the principal components of the number of consecutive dry days and those of the number of days above the 1961-90 90^{th} percentile of wet day amounts are correlated to the climate of the North Atlantic, with the North Atlantic Oscillation (NAO) playing a significant role. The analysis of heat waves, as simulated with the HIRHAM4 of the Danish Meteorological Institute at 50-km resolution, presented in terms of heat wave frequency and

heat wave duration indices, reveal that the frequency and duration should increase by a factor from 3 to 10 on average, implying that, for example, South-west France or Hungary may experience occurrence of temperature above 30°C as frequently as currently observed in Southern Spain or in Sicily. In addition, the study of extreme precipitation also indicated a drying on average in Central and Southern Europe in late summer coincides with increases in extremes precipitation in a number of regions.

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

Session 6: Extreme Events and Impacts II

Christoph Frei gave a comprehensive presentation on *Scenarios of European precipitation extremes: An analysis and intercomparison of RCM simulations.* An analysis was presented of precipitation *extremes* and *not-so-extremes* in 3 RCMs: CHRM, HadRM3 (ensemble of 3 runs), and HIRHAM. STARDEX indices were presented and climate change differences tested for statistical significance using non-parametric bootstrap tests. Extreme precipitation events were also modelled using the GEV probability model (maximum likelihood fits). Seasonal maxima were used to do the GEV fits and care was taken to include only non-zero maxima. To get better estimates of the GEV parameters, the geophysical prior approach of Martins and Stedinger (2000) was used. Model results were evaluated by comparison with precipitation data from 6471 Alpine stations aggregated on regional climate model scale. Christoph presented the mean annual cycle of the mean and 90% quantiles over the Alps. The models were able to reproduce the Autumn peak in the 90% quantile although there were some biases. Winter wet day intensity shows enhanced intensity along the Alpine region – all models were able to capture this but there were some important quantitative differences. RCM results and ERA15 forced RCM results were found to be very similar and so were not affected by GCM driving. The biggest differences were found in HadRM3, which is drier when driven by ERA15. RCMs tended to be wetter in Spring and Autumn when driven with RCMs than when driven directly with ERA15. In summary, the RCMs show encouraging skill at reproducing mesoscale patterns of precipitation. Christoph then went on to present differences between the scenario and control runs. Relative change in DJF mean precipitation maps showed decreases to the south of 45N and increases in northern Europe of up to about 30%. Relative changes in wet day frequency were less than changes in the

mean but decreases in the south were similar to changes in the mean. All three models showed increases in wet-day intensity in the north with a strange low patch in central Europe in two of the models. Changes in the 5-year extreme 5-day rainfall return level showed a similar picture to precipitation intensity. In northern Europe, rare extreme events became three times more frequent: the 15-year event became a year event in the future scenarios. The 20-year return levels showed less statistically significant changes. A quantitative summary of Scandinavia was presented of the relative change of various statistics. Mean change was equally due to changes in wet day frequency and intensity. Summer mean changes showed similar spatial patterns for different models but magnitudes differed. HIRHAM did not show much drying whereas CHRM showed strongest drying mainly due to changes in wet-day frequency in CHRM. Wet-day intensity changes were less consistent across models. The changes in 1-day 5-year return values were not very statistically significant. Maximum number of consecutive dry days in JJA showed that central Europe spell lengths decreased by 50% with similar patterns between models. In the final summary, Christoph noted that winter magnitudes varied little between RCMs and showed similar behaviour for different quantiles, there was more variation between model changes in JJA, and heavy summer precipitation only increased slightly (over Central Europe).

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

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

climatic events such as Alpine floods (as compiled by Pfister since the 1500s) and argued that we should put more attention into understanding the clustering of climate extremes.

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

Session 7: Climate Impacts and Climate Change Policies I

This session included four presentations; the first three concerned impacts from climate change and the fourth was a presentation from one of the regional climate models (in place of a scheduled impacts presentation that was cancelled). Kirsten Halsnaes opened her keynote presentation, “The value of improved climate information in relation to investments in

the agricultural sector," with some overall questions to the modelling community. How important are climate change impacts on human welfare and what are the economic impacts of climate change compared to the costs of mitigation? Such issues need to be brought forth to address socio-economic aspects of climate change. Evaluation should be based on sustainability indicators as an alternative to monetary impact assessments. Some focal impact areas are crops, tourism, water availability, human settlements, glaciers and vegetation. Her presentation ended with a general request to other Prudence partners to open a dialogue on how we can best communicate the outcomes of Prudence to policy makers. A workshop with decision makers and a few selected Prudence participants will take place toward the end of 2004.

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

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

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

Session 8: Climate Impacts and Climate Change Policies II

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

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

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

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

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

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

Last-day sessions

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

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

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ESF / PRUDENCE / WENGEN-2003 WORKSHOP

Hotel Regina, Wengen, Switzerland

September 29-October 3, 2003

WORKSHOP PROGRAM

Monday, September 29, 2003

	08:15-08:45	**Opening remarks**: objectives of science and PRUDENCE business Martin Beniston and Jens H. Christensen **ESF Sponsorship**: A representative of the European Science Foundation
		SESSION 1: MODELING ACTIVITIES
		Chairperson: ***René Laprise, University of Quebec at Montreal, Canada***
1.1	**08:45-09:30** **Keynote**	**Assessing uncertainties in climate projections using the PRUDENCE simulations** Jens H. Christensen, PRUDENCE Coordinator *Danish Meteorological Institute, Copenhagen, Denmark*
1.2	**09:30-10:00**	**How representative is the interannual variability of the PRUDENCE control run in Western Europe?** Aad P. van Ulden *KNMI, De Bilt, The Netherlands*
1.3	**10:00-10:30**	**Uncertainties in the temperature and precipitation response of PRUDENCE runs over Europe** Michel Déqué *Météo-France, CNRM, Toulouse, France*
	10:30-11:00	***Coffee, tea, refreshments***
1.4	**11:00-11:30**	**Evaluation of coupled GCM/RCM runs based on circulation patterns** Dietrich Heimann and Maria José Costa Zemsch *DLR, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Weßling*
1.5	**11:30:12:00**	**Water mass analysis of a regional coupled Mediterranean simulation** S. Somot[1], K. Haines[2], M. Deque[1], F. Sevault[1] and M. Crepon[3] *1: Meteo-France, CNRM, France; 2: University of Reading, ESSC, UK; 3: CNRS, IPSL, France*
	12:00-14:00	***Lunch***
		SESSION 1: MODELING ACTIVITIES (Continued)
		Chairperson: ***Ole Bøssing Christensen, DMI, Copenhagen, Denmark***
1.6	**14:00:14:45** **Keynote**	**Climate change and the water cycle: from processes to scenarios** Christoph Schaer *Atmospheric and Climate Science ETH, Zürich, Switzerland*
1.7	**14:45-15:15**	**Influence of boundary relaxation schemes on the warm summer bias in RACMO** Geert Lenderink *KNMI, De Bilt, The Netherlands*
1.8	**15:15-15:45**	**Causes of future summer drying over Central Europe** Dave Rowell *Hadley Centre for Climate Prediction and Research, Bracknell, UK*
	15:45-16:15	***Coffee, tea, refreshments***

1.9	**16:15-16:45**	**A simulation of the Mediterranean Sea driven by PRUDENCE fluxes for the 1960-2100 period** Florence Sevault *METEO-France, CNRM/GMGEC, Toulouse, France*
1.10	**16:45-17:15**	**On the development of a regional climate model for Central Europe** Tomas Halenka *Department of Mathematics and Physics, Charles University, Prague, Czech Republic*
	18:30	***Icebreaker***

Tuesday, September 30, 2003

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

Tuesday, September 30, 2003

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

Wednesday, October 1, 2003

		SESSION 3: EXTREME EVENTS AND IMPACTS
		Chairperson: ***Martin Beniston, University of Fribourg, Switzerland***
3.1	**08:30-09:15** **Keynote**	**Statistical methods for diagnosing changes in extreme events** David B. Stephenson *Department of Meteorology, University of Reading, UK*
3.2	**09:15-09:45**	**Extremes in a non-stationary climate: a statistical approach** Christopher Ferro *Department of Meteorology, University of Reading, UK*
3.3	**09:45-10:15**	**Interannual variability of European extreme winter rainfall and lins with large-scale circulation** Malcolm Haylock *Climatic Research Unit, University of East Anglia, Norwich, United Kingdom*
	10:15-10:45	***Coffee, tea, refreshments***

3.4	**10:45-11:15**	**Heat waves in Europe under climate change** Brigitte Koffi *Department of Geosciences, University of Fribourg, Switzerland*
3.5	**11:15-11:45**	**Extreme precipitation in the DMI PRUDENCE simulations** Ole Bøssing Christensen *Danish Meteorological Institute, København, Denmark*
3.6	**11:45-12:15**	**Heavy precipitation episodes as simulated by the regional climate model HIRHAM4** Susana Margarida Mendes *Evora Geophysics Center, University of Evora, Portugal*
	12:15-14:00	***Lunch***
		SESSION 3: EXTREME EVENTS AND IMPACTS (Continued)
		Chairperson: *David Stephenson, University of Reading, United Kingdom*
3.7	**14:00-14:30**	**Scenarios of European precipitation extremes: An analysis and intercomparison of RCM simulations** Christoph Frei, Sophie Fukutome, Jürg Schmidli and Regina Schöll *Atmospheric and Climate Science ETH, Zürich, Switzerland*
3.8	**14:30-15:00**	**Modelling extreme events - a climate change simulation over Europe using the regional climate model REMO** Tido Semmler *Max-Planck-Institute for Meteorology, Hamburg, Germany*
3.9	**15:00-15:45** **Keynote**	**Recent and future changing coastal climate: storminess and impacts for the North Sea** Hans von Storch[1], Ralf Weisse[1], Arnt Pfizenmayer[1], Frauke Feser[1], Lars Bärring[2] and Hans Alexandersson[3] *1: GKSS Research Center, Geesthacht, Germany; 2: Lund University, Sweden; 3: SMHI, Norrköping, Sweden*
3.10	**15:45-16:15**	**How certain are changes in North Sea storm surges extremes expected at the end of the 21st century?** Katja Woth *GKSS Research Center, Geesthacht, Germany*
	16:15-16:45	***Coffee, tea, refreshments***
		PRUDENCE BUSINESS MEETING: SECOND SESSION
	16:45-18:30	Working Group Breakout Sessions

Thursday, October 2, 2003		
		SESSION 4: CLIMATE IMPACTS AND CLIMATE CHANGE POLICIES
		Chairperson: *Christoph Frei, ETH-Zurich, Switzerland*
4.1	**09:00-09:45** **Keynote**	**Runoff in regional climate models – evaluation of simulations and assessment of impacts** Phil Graham *SMHI, Norrköping, Sweden*
4.2	**09:45-10:15**	**Climate change and runoff statistics: A process study for the Rhine Basin using a coupled climate-runoff model** Jan Kleinn *Institute for Atmospheric and Climate Science ETH, Zurich, Switzerland*
4.3	**10:15-10:45** **Keynote**	**Assessment of different climate outputs with crop model in Southwestern Europe** Carlos G. H. Diaz-Ambrona *E. T. S. I. Agonomos, Universidad Politecnica de Madrid, Spain*
	10:45-11:15	***Coffee, tea, refreshments***
4.4	**11:15-11:45**	**Mapping shifts in crop suitability under a range of SRES-based climates** Stefan Fronzek and Timothy R. Carter *Finnish Environment Institute, Helsinki, Finland*
4.5	**11:45-12:15**	**Climate change and CO_2 influence crop production and nitrogen cycling in arable cropping systems** Jørgen E. Olesen *Danish Institute of Agricultural Sciences, Tjele, Denmark*
	12:15-14:00	***Lunch***
		SESSION 4: CLIMATE IMPACTS AND CLIMATE CHANGE POLICIES (Cont)
		Chairperson: *Phil Graham, SMHI, Norrköping, Sweden*
4.6	**14:00-14:45** **Keynote**	**The value of improved climate information in relation to investments in the agricultural sector** Kirsten Halsnaes *Risoe Research Centre, Risoe, Denmark*
4.7	**14:45-15:15**	**Predicted impacts of climate change on soil moisture availability in the Mediterranean** Jean Palutikoff *Climatic Research Unit, University of East Anglia, Norwich, UK*
4.8	**15:15-15:45**	**LPJ guess: Validation and an application of a dynamic ecosystem model using EUROFLUX data and RCM model output** Pablo Morales, Deniz Koca, Martin T. Sykes, and Ben Smith *Geobiosphere Science Center, Lund University, Sweden*
4.9	**15:45-16:15**	**Extreme weather events and the insurance industry** Andreas Tuerk *Department of Economics, University of Graz, Austria*
	16:15-16:45	***Coffee, tea, refreshments***

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

Friday, October 3, 2003

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

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

Saturday, October 4, 2003

All Day	***Optional excursion to the Jungfraujoch High Alpine Research Station***

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