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Regional climate change in the Northern Adriatic

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ABSTRACT

An analysis of the climate change signal for seasonal temperature and precipitation over the Northern Adriatic region is presented here. We collected 43 regional climate simulations covering the target area, including experiments produced in the context of the PRUDENCE and ENSEMBLES projects, and additional experiments produced by the Swedish Meteorological and Hydrological Institute. The ability of the models to simulate the present climate in terms of mean and interannual variability is discussed and the insufficient reproduction of some features, such as the intensity of summer precipitation, are shown. The contribution to the variance associated with the intermodel spread is computed. The changes of mean and interannual variability are analyzed for the period 2071–2100 in the PRUDENCE runs (A2 scenario) and the periods 2021–2050 and 2071–2100 (A1B scenario) for the other runs. Ensemble results show a major warming at the end of the 21st century. Warming will be larger in the A2 scenario (about 5.5 K in summer and 4 K in winter) than in the A1B. Precipitation is projected to increase in winter and decrease in summer by 20% (+0.5 mm/day and −1 mm/day over the Alps, respectively). The climate change signal for scenario A1B in the period 2021–2050 is significant for temperature, but not yet for precipitation. In summer, interannual variability is projected to increase for temperature and for precipitation. Winter interannual variability change is different among scenarios. A reduction of precipitation is found for A2, while for A1B a reduction of temperature interannual variability is observed.

1. Introduction

Anthropogenic greenhouse gas (GHG) emissions, as well as changes in aerosol concentration and land use can profoundly change the Earth's climate at scales from global to regional/local (IPCC, 2007). Changes in future climate are mostly investigated through low resolution coupled atmosphere–ocean global climate models (AOGCMs) under assumptions of emission scenarios defined in the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES, Nakicenovic et al., 2000). Regional climate change information in the presence of complex topography and land-sea distribution can be improved by high resolution downscaling of the GCM data. This can be achieved by increasing the resolution of global atmospheric GCMs either uniformly or in a smoothly varying way (Cubasch et al., 1995; Déqué and Piedelievre, 1995), by dynamical downscaling through one-way nesting of regional climate models (RCMs, Giorgi and Mearns, 1999), or by statistical downscaling (Wilby et al., 1998).

Uncertainties in projected regional climate changes arise from the ability of GCMs to describe the global climate system, assumptions concerning the GHG emission scenarios and the internal climate variability (e.g. Cubasch et al., 2001). In case of dynamical downscaling also errors associated to RCMs and to the interactions between RCMs and GCMs have to be taken into account. In order to characterize these uncertainties relatively large ensembles of model simulations are necessary (Giorgi, 2005; Stainforth et al., 2005). Towards this purpose a series of EU-funded projects have been conducted to produce climate change scenarios for the European region based on ensembles of RCM simulations. Among such projects are PRUDENCE (Christensen et al., 2002), which was completed in 2007, and the ongoing project ENSEMBLES (Hewitt and Griggs, 2004). Both projects generated relatively large ensembles of RCM simulations of climate change over the European region.

The main results obtained from the PRUDENCE project are discussed in a special issue of Climatic Change of May 2007 (Christensen et al., 2007). In particular, Jacob et al. (2007) addressed the ability of the models to simulate the present observed climate of Europe while Déqué et al. (2005, 2007) investigated the

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corresponding climate change signal. These experiments indicated that the Mediterranean region appears especially responsive to global warming, especially in the summer, where it is projected to undergo substantial warming and drying (Giorgi and Lionello, 2008; Rowell and Jones, 2006). In fact, an analysis of the latest generation climate change scenarios indicates that the Mediterranean is one of the most prominent climate change hotspots in the globe (Giorgi, 2006).

In this paper, we analyze the climate change in the Northern Adriatic region. Pronounced climatic changes can in fact affect the environment of this region (such as its coastal ecosystems and cities) and important activities (such as fisheries and tourism). We present an assessment of climate change projections over this region and because the region is of relatively small size, several hundred kilometers, this is based on available RCM simulations. We include in our analysis the PRUDENCE and ENSEMBLES sets of simulations as well as an ensemble of experiments produced by the Swedish Meteorological and Hydrological Institute (SMHI, Kjellström et al., 2009). All model domains were focused on Europe. We focus on temperature and precipitation mean and interannual variability, two variables of importance for climate change impacts. More specifically, our objectives are to

– assess the ability of model to simulate present climate and interannual variability,

– analyze the spread of the models and quantify the contribution of the related variance attributed to the modeling system, and
– provide an assessment of projected changes in mean and interannual variability for the Northern Adriatic region.

After data and methods are described in Section 2, our results and conclusions are presented in Sections 3 and 4.

2. Data and methods

RCM simulations outputs for 2 m temperature and precipitation were downloaded from the PRUDENCE project web-site. They are listed in Table 1, where each row describes the main features of the corresponding simulation. More specifically, the reference simulations are for the period 1961–1990 (CTR) while the future climate simulations are for period 2071–2100 under the A2 GHG emission scenario conditions (SCN-A2). The regional models contributing to the PRUDENCE ensemble are: ARPEGE (Gibelin and Déqué, 2003), CHRM (Vidale et al., 2003), CLM (Steppeler et al., 2003), HadRM3H (Buonomo et al., 2007), HIRHAM (Christensen et al., 1996), RACMO (Lenderink et al., 2003), RCAO (Döscher et al., 2002), RegCM (Giorgi and Mearns, 1999), REMO (Jacob, 2001) and PROMES (Castro et al., 1993). Most lateral driving data are from the HadAM3H (Buonomo et al., 2007) global circulation model, while alternative boundary conditions used by some PRUDENCE RCMs are produced by ECHAM4 and ECHAM5 (Roeckner et al., 1996, 2003, respectively). Each model is run on its own grid that encompasses the Northern Adriatic region at a grid spacing of about 50 km. CNRM, the Hadley Centre and DMI produced their own ensemble of simulations using different modeling system configurations. Some models also performed B2 scenario simulations, but these are not considered here. A more detailed description of models and simulations is presented in Jacob et al. (2007).

The ENSEMBLES RCM data archive was recently opened for public download. Up to the time this paper was prepared only a subset of the full ensemble of model experiments has been made available, as listed in Table 2. The RCMs contributing to this project are the same as in the PRUDENCE project, however in ENSEMBLES the emission scenario considered is A1B, which has slightly higher GHG concentrations than A2 in the early 21st century decades, but lower in the late decades. Other differences compared to the PRUDENCE project consist of improved resolution (25 km vs. 50 km grid spacing), a larger integration area encompassing the entire Mediterranean Sea, the completion of full transient runs from 1950 to 2100, and the use of boundary conditions from a more varied set of global model simulations, such as ARPEGE (Déqué et al., 1994) and BCM (Furevik et al., 2003).

The SMHI ensemble data is described in Table 3. Each simulation essentially covers the ENSEMBLES period and the A1B scenario and different five GCMs (including the CCSM3 model that was not used neither in PRUDENCE nor in ENSEMBLES; Collins et al., 2005). The model grid spacing in this ensemble is 50 km.

As evident from Tables 1–3, the overall simulation ensemble is quite inhomogeneous, with varying RCM, driving GCM, resolution and scenario. Thus, we decided to perform only simple statistical analysis (mean and variance) over the maximum possible amount of data. Multiple runs with the same model configuration (same RCM and same GCM) are not taken into account in the ensemble mean in order to avoid biasing. Since it is not possible to use all potential realizations to investigate the portion of variability associated to RCMs, GCMs and resolution, we have performed a simplified analysis of variance to isolate the interannual variability. The remaining variability is associated in general to the 'modeling system', thus it is an overall effect of the use of different RCMs and

Table 1
PRUDENCE RCM simulations for periods 1961–1990 (CTR) and 2071–2100 (A2 scenario). In the columns, from left to right, the contributing institutions and their regional climate models, the number of runs, the GCM boundary condition and the model resolution are listed.

Institute-model	Number of runs	Boundary conditions	Resolution (km)
DMI-HIRHAM	3	HadAM3H	50
	1	ECHAM4	50
	1	ECHAM5	50
	1	HadAM3H	25
	1	HadAM3H	12
HC-HadRM3P	3	HadAM3H	50
ETH-CHRM	1	HadAM3H	50
GKSS-CLM	1	HadAM3H	50
MPI-REMO	1	HadAM3H	50
SMHI-RCAO	1	HadAM3H	50
	1	HadAM3H	22
	1	ECHAM4	50
UCL-PROMES	1	HadAM3H	50
ICTP-REGCM	1	HadAM3H	50
MET.NO-HIRHAM	1	HadAM3H	50
KNMI-RACMO	1	HadAM3H	50
CNRM-ARPEGE	3	HadAM3H	50

Table 2
ENSEMBLES RCM transient runs for the A1B scenario. In the columns, the contributing institution with their regional climate models, the GCM boundary conditions, the resolution and the simulation periods are listed, from left to right. †Only temperature data.

Institute-model	Boundary conditions	Resolution (km)	Period
CNRM-ALADIN	ARPEGE	25	1950–2050
DMI-HIRHAM5	ARPEGE	25	1951–2100
ETHZ-CLM	HadCM3Q0	25	1951–2099
KNMI-RACMO2	ECHAM5	25	1950–2100
METNO-HIRHAM	BCM	25	1950–2049
METO-HC_HadRM3	HadCM3Q0	25	1951–2099
	HadCM3Q3	25	1951–2099
	HadCM3Q16	25	1951–2099
MPI-M-REMO	ECHAM5	25	1951–2100
SMHI-RCA	ECHAM5	50	1961–2100
UCLM-PROMES	HadCM3Q0	25	1951–2050