The CMIP6 landscape

CMIP6 output is growing rapidly and will afford a re-examination of important aspects of the climate system.

The IPCC is hard at work keeping to the Sixth Assessment Report (AR6) timeline, with the Synthesis Report expected in June 2022. The contribution of Working Group I (WGI) — *The Physical Science Basis* — is due by April 2021, and it will feature model projections organized by the Coupled Model Intercomparison Project, now in its sixth phase (CMIP6)^{1,2}. To earn a spot in CMIP6, modelling groups (see image) must complete a core series of experiments that permit consistent comparison to previous CMIPs. At the time of writing, 20 of 42 committed groups have posted data, though this number will increase as more finalize their output.

The CMIP6 archive will represent nearly a decade of development relative to its predecessors. The number of modelling centres registered to provide simulations has increased by over one-third compared with CMIP5, and the number of individual models has nearly doubled. But provision of the core experiments has been slower than expected, and as a result, the first draft of WGI in April 2019 — which would ideally feature CMIP6 literature — relied primarily on CMIP5.

This discrepancy is a side effect of the slow speed of model development relative to that of the assessment report cycle. But the CMIP6 archive does appear to be reaching critical mass, and results are trickling into scientific discourse. One major discussion point centres on the models' equilibrium climate sensitivity (ECS) — the global temperature change estimated from a doubling of CO₂. As of March 2019, more than half of CMIP6 models exhibited an ECS of 5 °C or higher (<https://go.nature.com/2kJv8YV>; ref. ³), notably larger than the upper value of the CMIP5 range of 4.5 °C. By late August, with additional models available, a similar proportion still registered at 4.7 °C or higher (<https://go.nature.com/2lOJHdZ>).

Historically, the ECS range reported in CMIP has remained quite stable. The IPCC First Assessment Report in 1990 estimated an ECS of 1.5–4.5 °C, and the Second and Third Assessment Reports in 1996 and 2001 both confirmed this window. AR4 bumped up the lower end to 2.0 °C, but AR5 then reverted to the original range. All of these echo the 1979 US National Academies of Sciences 'Charney Report'⁴ — the first comprehensive global assessment of climate change — which estimated ECS at 1.5–4.5 °C. If the higher CMIP6 ECS

Credit: Locations of CMIP6 modelling groups, adapted from <https://pcmdi.llnl.gov/CMIP6/>

estimates hold true as the archive fills out, this will represent a departure from over four decades of research. Higher-sensitivity climates experience a greater probability of long-term temperature pauses and short-term trends⁵, which can translate to more warming hiatuses or periods of fast temperature increase.

A major difference between CMIP5 and CMIP6 is the set of future scenarios used to project climate evolution. CMIP5 implemented four representative concentration pathways (RCPs) defined for the additional radiative forcing reached by 2100⁶. These RCPs have come under scrutiny lately; labelling RCP 8.5 a 'business-as-usual' scenario has been called into question, given that an RCP 8.5 world would require a drastic return to coal as an energy source (<https://go.nature.com/2m6PDz4>; ref. ⁷). CMIP6, in contrast, employs scenarios rooted in socioeconomic trajectories: the shared socioeconomic pathways (SSPs)^{1,8}, which work in harmony with RCPs via shared policy assumptions. In this sense, multiple business-as-usual scenarios will be possible in CMIP6, implying more reasonable future scenarios in the new archive.

Another important CMIP6 update is the expansion and endorsement of MIPs (<https://go.nature.com/2meWkiM>) focused on biases, processes and feedbacks in climate models⁹. For example, AerChemMIP will address uncertainty in aerosol radiative forcing and climate chemistry, while CFMIP takes aim at cloud forcing uncertainties. Some of these are a continuation from CMIP5, while others have arisen from uncertainties in previous model archives.

Placing better constraints on regional climate change is a desired outcome of CMIP6 and AR6, and several MIPs will help to address this CORDEX, the Coordinated Regional Downscaling Experiment, will downscale CMIP6 model output using regional climate models over regions of interest. HighResMIP will organize global, high-resolution model runs, offering complementary simulations to both the CMIP6 archive and CORDEX. These MIPs will allow for regional climate change intercomparisons at an unprecedented level of spatial detail. LUMIP (land use) and GMMIP (global monsoons) will provide new insights into the impacts of land-use change and altered monsoon systems on regional climate. And this is only a subset of the 23 endorsed and 16 unendorsed MIPs. Together, these community-driven efforts are creating an indelible resource for climate science research and its progress in the years to come. We're looking forward to it. □

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