Project: 693 Requested Period: 01-01-2011 – 31-12-2011
Project Title: COMBINE - Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection.
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Project summary

The aim of the on going EU-funded project COMBINE (Contract number 226520) is to bring together research groups to advance Earth system models (ESMs) for more accurate climate projections and for reduced uncertainty on the prediction of climate and climate change in the next decades. COMBINE will contribute to better assessments of changes in the physical climate system and of their impacts in the societal and economical system. The proposed work will strengthen the scientific base for environmental policies of the EU for the climate negotiations, and will provide input to the IPCC/AR5 process. COMBINE proposes to improve ESMs by including key physical and biogeochemical processes to model more accurately the forcing mechanisms and the feedbacks determining the magnitude of the climate change in the 21st century.

Project Objectives

Over the last few decades the understanding of the circulation of the atmosphere and the ocean, of the role of biogeochemical processes and of the role of humankind in climate evolution has made great advances, based on observations, laboratory work, theory and numerical modelling. Comprehensive models of the climate system have become major tools for the investigation of climate dynamics and climate change since the beginning of industrialization (IPCC, 2007) and consequently for the development of policies that mitigate climate change or adapt societies to inevitable changes.

In this context, a critical review of the quality of models used for climate projections is essential (IPCC AR4, WG1, chapter 8). Though many improvements have been achieved in climate modelling, or in Earth system modelling, it is clear that the current models need to be improved further in many aspects. Critical to this endeavor are:

- Knowledge on the processes acting in the climate system, on the dynamics of the coupled climate system and on feedback mechanism regulating the magnitude of climate fluctuation and climate change on timescales from days to centuries.
- Knowledge on the modelling of the coupled system, including parameterizations of processes and the discretization in time and space of the full system.
- Observation to quantify the state of the system and its dynamics, as reference for model testing and for challenging the current understanding
- Experienced personnel, whose collective expertise grows with the complexity of the Earth system models
- Powerful computing resources to allow practically increased model resolutions, the incorporation of further processes, and the use of refined experimental designs.

COMBINE will improve ESMs with focus on 5 topics: (1) the carbon and nitrogen cycles, (2)

aerosols including their microphysical coupling to clouds and chemistry, (3) the stratosphere, (4) inland ice and sea-ice, and (5) the initialization technique for decadal climate forecasts.

Therefore, the COMBINE project has the following major objectives:

- To improve Earth system models by incorporating additional processes and representing more Earth system parameters. The processes selected for this project represent: C- and N-cycle; aerosols coupled with clouds and chemistry;stratospheric dynamics and increased resolution, and ice sheets, sea ice and permafrost for the cryosphere.
- To improve initialization and error correction schemes for decadal climate predictions;
- To use the Earth system models for decadal climate prediction and climate projection experiments following the protocols of the Coupled Model Intercomparison Project for IPCC AR5 simulations.
- To understand and quantify how single or combined new process components influence different climate feedbacks and the magnitude of projected climate change in the 21st century;
- To understand how the initialization by itself or initialization combined with improved process components or improved resolution can reduce the uncertainty in decadal climate prediction.
- To analyze projected climate change in three different climate regions: the Arctic, the Eastern Mediterranean and the Amazon basin; where different feedbacks are important. To analyze effects of selected new components in each region. To test if high spatial resolution has significant influence on strength of feedbacks.
- Quantify the impacts in two sectors: water availability and agriculture, globally and within the regions, and analyze the effect of selected new components on these impacts.
- Use Earth system models to find CO2 emissions that are compatible with representative concentration scenarios specified for IPCC AR5 climate projections, and use an integrated assessment model to revise the scenarios accordingly.
- Contribute to IPCC AR5 by relevant research and by disseminating climate prediction and projection data to IPCC data archives.

Our contribution to this project

The Max Planck Institute for Meteorology (MPI-M) is focused on two main areas: scenarios and impacts from current and new generations of ESMs on regional and global scale.

Tasks description on the work package include: impacts of additional regional feedbacks in three individual case study regions will be assessed. The regions under consideration are: the Arctic, with a very strong warming and major sea-ice albedo feedbacks, the Mediterranean, with aerosol cloud precipitation feedback in a hot spot area of global climate change and the Amazon, with its dominant role of land-use vegetation feedback. Decadal predictions runs will be dynamically downscaled to assess the addition regional feedback and to connect to local scale activities, like for Greece, Crete and Cyprus.

From our previous experience achieved on the CIRCE project simulating Mediterranean climate using an atmosphere-ocean coupled regional model, the MPI-M contribution to COMBINE project is in relation of **the assessment of additional regional feedbacks due to**

aerosol-cloud-precipitation interaction focused on the Mediterranean basin.

The aerosol model HAM-M7 has been implemented from the global climate model ECHAM5-HAM to the regional model REMO. HAM-M7 is an aerosol chemistry and physics model, which predicts the evolution of an ensemble of microphysically interacting internally- and externally-mixed aerosol population as well as their size-distribution and composition (Stier et.al 2005; Vignati et.al 2004). In order to use the detailed information about the aerosols, a double moment cloud scheme by U. Lohmann (2007) has been implemented and fully coupled with the aerosol module. In this way, the aerosol information is used when the cloud droplet number concentration is calculated. At the current setup, the aerosol information is only passed to the stratiform (large scale) cloud scheme.

MPI-M will perform a limited set of scenarios with a regional coupled model (Mediterranean simulator (MS)), using boundary conditions from the new global scenarios created on COMBINE project in contribution to the IPCC AR5 following CMIP5 protocol. The results of this work will used for comparison with the baseline given by IPCC AR4 and the CMIP3 data base.

The planed simulations with the MS:

Scenario simulation: from 1950 to 2050 driven by a GCM (RCP 4.5 and 8.5 scenarios)