

P 2.2 RECLIM

Regional Climate Processes and Scenarios

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1. Three research questions of the project

The research in phase two will continue to focus upon the role of continental to Alpine-scale processes in climate variability and climate change. The three key questions to be addressed are:

- (A) What is the role of continental-scale land-surface processes for interannual climate variability and climate change?
- (B) What is the sensitivity of extreme events in the European and Alpine region – in particular heavy precipitation events, flood and droughts – with respect to climate change?
- (C) How can we use regional-scale climate change simulations to construct climate change scenarios and probabilistic climate change projections?

The research will involve conducting climate change scenario experiments as well as process and sensitivity studies using our regional climate model (RCM). To drive the RCM, we will use lateral boundary data from global scenario experiments (e.g., GLOBCLIM, WP2) as well as reanalysis data. Systematic validation will be conducted using a wide range of observational data sets, and involve collaborations with NCCR and international partners. Sensitivity and process studies will be conducted to investigate the dynamics of interannual variability and extreme events such as summer drought and heavy precipitation events. Statistical methods will be used to construct climate change scenarios and to derive probabilistic projections from large ensembles of climate-change simulations. Our project will exploit collaborations within and beyond NCCR climate to tackle these goals.

2. The rationale and state of knowledge

Recent intercomparison studies suggest that the quality of high-resolution global climate models has substantially improved in the past decade (e.g. Covey et al. 2003, IPCC 2001). In particular, the representation of large-scale atmospheric circulation anomalies has become more realistic. We thus believe that credible climate-change scenarios and probabilistic climate projections on continental to sub-continental scales represent realistic targets for the next decade. Exploiting the predictive potential will require a better understanding of climate variations and an improved representation of the key processes that shape the regional climate in response to the larger scale forcing.

During the first phase of the NCCR climate, our group has been active in developing, validating and applying a regional climate model (the CHRM, see Vidale et al. 2003). Partial funding for these activities has been secured from other sources (EU projects PRUDENCE and ENSEMBLES, see Christensen et al. 2002). We have conducted control, scenario, validation and sensitivity experiments using lateral boundary conditions from the HadAM3 and ECHAM5 climate-change simulations, and from the ECMWF reanalyses ERA-15 and ERA-40. Major efforts were devoted to the representation and validation of the water cycle (e.g. Vidale et al. 2003, Frei et al. 2003, Andersen et al. 2003, Seneviratne et al 2004, Stöckli and Vidale 2004, Hagemann 2004). In addition, a series of process and climate change studies has been performed (Seneviratne et al. 2002, 2003, Schär et al. 2004, Kleinn et al. 2005) and climatological studies conducted (Schmidli et al. 2003). Our research has contributed to an improved understanding of the land-surfaces' role in climate variability and change. Results indicate that future summer climates might not only be associated with a warming, but also with an increase in interannual variability (Schär et al. 2004). The underlying physical mechanism is associated with large-scale drought conditions. Currently, a wide range of climate-change experiments is investigated in order to explore the sensitivity of this feature to model formulation.

It is important to better understand the role of the water cycle in a changing climate. On the one hand, this need derives from the importance of the water cycle for the climate system and its variability. On the other hand it derives from the potential repercussions of a changing water cycle for the economy and ecology. Scenarios suggest that in the global mean there is an increase of the atmospheric water content by ~6% per degree warming (consistent with the Clausius-Clapeyron relationship), but simulations suggest a much smaller increase in global mean precipitation by 1-3% per degree warming (Allen and Ingram 2002). These increases are expected to lead to an intensified hydrological cycle, with important implications for the frequency of droughts (Wetherald and Manabe 1995), heavy precipitation events (Semenov and Bengtsson 2002, Palmer and Räisänen 2002, Christensen and Christensen 2002, Frei and Schär 2001) and floods (Milly et al 2002, Kleinn et al 2004). Yet the interactions of the water cycle with the climate system are still poorly understood.

Scenarios of future climate change are confronted with a wide range of uncertainties (see e.g. Hulme and Carter 2001). Over the last years, several studies have estimated the uncertainty of future global-mean surface air temperature by means of a quantitative probabilistic approach (e.g. Wigley and Raper 2001; Stott and Kettleborough 2002, Knutti et al. 2003). The derivation of probabilistic scenarios requires probability weighted emission scenarios and

climate model ensembles, possibly constrained by observations (Allen et al. 2000). On a regional scale, there is comparatively little quantitative knowledge on scenario uncertainties. Yet probabilistic statements on regional climate change are highly desirable for regional vulnerability and adaptation assessments. Probabilistic regional projections may be constructed using a global predictor in combination with ensemble techniques. Several of these techniques are reviewed in Katz (2002). Mitchell (2003) reviews the pattern scaling technique. Scaling techniques have been used to assess uncertainty in sea level rise (Titus and Narayanan, 1996), hydrological impacts (New and Hulme, 2000) and regional temperature and precipitation change in the UK (Hulme et al. 2002).

3. Objectives of the project

Regional Climate Modeling

Our regional climate model (RCM) – the Climate High Resolution Model (CHRM, see Vidale et al. 2003) – will continue to be the main tool for our study. It will be used as a downscaling and research tool. GCM data from the Hadley Center (HadAM) and project GLOBCLIM and the Max Planck Institute (ECHAM5) as well as reanalysis data ERA-15 and ERA-40) will be used as lateral boundary conditions. In extending the modeling strategy beyond phase 1, our project will use higher spatial resolution (up to 20 km, compared to 56 km in phase 1). This will allow to better represent topographic and the land-surface processes. The simulations will cover either 30-year periods under current and future climatic conditions (1961-1990 and 2071-2100, respectively), or extended transient integrations (1950-2050). The simulations will use standard SRES greenhouse gas scenarios of the Intergovernmental Panel on Climate Change (IPCC).

Initially, our planned activities revolve around the downscaling of the newly available EMCWF re-analysis (ERA-40) data set, which will be used for process and validation studies, with special focus on the continental and Alpine-scale water cycle. Validation studies will soon be conducted using the high-resolution mode (grid spacing 20 km) driven by ERA-40 data. We intend initially to limit this type of high-resolution work to the validation mode, but plan to turn further to higher resolution, as soon as we are convinced of the soundness of the performance for this kind of simulation.

Process and Sensitivity Studies

Research questions (A) and (B) will be tackled by a combination of process and sensitivity studies. These will involve both observational data and numerical simulations. The purpose of these studies is to better understand how the continental to Alpine-scale climate is established in response to the larger-scale forcing. This will include studies on extremes such as heavy precipitation and droughts. Currently we foresee four areas of study:

- (i) Systematic validation of RCMs' and GCMs' land-surface evolution using diagnosed terrestrial water storage data from Seneviratne et al. (2004). Currently, the methodology developed is extended to cover a large number of catchments in the northern extratropics.
- (ii) RCM simulations will address the summer 2003, which has been extremely unusual (see Schär et al. 2004). Simulations will be conducted using various combinations of prescribed and dynamically active surface conditions to isolated the role of land-surface processes.
- (iii) Addition process studies of physical processes related to the hydrological cycle.

Tasks (i) and (ii) are the main objectives of the PhD projects of Martin Hirschi and Erich Fischer, respectively. These are planned for completion by year 2 and 3 of NCCR, respectively.

From Climate Change Scenarios to Probabilistic Projections

Research questions (B) and (C) will involve generating climate change scenarios. A particular objective is to derive probabilistic scenarios for precipitation and temperature change in the Alpine region for the 21st century. Recent analyses for mean seasonal precipitation and temperature (undertaken within NCCR phase 1) will be extended to describe the change in the frequency distribution of daily precipitation. In an early phase an ensemble of RCM climate change integrations will be used from the NCCR phase 1 and EU project PRUDENCE, and encompass a total of 20 RCM climate change scenarios (2 emission scenarios, 2 AOGCMs, 8 RCMs). Later the analysis will be extended to use results from the EU project ENSEMBLES. Several probabilistic concepts will be tested, among them the framework of generalized linear models (McCullagh and Nelder 1989, Buishand et al. 2004). The results of this sub-project can be used in probabilistic climate impact studies within NCCR (Workpackages 3 and 4).

4. Data and methods

Observational data sets: we will use ERA-40 reanalysis (set-up at CSCS in collaboration with other NCCR projects), a wide range of precipitation data sets (GPCP, CRU, own Alpine precipitation climatology), as well as other observational data sets for validation purposes (e.g. BSRN from GLOBCLIM)

GCM data sets: we will use GCM simulations from NCCR project GLOBCLIM and European projects.

Regional climate model: our CHRM regional climate model has been developed and validation in a long-standing effort in close collaboration with VARCLIM. Recently, the CHRM has been ported to both IBM-SP and NEC SX-5 supercomputers at CSCS.

5. Milestones and deliverables

Available at end of phase 1

- RCM simulations from phase 1. The data will be available by means of an internet-based system (OPeN-DAP/DODS) that allows users to conveniently browse the data and make selections for download in the form of ASCII tables or NetCDF files. The data from our project will reside on our own DODS server, but access will also become available to all simulations from the EU project PRUDENCE.
- Preliminary probabilistic scenarios for the 21st century for mean precipitation and temperature in the Alpine region. This data will be useful for a wide range of impact studies in WP3, WP4, Integrated Projects and Applied Studies. The scenarios will be available as a function of time, or as a function of equivalent greenhouse gas concentrations.

Year 1

- Output of ERA-40 driven simulations at low resolution (56 km).
- Output of ECHAM5 driven climate change simulations at low resolution (56 km).
- Intercomparison of RCM and GCM simulations regarding the hydrological cycle.

Year 2

- Initial results at high resolution (~20 km) for ERA-40 driven simulations covering the European region.
- Process studies for summer 2003.

Year 3 and 4

- Output of additional climate change simulations. The decision about driving GCM and simulation period will be taken later in the project.

Year 4

- Probabilistic scenarios based on an extended set of GCM and RCM simulations for standard parameters and heavy precipitation parameters.

6. Contribution to the WP and collaboration with other NCCR projects and 3rd parties

Collaboration within NCCR

Provision of climate change scenarios: We will provide scenarios for a broad group of potential users within and outside the NCCR Climate. The scenarios will be provided in the form of probabilistic scenarios for the major climate parameters (mean temperature and precipitation, frequency of heavy precipitation events), as well as direct model output of all relevant parameters on an internet-based platforms.

Data Exchange within WP2: Our project is partly based on output data from the ECHAM5 model (project GLOBCLIM) and the ERA-40 reanalysis (made available at CSCS by PRECLIM, VARCLIM and RECLIM). In addition, there will be data exchange for validation and collaborative analysis and validation purposes.

Joint model development and validation: We will continue our long-standing collaboration with VARCLIM regarding the further development, implementation and validation of our regional climate model.

Collaboration with 3rd parties

EU Projects: We are active partners in the EU projects PRUDENCE (ends 2004), STARDEX (ends 2005) and ENSEMBLES (starts 2004). Collaboration with these partners will provide synergies in terms of model development and simulations, and provide access to a wide range of data sets.

Other collaborations: We have established research contacts with a number of partners outside Switzerland, among these are ECMWF, NASA Goddard, KNMI and several European universities.

SwissRe: We have been active in establishing a small project with SwissRe and VARCLIM, which is dedicated to link an insurance-loss model to our climate simulations.

Provision of scenarios: Our climate change scenarios are used by a range of projects within Switzerland and abroad. Examples of partners include Prof. Wilfried Häberli (University of Zürich, permafrost), Prof. Eberhard Jochem (CEPE ETH Zürich, energy consumption), Prof. Hans von Storch (GKSS Geesthacht, storm surges), Dr. Bart van den Hurk (KNMI, water resources), Dr. Stefan Hagemann (MPI Hamburg, hydrology), and others.

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