

OPINION

Towards provision of regularly updated climate data from the Coupled Model Intercomparison Project

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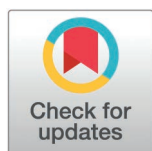
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Introduction

The Coupled Model Intercomparison Project (CMIP) is a flagship of the World Climate Research Programme (WCRP). CMIP has become a recognised 'brand' in climate circles evolving over the last 30 years from a targeted research activity by a small number of climate modelling centres intercomparing their Earth System Model (ESM) simulations to a broad international coordinated research effort [2]. CMIP is organized as a research activity leveraging funded and in-kind contributions from experts within modelling centres and the broader scientific community supported more recently by a fully-funded International Project Office.

Within CMIP, Model Intercomparison Projects (MIPs) are community-designed to understand past, present and future climate. CMIP data provides a valuable resource for climate research and is routinely used to assess model representation of climate processes and test scientific hypotheses in the context of model uncertainty and (forced and internal) variability as evident from its prolific use in scientific publications [Google scholar gives over 10,000 citations for the [3] CMIP6 description paper and



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over 83,000 hits from CMIP6 (August 2025)]. The impact relies on enabling infrastructure (most prominently via the Earth System Grid Federation (ESGF)), which allows sharing of simulation output, provision of the boundary conditions used in each simulation, and definition of the data standards that are essential to facilitating wide use of the data. The impact is supplemented by the wide-ranging scrutiny to which model simulations are subjected.

Beyond its use in research, CMIP data is a key resource for communities producing derived climate information from downscaling and impact studies, such as the Coordinated Regional Downscaling Experiment (CORDEX; [8]) and the Intersectoral Impacts MIP (ISIMIP; [7]). Government, academic and commercial entities also increasingly rely on CMIP and its downstream data for climate risk assessments and climate services (for example, Copernicus Climate Change Service and World Bank portal). This means that, although CMIP is a research activity, it increasingly serves a secondary and very relevant role as a provider of climate data – a long-recognised dichotomy [13].

Research and applications have distinct needs, with the former requiring flexibility and generality and the latter consistency. Here we explain how the design of the research activity has been adapted to reduce the burdens imposed by applications and how the research infrastructure might evolve to further enable scientific inquiry. We propose one possible approach to consistently providing model information and projections for applications in the future.

Research, applications, and the design for CMIP7

The design of the current phase of CMIP is informed both by a community consultation exercise, which indicated that it was unsustainable for modelling centres to continue as in previous CMIP phases [1], and by wider discussion of the research and operational activities of climate modelling [10,13]. In response, the CMIP Panel evolved the experimental design of CMIP7 towards a more agile framework, focusing on a smaller set of “fast tracks” that balance scientific priorities with the capacity of modelling centres.

The CMIP7 Assessment Fast Track (AFT; [1]) is oriented towards informing the Intergovernmental Panel on Climate Change (IPCC) and other international and national climate assessments based on relevant results obtained from the most recent climate simulations. The AFT is a focus for coordinating updates and extensions to historical forcing, new scenarios and climate projections, as well as targeted process-oriented experiments. The AFT includes tailored experiments drawn from MIPs to address uncertainties in key aspects of the climate system and benchmarks the capabilities of the latest ESMs [9]. It is intended to advance scientific understanding of regional patterns linked to climate change, changing weather extremes, the connections between water, energy, and carbon cycles, and tipping points. The AFT is also compact which enables CMIP7 to efficiently inform downstream activities of CORDEX and ISIMIP as described in Jones and colleagues [11] in a timely manner.

A sustained structure for the future

How might CMIP support the needs of both research and applications communities in the future? We suggest that the research remain underpinned by MIPs focused on scientific understanding, while applications should provide high demand data on a frequent, regular schedule ([Fig 1](#)).

Most applications rely on a relatively small range of simulations: by far the most downloaded CMIP data are from the historical and future projection simulations [2]. This data, along with the historical and future boundary conditions, enables short term reanalysis, attribution, climate predictions and projections which support mitigation and adaptation efforts, and climate service activities.

Given the cadence of model development and the high computational cost of simulations we propose that sustained delivery of CMIP data be conceptually split between more frequent simulations of the recent past, which leverage the increasing length of the observed record, and somewhat less frequent projections of the future to account for both modelling advances and refined views of emissions trajectories. For the recent past, a realistic ambition is to provide regular extensions of historical forcings [12] and corresponding simulations of the historical period on an annual timescale. Data on an annual timescale would support the broader climate observations and modelling landscape including effort in monitoring radiative forcing and response (e.g., Indicators of Global Climate Change; [5]), the Global Carbon Budget [6], WCRP Explaining and Predicting Earth System Change [4]).

Aligning ESM projections to the five-year cycle of the Global Stocktake enables them to reflect changing policy decisions (e.g., the emergence of overshoot scenarios in CMIP7 AFT, [15]). The five-year cycle of the UNFCCC Global

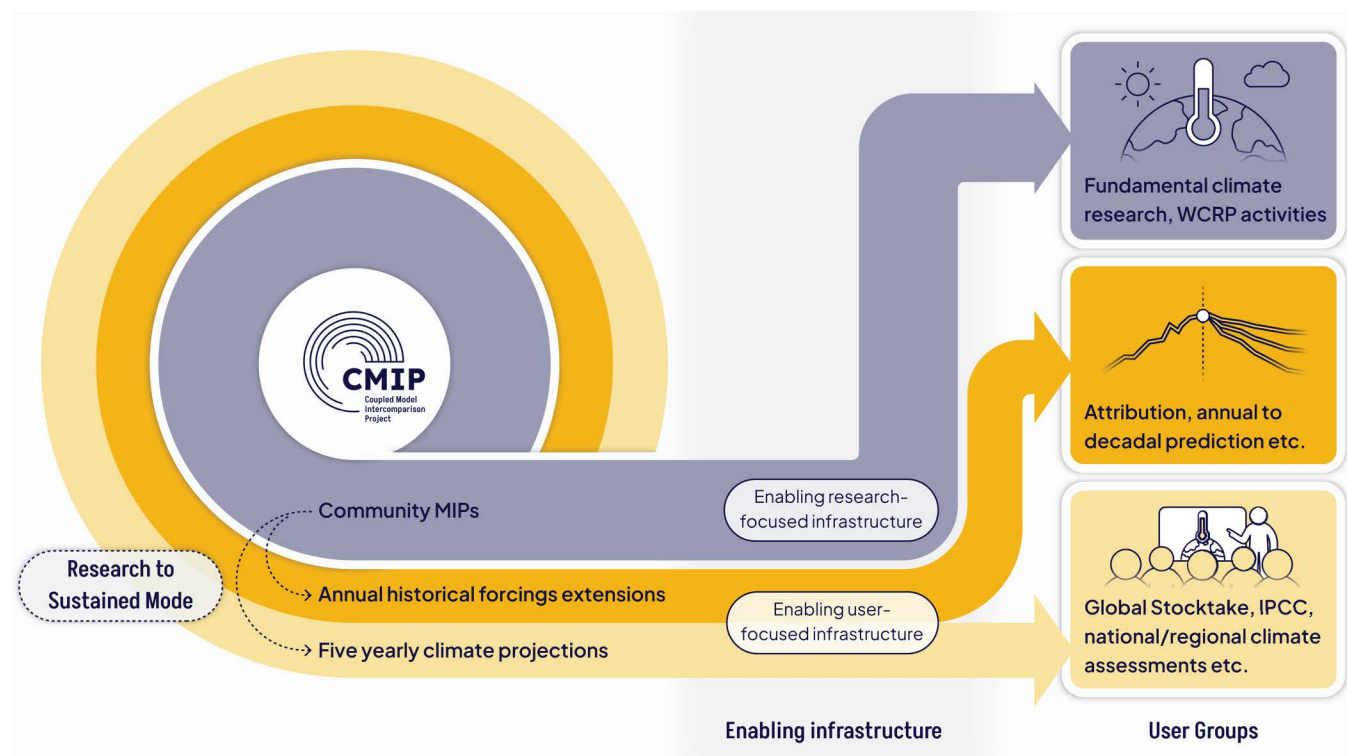


Fig 1. Reimagining of CMIP structure linking to observations, forcings, and modelling landscapes. The outer circles represent CMIP activities which could be prototyped for regular delivery on the annual and five-year timescales with a view to transition to an operational capability. Model inter-comparison projects (MIP) would continue to support these activities with research informing regular delivery (a 'research to operations' activity).

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Stocktake is reasonably well-aligned to the development of improved ESMs at modelling centres but we note that a) updates to ESMs would not be essential with every cycle of projections and b) ESM projections could in practice be run at any point in the cycle with the latest scenarios. With a fixed multi-year timeline and established protocols for data exchange, the link to downstream activities would be more effective.

To achieve sustained provision of this valuable information, the above activities could continue to serve user needs funded as a research activity. However, we suggest that activities aimed primarily at supporting applications should be prototyped with a view to transition to a semi-operational activity separate from CMIP's research mandate. Sustained, semi-operational efforts might leverage aspects of the enabling infrastructure WCRP and CMIP already has in place, lowering barriers between scientifically-focused and applications-motivated activities. However, in the process of creating a prototype, divergence between the timely delivery of data for research and applications might be needed in some areas, particularly in view of machine learning needs, since the data for applications might prioritize interoperability with platforms designed to maximise the decision-making impact of the CMIP data.

Prototyping some CMIP tasks in a semi-operational mode, will allow CMIP to maintain its critical role supporting the research community with an innovative set of MIPs. Science activities spanning model experiments and observations are essential for answering science questions, both new and old, including recalcitrant questions that take time to resolve robustly. Understanding of climate science questions via MIPs continues the long tradition of CMIP in supporting important research questions.

For regular delivery of historical simulations on an annual basis and scenario simulations on a five-year timescale and research via MIPs, an enabling infrastructure and associated sustained stream of funding are required, as well as strong community partnerships. Further work is also needed to determine how the organisation and governance of CMIP need to evolve to continue to serve such a diverse community and new delivery modes. To be most effective, CMIP needs to continue its strong collaboration with other communities including the Integrated Assessment Modelling Consortium (IAMC), CORDEX, ISIMIP, VIACS, and ESGF.

Perspective

CMIP has successfully delivered to the research and wider communities over many years encompassing not only existing climate services but also national meteorological services and academic institutions which are increasingly involved in providing climate-relevant information to their users. The inception of the International Project Office has enabled CMIP to operate with the transparency and programme management expected from world-leading modelling centres and to support greater engagement with CMIP from experts around the world. The AFT for CMIP7 is a first step towards a reimagining of CMIP into delivering more regular data to support historical assessments and future projections while maintaining the fundamental research stream of MIPs, all underpinned by an enabling infrastructure.

While CMIP remains a WCRP research project, it offers many opportunities in terms of research to operations capability to the developing field of operational climate services. The vision presented here is to prototype specific CMIP activities in semi-operational mode with a view to transitioning them to an operational status. Initially, this would focus on prototyping annual forcing extensions before exploring climate projection capability.

Finally, we are already seeing that climate emulators can play a role in the climate change projection space (e.g., [14]). For climate prediction, as artificial intelligence and machine learning techniques evolve, the CMIP Fig 1 structure will need to be flexible enough to continue supporting intercomparison and its applications.

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