ESF Exploratory Workshop

WENGEN-2003 Workshop

EU-PRUDENCE Annual Meeting

REGIONAL CLIMATIC CHANGE
IN EUROPE: PROCESSES
AND IMPACTS

Abstracts of Oral Presentations

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

Assessing uncertainties in climate projections using the PRUDENCE simulations

Jens Hesselbjerg Christensen

Danish Meteorological Institute, Copenhagen, Denmark

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

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

1.2

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

Aad P. van Ulden

KNMI, De Bilt, The Netherlands

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

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

Michel J. Déqué

Météo-France, CNRM, Toulouse, France

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

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

1.4

Evaluation of coupled GCM/RCM runs based on circulation patterns

Dietrich Heimann and Maria José Costa Zemsch

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

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

Water mass analysis of a regional coupled Mediterranean simulation

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

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

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

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

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

1.6

Climate change and the water cycle: from processes to scenarios

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

Atmospheric and Climate Science, ETH Zürich, Switzerland

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

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

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

Geert Lenderink

KNMI, De Bilt, The netherlands

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

1.8

Causes of future summer drying over Central Europe

Dave Rowell

Hadley Centre for Climate Prediction and Research, Bracknell, UK

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

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

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

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

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

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

Florence Sevault

METEO-France, CNRM/GMGEC, Toulouse, France

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

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

1.10

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

Tomas Halenka

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

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

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

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

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

Richard Jones

Hadley Centre, Bracknell, UK

2.2

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

Daniela Jacob

Max-PLanck-Institute for Meteorology, Hamburg, Germany

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

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

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

A new methodology to overcome this problem will be presented.

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

Juerg Schmidli

Atmoshperic and Climate Science ETH, Zuerich, Switzerland

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

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

2.4

Future changes in summertime precipitation over the Baltic

Erik Kjellström

SMHI, Norrköping, Sweden

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

Bart van den Hurk, Erik van Meijgaard and Geert Lenderink

KNMI, De Bilt, The Netherlands

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

2.6

Results from simulations with the CLM for PRUDENCE

Burkhardt Rockel

GKSS Research Center, Geesthacht, Germany

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

Regional climate under a warming scenario: Views from the Alps

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

Atmospheric and Climate Science -ETH, Zürich, Switzerland

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

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

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

2.8

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

Enrique Sanchez

Dept. Geofisica y Meteorologia, Fac. CC Fisicas, Universidad Complutense, Madrid, Spain

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

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, Tel Aviv, Israel

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

2.10

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

Virginie Lorant

Canadian Center for Climate Modelling and Analysis, University of Victoria, Canada

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

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

3.1

Statistical methods for diagnosing changes in extreme events

David B. Stephenson

Department of Meteorology, University of Reading, Reading, UK

3.2

Extremes in a non-stationary climate: a statistical approach

Christopher Ferro

Department of Meteorology, University of Reading, Reading, UK

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

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

Malcolm Haylock

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

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

3.4

Heat waves in Europe under climate change

Brigitte Koffi

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

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

Extreme precipitation in the DMI PRUDENCE simulations

Ole Bøssing Christensen

Danish Meteorological Institute, København, Denmark

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

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

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

3.6

Heavy precipitation episodes as simulated by the regional climate model HIRHAM4

Susana Margarida Mendes

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

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

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

Christoph Frei, Sophie Fukutome, Jürg Schmidli and Regina Schöll

Atmospheric and Climate Science ETH, Zurich, Switzerland

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

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

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

3.8

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

Tido Semmler

Max-Planck-Institute for Meteorology, Hamburg, Germany

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

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

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

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

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

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

3.10

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

Katja Woth

Institute for Coastal Research, GKSS Research Center, Geesthacht, Germany

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

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

Phil Graham

Rossby Center, Swedish Meteorological & Hydrological Institute, Norrköping, Sweden

4.2

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

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

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

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

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

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

Assessment of different climate outputs with crop model in Southwestern Europe

Carlos G.H. Diaz-Ambrona

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

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

4.4

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

Stefan Fronzek and Timothy R. Carter

Finnish Environment Institute, Research Programme for Global Change, Helsinki, Finland

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

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

Jørgen E. Olesen

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

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

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

4.6

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

Kirsten Halsnaes

Risoe Research Centre, Risoe, Denmark

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

Jean Palutikof

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

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

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

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

4.8

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 Centre, Department of Physical Geography and Ecosystems Analysis, Lund University, Sweden

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

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

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

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

Smith, B. Prentice, I.C. & Sykes, M.T. 2001 Representation of vegetation dynamics in modelling of European ecosystems: comparison of two contrasting approaches. Global Ecology and Biogeography 10, 621-638.

Sitch, S., Smith, B., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K. & Venevsky, S. 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ Dynamic Global vegetation model Global Change Biology. 9:161-185.

Extreme weather events and the insurance industry

Andreas Tuerk

Department of Economics, University of Graz, Austria

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

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

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

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

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

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

5.2

Title to be defined

Penny Whetton

CSIRO, Division of Atmospheric Research, Aspendale, Victoria, Australia

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

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

Richard W. Katz

Environmental and Societal Impacts Group, National Center for Atmospheric Research, Boulder, CO USA

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

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

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

From the astronomical theory to sustainable development

André Berger

Université catholique de Louvain, Institut d'Astronomie et de Géophysique G. Lemaître, Louvain-la-Neuve, Belgique

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