The ENSEMBLES Project

Providing ensemble-based predictions of climate changes and their impacts

by Dr. Chris Hewitt

Abstract

The main objective of the ENSEMBLES project is to provide probabilistic estimates of climatic risk through ensemble integrations of Earth system models. The project will develop an ensemble climate forecast system for use across a range of timescales (seasonal, decadal and longer) and spatial scales (global, regional and local). This modelling system will be used to construct scenarios of future climate change which will provide a basis for quantitative risk assessment of climate change and climate variability. Emphasis will be placed on changes in extreme events (for example the severity and frequency of heatwaves, drought, forest fires, storminess and flooding), and the effects of high-impact but low-probability events such as a shutdown of the thermohaline circulation in the North Atlantic. The project will also validate the ensemble prediction system using quality-controlled, high-resolution gridded data sets for Europe; quantify and reduce the uncertainty in the representation of physical, chemical, biological, and human-related feedbacks in the Earth system (including water resource, land-use, and air quality issues, and carbon cycle feedbacks); and link the outputs of the ensemble prediction system to a range of applications, including agriculture, health, energy and water resources. The 5 year project is funded by the European Commission’s Sixth Framework Programme as an “Integrated Project”, and is now into its second year.

Background

Predicting the future climate is a major challenge due to the complex nature of the Earth system. The only tools for this task are physically-based climate models of the key components of the Earth system (Figure 1). However, predictions of natural climate variability and the human impact on climate are inherently probabilistic, due to uncertainties in the representation of key processes within models, initial conditions used for the forecasts, and climatic forcing factors such as future concentrations of atmospheric carbon dioxide. Hence, estimates of climatic risk are best made through multiple integrations of models of the Earth system in which the uncertainties are explicitly incorporated by using different representations of processes within a model and different models, slightly varying the initial conditions, and exploring different scenarios of climatic forcing.

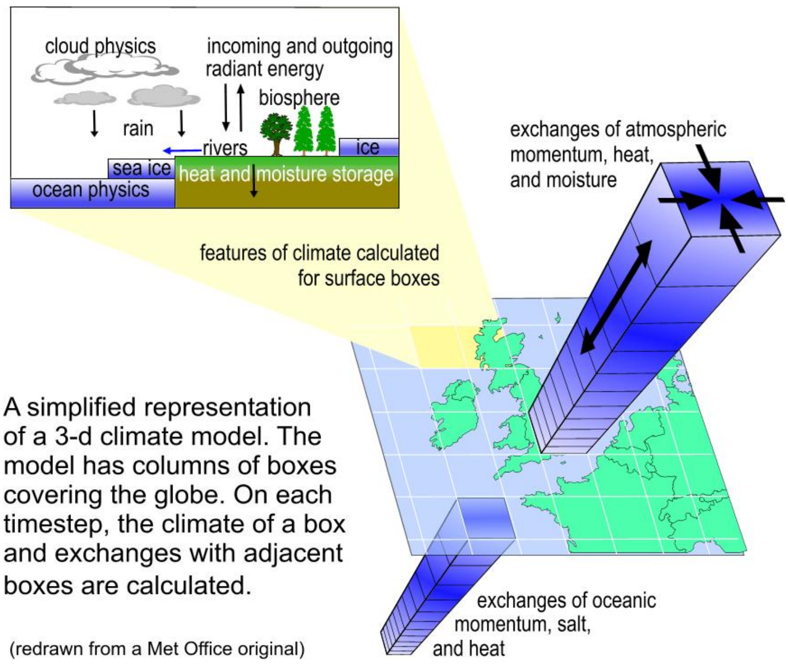

Figure 1: A schematic example of a climate model.

The ensuing ensemble of results (see Figure 2 for an example) allows us to quantify the uncertainty in the climate projections by using statistical techniques. The ENSEMBLES project will develop an ensemble climate forecast system for use across a range of timescales (seasonal, decadal and longer) and spatial scales (global, regional and local). Hindcasts made by the model system for the 20th century will be validated against quality controlled, high-resolution gridded datasets for Europe. The model system will be used to construct scenarios of future climate change which will provide a basis for quantitative risk assessment of climate change and climate variability, to provide policy relevant information on climate change and its interactions with society. Emphasis will be placed on changes in extreme events (for example the severity and frequency of heatwaves, drought, forest fires, storminess and flooding), and the effects of high-impact but low-probability events such as a shutdown of the thermohaline circulation in the North Atlantic. The outputs of the ensemble prediction system will be used to drive a wide range of applications, including agriculture, health, energy and water resources. In turn, feedbacks to the climate system from some of these impact areas will also be addressed.

Figure 2: An example of the predicted change in summer-average precipitation over Europe from a small ensemble of model simulations.

Objectives

The main objectives of ENSEMBLES are to:

• develop an ensemble prediction system based on state-of-the-art global and regional Earth system models developed in Europe, and evaluate the system using climate observations;

- quantify and reduce uncertainty in the representation of physical, chemical, biological and human-related feedbacks in the Earth system (including water resource, land use, and air quality issues, and carbon cycle feedbacks);
- apply the outputs of the ensemble prediction system to a range of applications, including agriculture, health, food security, energy, water resources, weather risk and insurance.

ENSEMBLES is being coordinated by the Hadley Centre at the Met Office in the UK. It is a 5-year Integrated Project funded under the Global Change and Ecosystems thematic priority of the European Commission's 6th Framework Programme. The project started in September 2004 and is a major undertaking by 66 institutions from 19 countries, mainly in Europe. ENSEMBLES directly addresses key objectives of the United Nations Framework Convention on Climate Change (UNFCCC) including the Kyoto Protocol, and the Intergovernmental Panel on Climate Change (IPCC), two of the most important international agencies formulating climate change policy. The relevant objectives of the UNFCCC and IPCC are to:

- provide the best available scientific information and assessment on climate change and its impacts, to provide input for policy makers concerning the assessment of dangerous anthropogenic interference with the climate system;
- reduce uncertainties in knowledge of the climate system and the adverse impacts of climate change;
- promote the development and implementation of education and training programmes;
- increase the awareness and public access to information on climate change.

The findings of the ENSEMBLES project will therefore be of great practical value to policy makers, stakeholders and the public. The results will be disseminated through web sites and informative leaflets intended to improve the understanding of climate change for wide-ranging audiences, along with the production of policy-oriented publications for bodies such as the UNFCCC and IPCC.

Progress

Work in the first year of the project has concentrated on developing methodologies and techniques, testing models that will be used in the project, such as impacts models, and using global general circulation models (GCMs) to perform historical simulations for 1860-2000 and climate change projections for the 21st Century using the IPCC SRES (Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios) forcing, the so-called A2, A1B, and B1 scenarios. It is important to have the global model results available at an early stage for use in other parts of the project. Some specific achievements are as follows.

The multi-model ensemble system for seasonal to decadal prediction is being installed on the supercomputer at ECMWF.

The database of ocean conditions for initialising the multi-model ensemble system has been updated based on the ENACT (enhanced ocean data assimilation and climate prediction) project under the EC's 5th Framework Programme. Results have been analysed from a large set of decadal hindcasts, constructed from small ensembles of simulations using the HadCM3 coupled ocean-atmosphere GCM sampling uncertainties in the initial conditions and including anthropogenic and natural variations in radiative forcing. The results reveal evidence of skill in predictions of surface temperature up to a decade ahead, both globally and in many regions. Improvements in regional skill are found relative to previously available predictions with the same model that only include projected changes in anthropogenic forcing.

The first simulations for the 21st Century for the multi-model ensemble are now available. Simulations for all three IPCC SRES scenarios reveal a clear signal-to-noise response for near surface temperature changes. Simulated changes are in the range of 1ºC to 4ºC (Figure 3). The signal-to-noise ratio for precipitation is lower than for temperature (not shown).

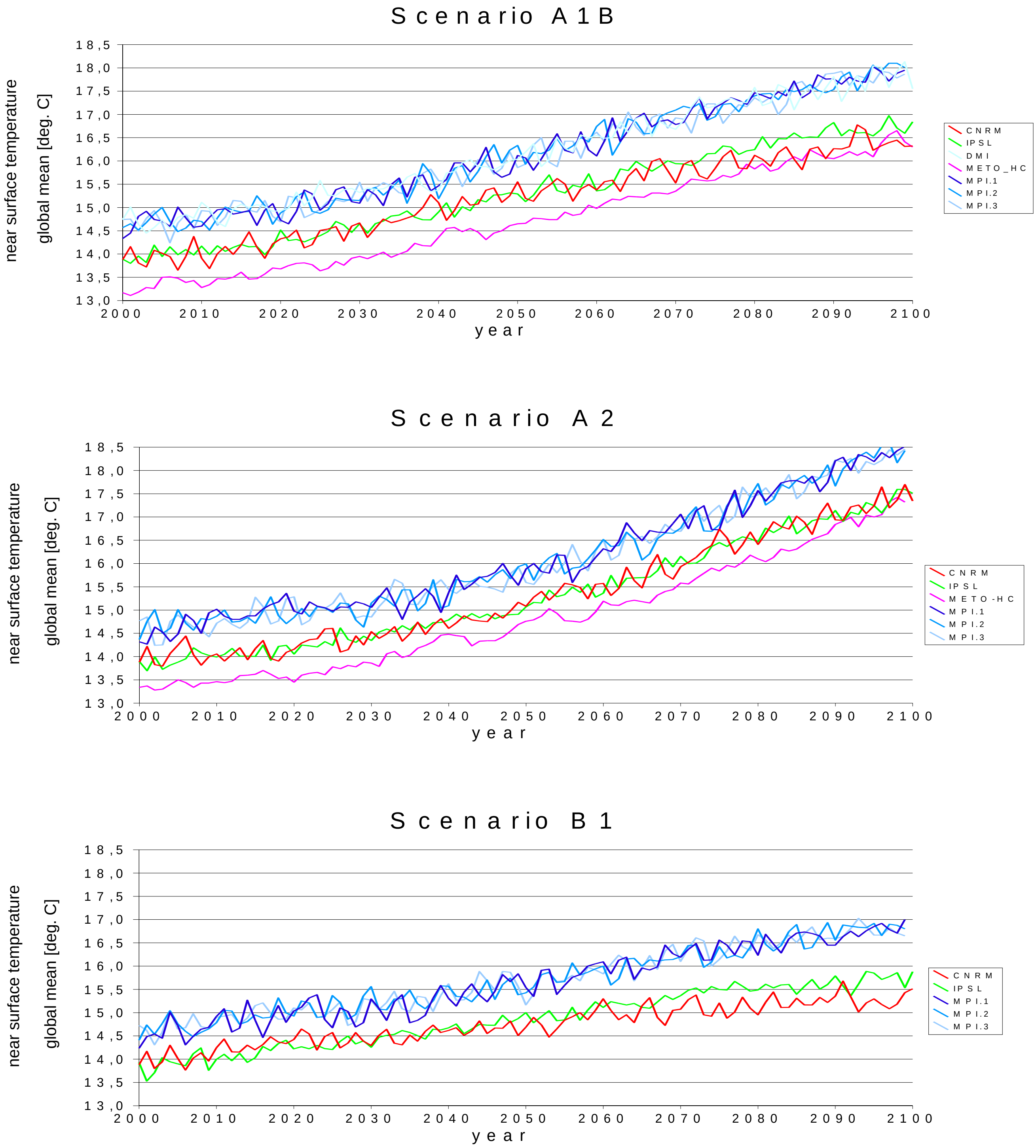

Figure 3: Globally averaged annual mean near surface temperature projections from 2000 to 2100 under the three IPCC SRES scenarios (A1B, A2 and B1) using the CNRM, IPSL, METO-HC, DMI and MPI models (3 simulations with the MPI model).

An approach to sampling modelling uncertainties has been further developed, whereby parameters within the climate model associated with modelling the physical processes are varied based on a range provided by experts. New and larger ensembles have been analysed and demonstrate the importance of non-linear interactions between processes in broadening the range of uncertainty. The approach has also been extended to produce an ensemble of transient climate change simulations using HadCM3 (Figure 4). This experiment revealed technical issues associated with the spin up of the models, leading to a revised methodology now being used to generate new ensembles simulating the response to IPCC SRES forcings.

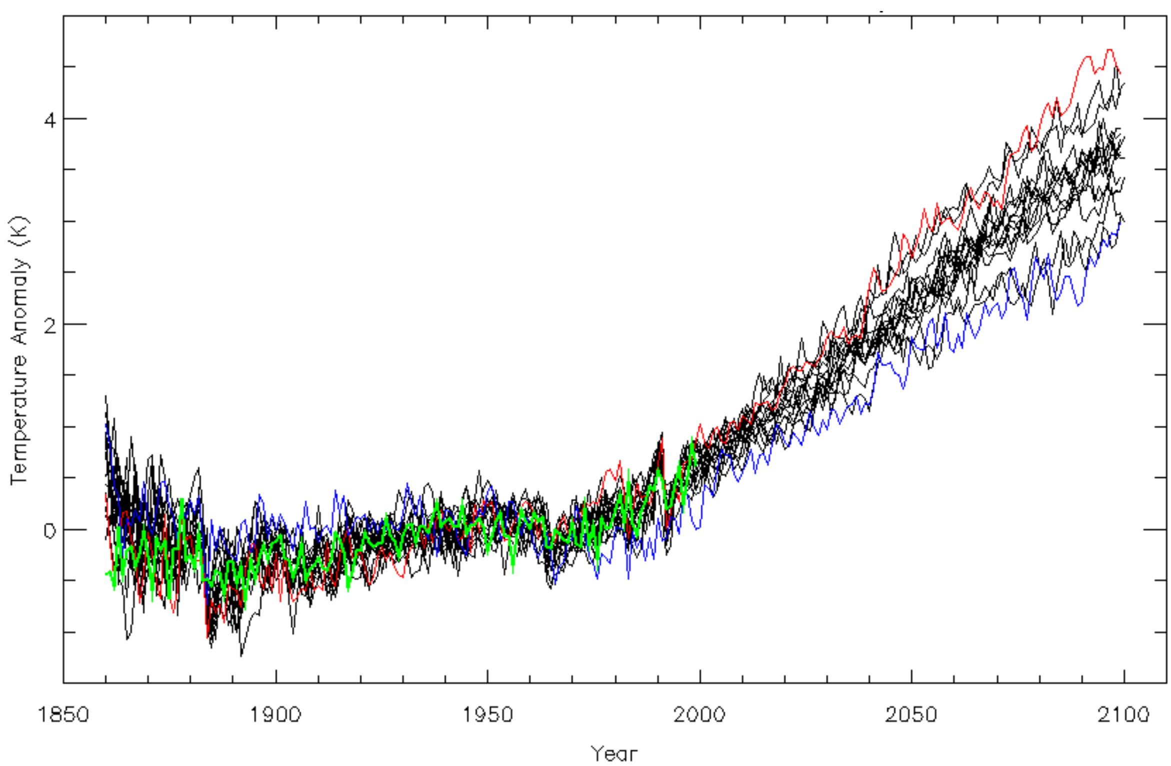

Figure 4: Anomalies in global mean land surface air temperatures from observations (green line) and from the HadCM3 perturbed physics ensemble (black, blue and red lines, the latter denoting the models with the lowest and highest respective climate sensitivities). Anomalies are computed with respect to years 1900 to 2000 and the model temperatures have been interpolated into the observational grid, and grid-boxes with missing observational data have been omitted.

Other methods of sampling modelling uncertainty and constructing probabilistic predictions have also been further developed, including strategies for the generation of ensemble members, the use of observational constraints and the effects of prior assumptions in affecting the posterior, likelihood-weighted distributions (Figure 5).

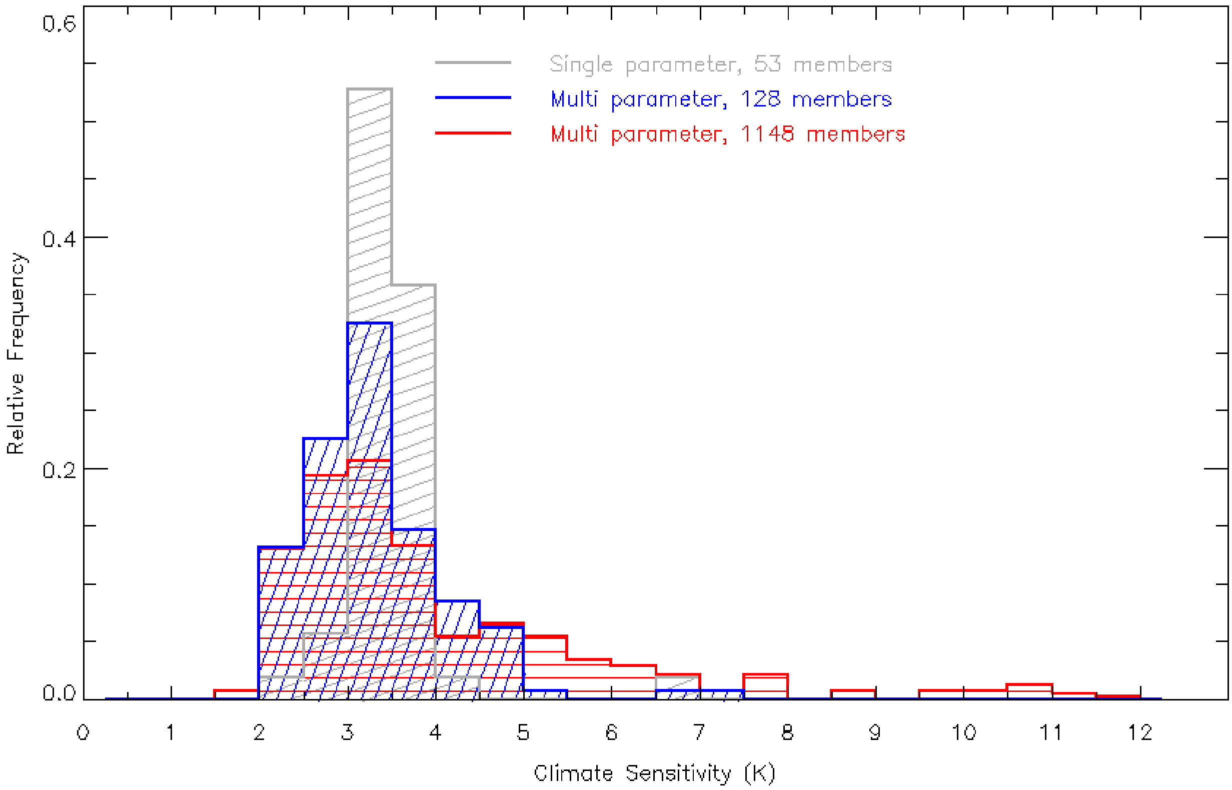

Figure 5: Histograms of climate sensitivity (the global mean temperature change for a doubling of CO_2) from three ensembles of HadSM3, an atmospheric GCM coupled to a simple static thermodynamic mixed-layer ocean model. The grey shaded histogram is from a 53 member ensemble in which 29 model parameters are varied one-by-one. The blue histogram is from 128 members in which 29 model parameters are varied simultaneously. The red histogram is from 1148 members (including some with different initial conditions) in which all combinations of the minimum and maximum of 6 model parameters are varied simultaneously.

A common minimum European domain and common resolution across the different regional climate models (RCMs) have been defined (Figure 6). The RCM simulations will be conducted first at ~50km (horizontal resolution of 0.44° latitude and longitude) and then at ~25km (horizontal resolution of 0.22°) later in the project. Several partners have now started RCM simulations for this common domain at 50km resolution, taking boundary conditions from the ERA40 (a 40-year European Re-Analysis covering the period mid-1957 to present) dataset. The purpose of these simulations is to crease an ensemble for detection and attribution of regional climate change and assessment of regional model performance on interannual and shorter time scales over several decades. The multi-decade period is important so that the capability of the models to simulate variability and extremes can be assessed in different phases of longer-term climate variability.

Acknowledgements

ENSEMBLES is a research project (contract GOCE-CT-2003-505539) supported by the European Commission under the 6th Framework Programme 2002-2006 (Project Officer Georgios Amanitidis). Results provided by the following ENSEMBLES participants are shown or quoted in this article: Dave Griggs (ENSEMBLES Co-ordinator), Matthew Collins, Tom Holt, James Murphy, Burkhardt Rockel, Jean-Francois Royer, Markku Rummukainen and Thomas Spangehl.

For more information about the project see the website: http://www.ensembles-eu.org or email ensemblesfp6@metoffice.gov.uk

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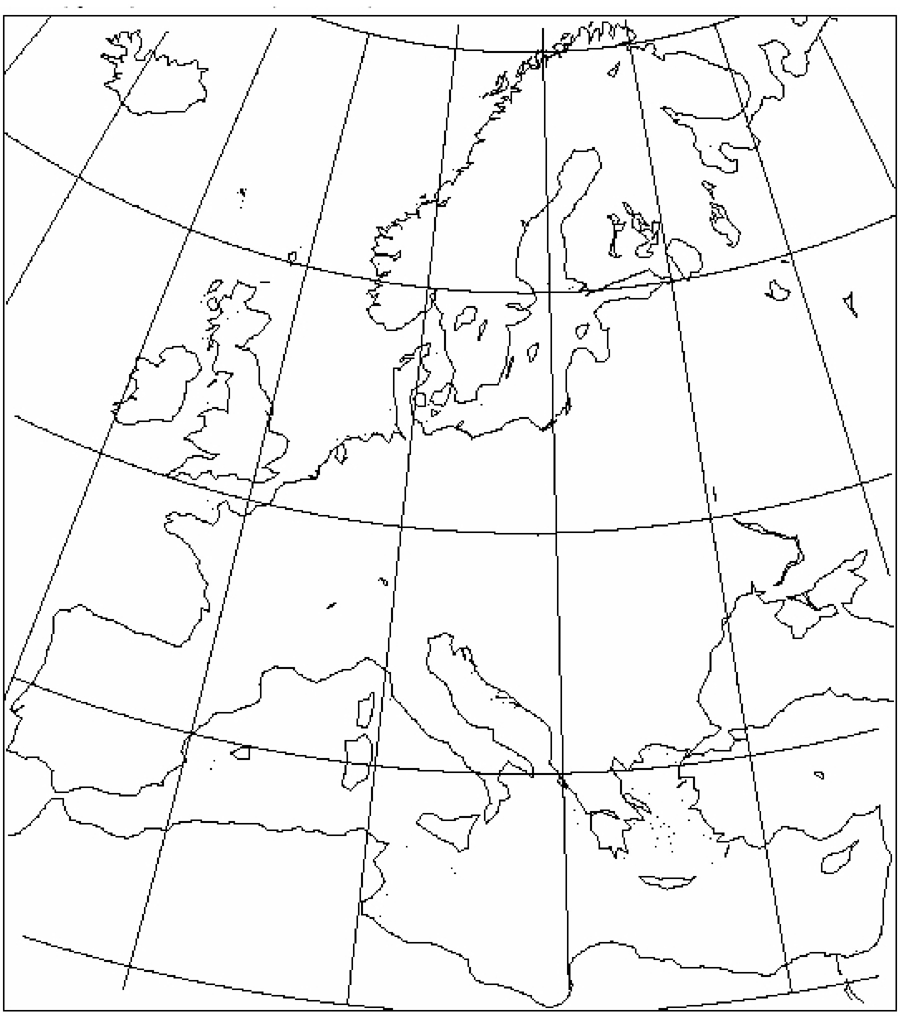

Figure 6: common domain for regional climate model simulations.