EUROPE SUPPORTS AN UNPRECEDENTED SET OF EXPERIMENTS TO IMPROVE OUR UNDERSTANDING AND PREDICTION OF CLIMATE CHANGE, EXPLAINS **DR SYLVIE JOUSSAUME** CO-ORDINATOR OF THE IS-ENES PROJECT

Climate modelling

IN September 2013, the Intergovernmental Panel on Climate Change delivered its Fifth Assessment Report (AR5) on the scientific basis of climate change. AR5 further confirms the impact of human activities on climate change and provides new estimates of future climate under different policy scenarios regarding greenhouse emissions. AR5 has also mobilised many climate scientists not only to prepare assessments but also to provide, through peer reviewed literature, the best knowledge available on climate variability and change using a wide range of observations and climate models.

Climate models

Climate models are complex three dimensional numerical models of the variety of processes occurring in the Earth's climate system. They represent the atmosphere, ocean and land, fully coupling together the physical and biological processes that form the basis of climate. Running for a month on computers capable of performing over a billion operations per second, they simulate the evolution of temperature, precipitation and other key climate variables over decades to centuries. They are key tools to understand how much the observed climate change results from human activities such as the emission of greenhouse gases and aerosols. They are also unique in that they make it possible to estimate possible future climate change under different pathways of greenhouse emissions and to thereby infer climate system feedbacks, such as the role of clouds.

Co-ordinated effort

The Coupled Model Intercomparison Project Fifth Phase (CMIP5) has now been launched by the World Climate Research Program (WCRP) to support AR5. Within CMIP5, 28 modelling groups around the world from Canada (1), USA (6), Brazil (1), Europe (7), Russia (1), China (5), Japan (4), Korea (1) and Australia (2) agreed to perform the same simulations with different climate models.

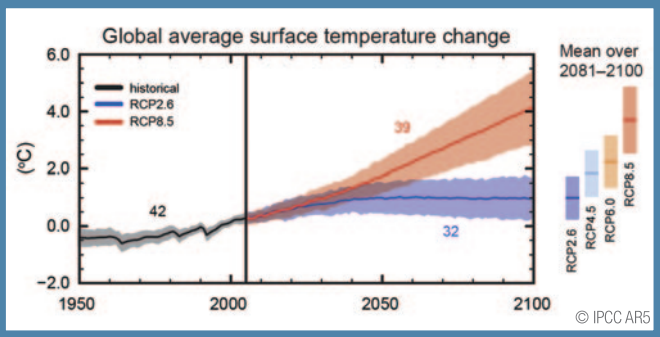
These experiments were designed to improve the evaluation of climate models and the understanding of key processes, such as cloud feedbacks, and provide estimates of possible future climate change. CMIP5 began in 2007 and required some five years to be completed, with key steps involving the design of experiments, the preparation of climate models, two years to perform the experiments on the most powerful supercomputers available, and to collect the results in a federated global data archive.

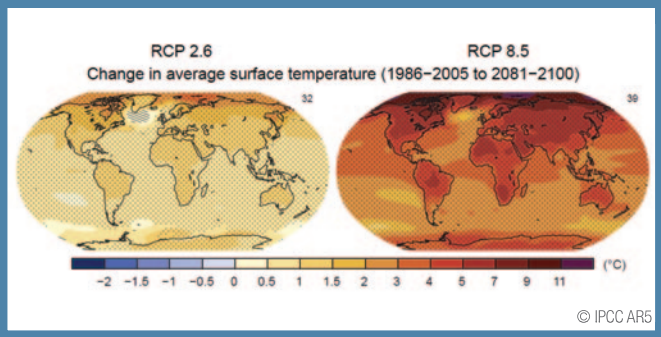
CMIP5 delivers an unprecedented set of co-ordinated experiments, each with 50-160 different simulations and from a total of 3,400-12,000 simulated years by each climate model, resulting in a huge dataset of model results. A subset of data produced, about two petabytes of data (i.e. 2 x 10^{15} (a million billion or a quadrillion)) bytes of data or 400,000 DVDs) have been made available for a large scientific community working on climate change. In order for this to be achieved, a large database was made available via the internet, which was deployed in a short space of time thanks to the Earth System Grid Federation (ESGF).

New insights

IPCC AR5 reports improvements in the representation of observed change by climate models, especially the more rapid warming since the mid-20th Century. It displays a further increase of warming that could reach 2.6 to 4.8°C for 2081-2100 relative to 1986-2005 for a high emission scenario (scenario 'RCP 8.5') but that could be limited to 0.3 to 1.7°C with mitigation policy (scenario 'RCP 2.6').

However, as estimated for the first time by climate models simulating the full carbon cycle, this low emission scenario would require future emissions of CO_2 to be restrained until 2100 to 140-410 billion scenario 'RCP 2.6' tonnes of





Simulations from the international co-ordinated experiments CMIP5, to which Europe has contributed, display a further warming in the 21st Century, whose intensity will depend on greenhouse gas emission scenarios, from low emissions (RCP2.6) to high emissions (RCP8.5)

carbon compared to the 545 already emitted since the pre-industrial period.

European contribution

The European climate modelling community, gathered within the European Network for Earth System modelling (ENES), has contributed to CMIP5 with seven models from the UK, Germany, France (two groups), Italy, Norway and a European consortium led by the Netherlands and Sweden. This was successfully achieved thanks to strong national supports but also to support from the EU FP7 programme through the COMBINE (Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection), EUCLIPSE (European Union Cloud Intercomparison, Process Study & Evaluation), METAFOR (Common metadata for climate modelling digital repositories), and IS-ENES (Infrastructure for the European Network of Earth System Modelling) projects.

Within IS-ENES, the European climate community strongly contributed to develop the internationally distributed database ESGF, which offers transparent and unique access to all model results. This required considerable developments regarding collaboration within the global federation led by the US Programme for Climate Model Diagnosis and Intercomparison, such as software to implement data nodes, check the quality control of datasets, the provision of archive systems, data documentation and access tools.

Regional downscaling

Global climate models provide key information on climate change but are, however, limited in their capacity to represent the relatively small scales needed for decision making on adaptation. Complementing CMIP5, WCRP launched for the first time a set of co-ordinated numerical experiments at the regional scale: the Co-ordinated Regional Downscaling Experiment (CORDEX).

Based on CMIP5 results, CORDEX provides ways to downscale information from the 100-200km scale of global models to 10-50km scale over limited areas. Downscaling techniques are based on either regional climate models (RCMs) or statistical methods. RCMs compute how climate evolves over limited areas when forced on their borders by CMIP5 data, whereas statistical approaches use physical links that exist between climate models and observations for the current climate and apply them to future climate simulations.

Both approaches are based on CMIP5 but allow a better account of orography, land-sea coastal areas, and surface-atmosphere exchange processes. Specific domains have been defined for Europe and the Mediterranean areas within the Euro-CORDEX and Med-CORDEX experiments. Strong international support has been given to Africa within Africa-CORDEX, led by South Africa.

Integrating data

IS-ENES is now beginning its second phase, which will last for four years (April 2013-March 2017) and has, as one of its first objectives, the integration of CMIP5 and CORDEX data access in ESGF. IS-ENES2 is leading this activity internationally and has started with Euro-CORDEX.

Integrating CMIP5 and CORDEX in the same framework will allow an easy and more transparent use of CORDEX data worldwide. A common distributed database requires agreement on common vocabularies, data format, data documentation and data structures. This is quite demanding for data providers but allows a wider use of data and better intercomparability. In order to also facilitate wider use by the scientific community working on the impacts of climate change on different sectors (such as agriculture, energy, water, and health) IS-ENES, in its first and second phases, supports the development of a dedicated portal based on ESGF, the 'climate4impact portal', providing access to model results from CMIP5 and CORDEX through ESGF as well as web services such as data access and visualisation, guidance on how to use model results, and a range of software tools.

Future simulations

The infrastructure dimension of climate modelling is not limited to the distribution of model results. It also encompasses the support for further developing climate models, the provision of software tools to efficiently run and analyse models, and access to high performance computers. Based on recommendations from the ENES infrastructure strategy 2012-2020 developed within the first phase of IS-ENES and reported in the sixth edition of Pan European Networks: Science & Technology, IS-ENES2 will further support the integration of the global and regional climate modelling communities, the development of common software, will share best practices, and will prepare high end simulations reaching the 25km scale with global climate models.

With these activities, IS-ENES2 aims to strengthen societal innovation in Europe by supporting and delivering climate change research in support of mitigation and adaptation policies. It will contribute in particular to the emerging European climate services, helped by the new FP7 project CLIPC (Climate Information Platform for Copernicus).

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