



SCIENCE FOR POLICY

WMO SUPPORT TO IPCC AND CLIMATE SCIENCE

Summary

The WCRP and its Coupled Model Intercomparison Project (CMIP) provides valuable multi-model climate simulations and projections that benefit all WMO members, both individually and collectively, providing the foundation for the Intergovernmental Panel on Climate Change (IPCC) assessments, the United Nations Framework Convention on Climate Change (UNFCCC) policy deliberations, and climate services and products disseminated worldwide.

The growing dependency on CMIP products by a broad sector of the research community and by national and international climate assessments means that CMIP activities require substantial efforts in order to provide timely and quality controlled model output and analysis. The current 'volunteer' based system is not sustainable and this vital international activity is at risk if certain aspects are not supported and 'operationalized' in some way.

Background

The World Climate Research Programme (WCRP) is a very broad effort overseen by the WMO, IOC-UNESCO and the International Science Council (ISC). Within the WCRP, the Working Group on Coupled Modelling (WGCM) coordinates international research on the development and improvement of global climate and Earth system models, as well as overseeing a collaborative application of these models in the areas of seasonal to decadal climate prediction and longer-term climate change projection. The Coupled Model Intercomparison Project (CMIP), now in its 6th phase, was initiated in 1995 and involves more than 40 climate modelling centres from around 20 countries. The WGCM and CMIP serve as both organizer and motivator of international climate research through the definition of experimental protocols and provider of supporting infrastructure that allows for coordinated multi-model climate simulations that serve as the foundation for the Intergovernmental Panel on Climate Change (IPCC) assessments, the United Nations Framework Convention on Climate Change (UNFCCC) policy deliberations, and climate services and products disseminated worldwide.

As quoted from the IPCC, "Climate model results provide the basis for important components of IPCC assessments, including the understanding of climate change and the projections of future climate change and related impacts. The IPCC Fifth Assessment Report (AR5) relies heavily on the Coupled Model Intercomparison Project, Phase 5 (CMIP5), a collaborative climate modelling process coordinated by the World Climate Research Programme" (http://www.ipcc-data.org/sim/gcm_monthly/AR5/index.html). The IPCC 6th Assessment Report will make extensive use of the CMIP6 multi-model archive that is now being populated. It is important to note that the IPCC does not produce its own climate projections – it assesses the projections initiated and organized by the WGCM's CMIP activity.

CMIP continues to have a profound and positive impact on climate science. Approximately 45% of climate research papers published recently in the Journal of Climate (designated by Thomson Reuters as one of the prestigious journals in the field of climate research) explicitly cite CMIP5. Approximately 15% of climate research papers in Nature Climate Change also

explicitly cite CMIP5. CMIP is cited almost 3 500 times in the IPCC Fifth Assessment, and CMIP5 results have been used in more than 1 000 peer-reviewed scientific publications.

CMIP model results also provide the scientific foundation for deliberations and decisions made under the UNFCCC. For example, the confident attribution of observed climate warming to human influence, the concept of a carbon budget, the need to achieve 'net zero' global emissions, the long lifetime of carbon dioxide in the atmosphere, the dependence of future climate on different emission pathways, and the essential irreversibility of temperature increase following cessation of emissions, are all underpinned by CMIP model results.

Regional climate change projections used to inform national and local impact assessments and adaptation plans, all ultimately depend on CMIP climate model projections. The WCRP also coordinates work on regional downscaling to provide more detailed information demanded by climate service providers and end users – but this downscaling requires the CMIP global climate model projections as input.

How do the WGCM and CMIP function?

The WGCM serves as the focal point for interaction and collaboration between climate modelling centres around the world. It organizes meetings, workshops and targeted research activities aimed at improving climate and Earth system modelling capabilities and at objectively evaluating climate model simulations through careful comparison to a wide range of observations. The WGCM has established two sub-groups to facilitate its work. The CMIP Panel is responsible for engaging with the climate modelling community to co-develop the CMIP experimental design and its documentation. The WGCM Infrastructure Panel oversees the complex technical infrastructure that allows model results to be archived and disseminated to users. The underlying system is called the Earth System Grid Federation that is comprised of a distributed system of servers running a software system for ingesting model output in a common format and allowing users from anywhere in the world to download and make use of it. The development of this system is largely supported by the US and Europe, and is augmented by individual nodes in 17 countries around the world. Currently the archive contains about 4PB of model output (expected to grow to about 20PB within a year) and supports 50 to 100 TB/day of downloads to over 10 000 users.

The WGCM and CMIP Panel also organize a rapidly growing suite of model evaluation tools that allow the modelling community to carefully assess model performance and guide ongoing model development. This constant model evaluation and improvement serves to push the envelope of climate science and provides the basis for much of the model-related assessment in IPCC reports.

What are the current issues?

Although CMIP has been extraordinarily successful, and leverages a large investment from individual countries, there are aspects that are fragile or unsustainable due to a lack of sustained funding. According to a recent review of the WCRP (*ISC, WMO, IOC of UNESCO, Review of the World Climate Research Programme (WCRP). 72 pp. Paris, International Science Council, 2018*), "A conservative estimate of the national investments in CMIP6 places their value in excess of US\$ 3 billion, based on scientists' time to develop and run the models and to design the experiments, and the super-computing costs to deliver the simulations."

This impressive leveraging is the consequence of volunteer efforts by the WGCM members, the CMIP Panel, and the individual scientists who contribute to the underlying essential infrastructure. This infrastructure includes the development and careful quality control of the 'forcing data' that goes into the climate model simulations (the specification of historical greenhouse gas and aerosol concentrations, land-use change, volcanic emissions, ozone and nitrogen concentrations, emissions of short-lived species, and solar variability, and the future scenarios of these quantities necessary to make climate projections). The infrastructure also

includes the careful development of data formats and standards, documentation, and software that allows modelling centres from around the world to contribute model output to a distributed archive system (the Earth System Grid Federation, 'ESGF') and allows users from around the world to access this massive multi-model data set. Similar, and equally ambitious efforts have been made to assemble and disseminate a vast array of observational data using the same formats and archival system to allow careful evaluation of model results.

The growing dependency on CMIP products by a broad sector of the research community and by national and international climate assessments means that basic CMIP activities, such as the creation of forcing datasets, the provision and archiving of CMIP products, and model development, require substantial efforts in order to provide timely and quality controlled model output and analysis. The current 'volunteer' based system is not sustainable. The coordinated production and delivery of climate model projections in particular serves as the basis for national and international climate assessments (e.g. IPCC) along with a growing network of climate services and climate service providers. This vital international activity is at risk if certain aspects are not 'operationalized' in some way.

Path Forward

The WCRP and its Coupled Model Intercomparison Project (CMIP) provides valuable multi-model climate simulations and projections that benefit all WMO members, both individually and collectively. CMIP is a large project with several hundred climate scientists involved, yet relying heavily on research funding and volunteer work. CMIP has now reached a stage where certain components and activities require sustained institutional support for it to meet the growing expectation to support climate services, policy and decision-making.

Of particular urgency is the systematic development of forcing scenarios that require institutionalized support so that quality controlled datasets and regular updates to present-day can be provided in a timely fashion. In addition, a more operational infrastructure needs to be put in place, so that core simulations that support national and international assessments can be regularly delivered and quality controlled. This includes the oversight and maintenance of the data standards, documentation and software capabilities that make possible this collaborative international enterprise.

The CMIP Panel would also benefit immensely from a dedicated project office to support the panel with organizational, communication, and dissemination aspects.

This would help insure that CMIP can be effectively coordinated to fulfil its growing demands, that the infrastructure remains viable, that the inputs required by modelling centres to conduct climate simulations and projections continue to be provided in time for IPCC assessments, and that the data continues to be effectively and efficiently quality controlled and disseminated in support of national and international policy development, decision-making and adaptation planning.
