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THIRD WORKSHOP ON ASEAN REGIONAL CLIMATE DATA, ANALYSIS AND PROJECTIONS (ARCDAP–3)

Concept Note

15 – 18 March 2021

SINGAPORE (VIRTUAL)

1 Summary

It is proposed to conduct a workshop to evaluate climate model datasets in support of national and regional efforts to deliver improved climate change projections across the ASEAN region. The Third Workshop on ASEAN Regional Climate Data, Analysis and Projections (ARCDAP-3) aims to encourage the uptake of the latest ensemble of climate simulations from the Coupled Model Intercomparison Project (CMIP6) and to improve regional knowledge in climate processes, variability and change. In addition, it will encourage regional collaboration and information sharing in research areas relevant to climate change projections.

Through the proposed overarching theme of "Developing regional capabilities in evaluating CMIP", the virtual ARCDAP-3 Workshop, 15 – 19 March 2021, will build upon recommendations from previous editions of ARCDAP (1 and 2 in 2018 and 2019 respectively) as well as other regional initiatives such as the Coordinated Regional Downscaling Experiment Southeast Asia (CORDEX-SEA) and similar workshops organised by the World Meteorological Organisation (WMO). Participants will be engaged through a mix of presentations and discussions led by scientists from both the Centre for Climate Research Singapore (CCRS) as well as regional and international experts with the relevant expertise to support the development of regional capabilities in using evaluation tools to explore the latest available model output from CMIP.

The objectives of ARCDAP-3 are:

1) Assess the status of regional understanding of the CMIP databases (CMIP5 and 6).
2) Obtain a shared understanding of CMIP's current status and latest developments of CMIP6.
3) Be introduced to certain resources for CMIP model evaluation (ESMValTool, Climate Explorer).
4) Work towards developing a common framework for studying key regional climate processes across a range of climate models.
5) Develop a common understanding of suitable global climate models that can be relied upon for the ASEAN region.
6) Discuss and develop a regional consensus on most relevant emission scenarios to use for regional climate change projections.
7) Link the developed understanding about CMIP databases with existing and on-going projects that generate downscaled climate projections across the ASEAN region.

Attaining these objectives will bring the region in line with the latest international standards of assessing climate models. Additionally, it will foster a regional community of data, knowledge and expertise regarding key meteorological and climatological processes influencing the region. The rest of this document will cover the background and motivation for ARCDAP-3's activities, an overview of the workshop details and programme.

2 Background

The ASEAN Regional Climate Data, Analysis and Projections (ARCDAP) workshop series was first held in 2018, in response to a proposal from the WMO Regional Association (RA) V Working Group on Climate Services (WG-CLS) for the ASEAN region to enhance synergies in generating regional/national climate change projections. An overview of the ARCDAP workshop series and its previous editions (ARCDAP-1, 2) is provided in Annex A. For ARCDAP-3, it is proposed to focus on building a shared regional framework for evaluating the latest ensemble of general circulation models (GCM) simulations from CMIP, motivated by recommendations from the past two workshops:

ARCDAP-1 (20 – 23 March 2018): Workshop Report, Pages 10, 46

A particular focus for workshop participants was the evaluation of GCMs. The same publicly available database of GCMs (currently CMIP5 and soon CMIP6) are evaluated by many groups across the region and it was noted that by-and-large the same features are evaluated. A standardisation of model selection criteria across the region was viewed as useful, especially considering it is the foundation of the climate change science. Models should be evaluated for their (i) representation of relevant climate phenomena, (ii) climate sensitivity, (iii) domain sensitivity, (iv) model biases and position in the uncertainty space and (v) degree of climate drift.

→ *It is recommended that a follow-on workshop is organised to review progress on the proposed scientific publications (i.e. regional datasets, weather and climate processes, successful applications of climate change information and guidelines to generate national projections), strategies to embed in existing national projections, the new set of global climate stimulations (CMIP6) and strategies to tackle the new scientific frontier, in particular the use of CPMs.*

ARCDAP-2 (25 – 29 March 2019): Workshop Report, Page 4

It is recommended that the workshop series be continued, with ARCDAP-3 tentatively scheduled for February 2020. The upcoming workshop will focus on the analysis of Phase 6 of the Coupled Model Intercomparison Project (CMIP6), the latest international database of Global Climate Models (GCM). This will provide a segue into discussions on climate processes relevant to the region and the evaluation of these processes in climate models. In the subsequent year, the agenda will likely broaden to include the sharing of Regional Climate Model (RCM) projections.

→ *It is recommended that funding opportunities are explored by CCRS, WMO, and AMSC in collaboration with the ASEAN NMHSs to continue the ARCDAP workshop series.*

An important aspect is the need for ASEAN climate change practitioners to upgrade their knowledge of the latest global climate model database. Current regional studies are driven by output from preceding global databases, CMIP3 and CMIP5, and will need to move to the latest available database, CMIP6. Taking advantage of the successful prior ARCDAP workshops in building common knowledge and establishing a regional community, ARCDAP-3 is an ideal platform to support ASEAN National Meteorological and Hydrological Services (NMHSs), related national agencies, and other academics into their next phase of national climate projection work. The ARCDAP-3 workshop will endeavour to deliver this outcome through

presentations and discussions to bring participants up to speed with the knowledge of the CMIP6 database, experimental design, current data availability latest evaluation tools/ online resources.

3 Workshop structure

The ARCDAP-3 workshop will cover five key components under the overarching theme of "Developing regional capabilities in evaluating CMIP". Workshop activities will contribute to developing methods and mechanisms for using CMIP and especially CMIP6 consistently across ASEAN NMHSs and related national agencies. An overview of the background of CMIP and the CMIP6 experimental design are provided in Annex B and C respectively.

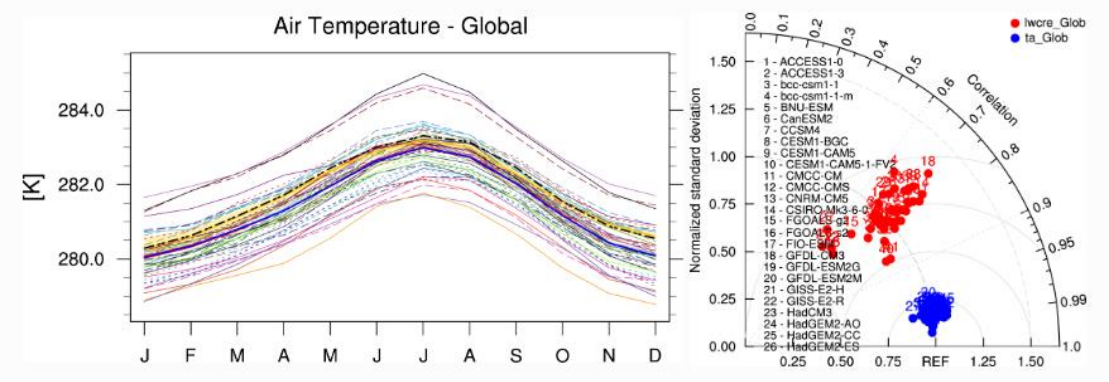
3.1 Getting to know CMIP

A formal introduction to the history of CMIP and CMIP6 in particular is necessary to ensure effective and proper use of the database. The emphasis will be placed on establishing continuity from CMIP5 to CMIP6 to ensure users understand the significance of CMIP6 results in the context of earlier studies based on CMIP5. At the beginning of the workshop, participants will learn about the history of CMIP, be introduced to CMIP6's design, improvements made on CMIP5, advancements in climate model development and the status of CMIP6. Participants will also be guided on how to access CMIP data via channels such as the Earth System Grid Federation (ESGF).

3.2 Learning to explore and evaluate the CMIP database

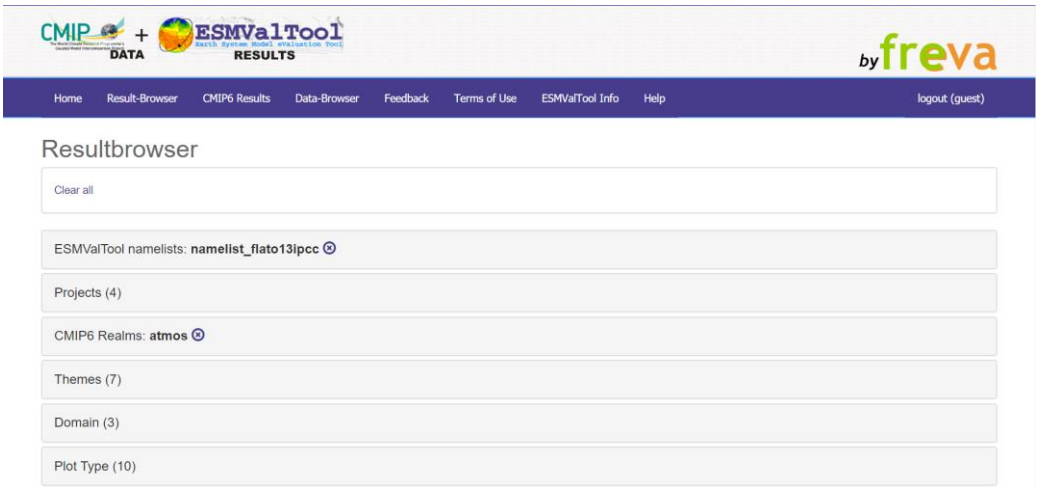
To support a shared foundation in using CMIP6 for future regional climate change studies, participants need to be aware of the resources available for exploring the CMIP database. Recommended methods from the international community will be introduced to ensure that regional users are equipped with the required skills to evaluate model output from CMIP6 efficiently. Participants will be introduced to several complimentary resources and tools for evaluating CMIP output which they can then explore on their own.

One such tool (for which a dedicated practical session was originally planned for the physical workshop) is the open source Earth System Model Evaluation Tool 2.0 (ESMValTool 2.0). It provides a collection of standard "recipes" for analysing variables across the atmosphere, ocean and land with diagnostics and performance metrics focusing on, e.g. the mean-state and trends. ESMValTool has been endorsed by the CMIP Panel, is already being widely used on CMIP5 and CMIP6 data and will continue to benefit from a large community of support and on-going development.



Example plots generated by ESMValTool 2.0 (Eyring *et al.*, 2019)

Other online resources will be introduced during the workshop include ESMValTool's Result Browser that hosts an archive of pre-computed results and diagnostic plots as well as the Climate Explorer developed by KNMI which allows users to quickly select and plot graphs of various climate variables from both observations and CMIP models.



ESMValTool Result Browser (Bock *et al.*, 2019)

Amongst the wealth of data available in CMIP6, the focus will be on model outputs from the basic simulations: the *historical simulations* and the *Scenario Model Intercomparison Project (ScenarioMIP)*. The CMIP historical simulations, which use either prescribed or calculated CO_2, from 1850 – 2014 serve as the benchmark for evaluating other experiments. Evaluating the CMIP historical simulation(s) output from a model will allow us to judge the model's capability in simulating the observed mean climate and recent changes.

ScenarioMIP on the other hand will allow us to explore (a) the impact of plausible future scenarios over physical and human systems, and the impact of different global mitigation strategies; and (b) to quantify projection uncertainties. Different representative concentration pathways (RCPs) will be explored and discussed to help form a consensus on which scenarios to prioritise for generating national and regional climate change projections.

Some additional sets of experiments that are likely to be introduced and discussed:

- Atmospheric Modelling Intercomparison Project (AMIP) due to their use of prescribed observed sea surface temperatures (SSTs) and sea ice concentrations (SICs), hence allowing us to understand the regional impacts of the oceanic biases in the CMIP historical simulation.
- Pre-industrial control experiments that would allow us to evaluate the true unforced variability of each model product.
- High-resolution simulations (HighresMIP and CORDEX) that are likely to provide suitable simulations to look at more localised climate change signals.

3.3 The evaluation of regional climate processes in CMIP6

Workshop participants will be engaged through presentations on state-of-the-art knowledge on critical climate processes relevant to the ASEAN region. They will be provided with insights into the CMIP models' ability to capture key climate processes of relevance to Southeast Asia.

3.4 Developing a common understanding of the most suitable CMIP models

Following the presentations on the application of CMIP data to analyse regional climate processes, workshop participants will discuss their national perspectives using results from the workshop to come up with a list of suitable models to deliver future national level studies. This will help establish across the ASEAN community a common starting point, which was an important pillar highlighted during ARCDAP-1 to ensure the community moves together towards best practices.

3.5 Future directions in using CMIP dataset across the ASEAN region

The final part of the workshop will engage participants across NMHSs, related agencies, academia and international experts in discussing optimal use of the CMIP6 dataset in generating regional climate change projections. This will lay the foundation for future workshops. Participants will be encouraged to share their current plans for national (e.g. NMHSs) and regional (e.g. CORDEX-SEA) downscaling studies in order to maximise synergies across the community.

4 Workshop details

4.1 Timing

A 4-day virtual workshop from Monday the 15th to Thursday the 18th of March 2021.

4.2 Medium

The workshop will be hosted virtually by CCRS over the Zoom videoconferencing platform. The GitHub platform will also complement the workshop as a repository for accompanying workshop material and presentations.

4.3 Objectives

To develop regional capabilities in evaluating the latest suite of model output from the CMIP6 database:

1) Assess the status of regional understanding of the CMIP databases (CMIP5 and 6).
2) Obtain a shared understanding of CMIP's status and latest developments of CMIP6.
3) Be introduced to certain resources for CMIP model evaluation (ESMValTool, Climate Explorer).
4) Work towards developing a common framework for studying key regional climate processes across a range of climate models.
5) Develop a common understanding of suitable global climate models that can be relied upon for the ASEAN region.
6) Discuss and develop a regional consensus on most relevant emission scenarios to use for regional climate change projection.
7) Link the developed understanding about CMIP databases with existing and on-going projects to generate downscaled climate projections across the ASEAN region.

4.4 Participation:

Workshop participants will be from the following groups:

(a) Representatives from each of the 10 ASEAN NMHSs or relevant national agencies – 2 representatives per country, ideally climate scientists with expertise in using climate data, and/or climate modelling, and/or analysing climate processes and using in-situ data.

(b) International experts who have been leading the development of the CMIP database (e.g. World Climate Research Programme (WCRP) CMIP Panel) and experts in key regional climate processes relevant to the ASEAN region.

(c) Producers and experienced users of regional climate models (CCRS and local experts from other Research Institutions in Singapore as well regional colleagues, e.g. contributing to CORDEX-SEA).

(d) Representatives from end-user sectors (e.g. AHA Centre) and the ASEAN secretariat

(e) Representative(s) from the relevant WMO Technical Commission.

The total number of participants is likely to range between 35 and 45.

5 Workshop Programme

The programme for each day will commence at 1030 and end no later than 1535 hrs to accommodate regional and international participants from various time zones.

Day 1: Introduction to CMIP/ Presentations by NMHSs on experiences with GCMs/	
AM	Introduction: welcome, opening address, workshop goals and structure Presentations by international experts on CMIP • Introduction to CMIP history • CMIP6 database: design, current status and future progress • Support, tools and information for obtaining CMIP6 data • Advances in modelling (high resolution and other MIPs of interest)/ (if suitable experts invited) • Model/ scenario and observational uncertainties
PM	Presentations by NMHSs on their GCM experience: • Past and current projects in support of national level studies, etc. • Either through exploration of CMIP database or through direct engagement with international modelling groups • Knowledge and experience using CMIP6 (if any) in particular • Review of progress made in terms of adopting best practices from ARCDAP-1

Day 2: Presentations by NMHSs on experiences with GCMs/ CMIP for evaluating regional climate processes	
AM	Presentations by NMHSs on their GCM experience (cont.)
PM	Presentations by experts in using CMIP to evaluate processes and their experiences • Individual talks on important climate processes that are important for participants to understand, e.g. ENSO, IOD, MJO etc. and findings from previous work Participants from NMHSs will be invited and encouraged to share about their previous work on evaluating climate processes • What are important drivers for their climate?

Day 3: CMIP for evaluating regional climate processes/ Applying CMIP to studying climate projections	
AM	Presentations by experts in using CMIP to evaluate processes and their experiences (cont.)
PM	Presentations by experts on suitable experiments in CMIP6 for projection studies, how to select suitable GCMs and relevant ESMValTool recipes and tools Presentations by several NMHSs and agencies/institutes (e.g. CCRS, NAHRIM, IMHEN) on how they have conducted their regional/national climate projection studies and their experiences

Day 4: Applying CMIP to studying climate projections/ Limitations of and future directions for CMIP in ASEAN, regional downscaling experiments	
AM	Breakout room discussion on building regional best practices for climate science and producing climate change information and services. • General rules/ guidelines for NMHSs to reference • Gauge interest in a regional best practices document for CMIP6/climate projection studies/etc. • What are the most important aspects of best practices? • Limitations of CMIP and using GCM output with regards to regional scale information Plenary discussion and expert panel • Reporting from breakout groups • Identifying the most important aspects of regional best practices and key takeaways from CMIP6
PM	Presentations by experienced producers or users in regional climate models (e.g. CCRS, CORDEX-SEA) • Current progress and plans for regional downscaling experiments • Scope for using CMIP6 data in the near future Presentation by CCRS on the current plans for ARCDAP-4 • Downscaling experiments, decadal variability Discussion amongst participants on future downscaling experiments • Where the current projects are headed, scope for future collaboration and more regular exchanges between project groups Workshop wrap up: Key messages, results and recommendations (guidelines)

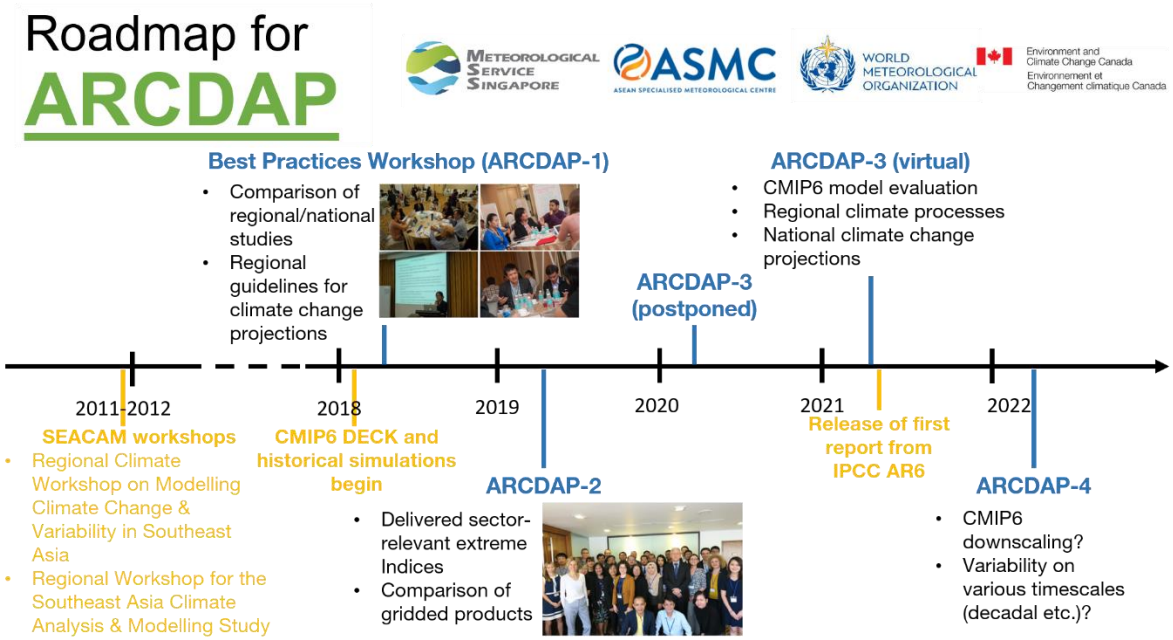
Annex A Background of ARCDAP

Southeast Asia is highly sensitive to climate change and variability from processes such as the El Niño-Southern Oscillation (ENSO), Monsoon seasons, Indian Ocean Dipole (IOD) and the Madden Julian Oscillation (MJO). Despite the efforts of countries in the region to develop their own climate change projections, up to 2 years ago there were no comprehensive attempts to consolidate the various studies and formulate a set of best practices in generating climate change scenarios. Following a proposal from the WMO Regional Association (RA) V working group on climate services, the ARCDAP workshop series was conceived in 2017 to bridge this gap and follow the lead of previous and existing regional initiatives such as the Southeast Asia Climate Analysis and Modelling (SEACAM, 2011 – 2014) and Coordinated Regional Downscaling Experiment Southeast Asia (CORDEX-SEA, 2013 – present).

The first ARCDAP-1, originally titled "Best Practice Workshop on Climate Change Projections and their Applications in ASEAN Countries", held from 20 – 23 March 2018 in Singapore saw ASEAN National Meteorological and Hydrological Services (NMHSs) work with experts and end-users to develop recommendations regarding the generation of climate change projections. Recommendations concerning the evaluation of existing gridded datasets and the need for sector-relevant extreme indices formed the basis for the theme of ARCDAP-2, which was held from 25 – 29 March 2019 in Singapore. There, participants engaged with experts and representatives from sectors such as disaster risk management and used the ClimPACT2 software to deliver sector-relevant extreme indices for ASEAN. A discussion and poll were conducted on gridded products as well as a post-workshop survey. Recommendations from ARCDAP-2 included the call for contributions from participating NMHSs to two peer-reviewed publications: one on trends in regional extreme indices and the other on evaluating gridded rainfall products, and the HadEX3 dataset, projects that are currently in the works.

The continuation of the ARCDAP workshop series

The natural progression from GCM model evaluation using CMIP6 as proposed for ARCDAP-3 will be to explore downscaling experiments with high resolution RCM simulations perform by various group across the region. This is likely theme for a follow-on workshop (ARCDAP-4) in 2022 that will aim to build on regional downscaling projects such as CORDEX-SEA. These next two ARCDAP workshops will ensure the ASEAN community of climate change practitioners is up to date with the consensus drawn from the 6th Assessment Report cycle of the Intergovernmental Panel on Climate Change (IPCC AR6), due for release 2021-2022.



ARCDAP workshop series roadmap up to 2022 within the regional and global context

Annex B Background of CMIP

The Coupled Model Intercomparison Project (CMIP), first organised by the World Climate Research Programme (WCRP) Working Group on Coupled Modelling (WGCM) in 1995, coordinates the comparison of general circulation models (GCMs). The CMIP was conceived with the aim of making a wide range of model output available to advance our understanding of past, present and future climate variability and change.

The CMIP is developed in phases, with the first two (CMIP1 and CMIP2) taking on relatively simple experimental designs with a long control integration with no interannual changes in radiative forcing and an idealised simulation where atmospheric CO_2 concentration increased 1% per annum. Such idealised experiments remain central to CMIP as they allow differences in model responses to be better understood and to give confidence for model projections of future climate change. Throughout the years, CMIP has evolved to include more specific twentieth-century and idealised simulations as well as projections for future changes in climate forcers in more detail. A paradigm shift in the climate science community was brought upon by CMIP3, which made model output broadly accessible by the scientific community at large. This vastly increased availability also extended the use of model data beyond the traditional climate modelling community to e.g. stakeholders concerned with the impacts of climate change from a variety of perspectives. The following CMIP phase (called CMIP4 by the WGCM) was a modest supplement to CMIP3 with the addition of single-forcing experiments that laid the basis for detection and attribution (D&A) studies. The next major phase was CMIP5, which introduced more idealised process- and feedback-oriented experiments. Experiments were also for the first time, divided into “near term” and “long term” time horizons. Furthermore, the community adopted a new method to specifying future scenarios through the definition of representative control pathways (RCPs).

Planning for phase 6 commenced in 2013, which involved a comprehensive consultation on the benefits and challenges of CMIP5 with modellers and researchers. An overview of the design and organisation of CMIP6 was published in 2016, which stressed on its new and more federated structure, three major elements that form its experimental design as well as its priorities of addressing three main questions arising from the Grand Science Challenges of the WCRP. The release of first results from GCMs taking part in CMIP6 began in 2018-19 with model output being made openly available online on the CMIP archive hosted by the Earth System Grid Federation (ESGF).

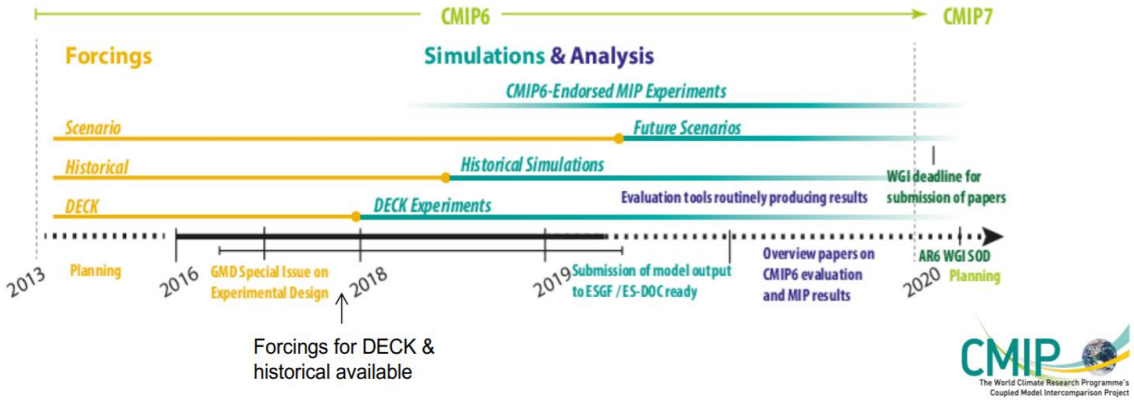
Annex C Further description of CMIP6 experimental design

In preparation for CMIP6, the CMIP Panel initiated a 2-year long consultation with the modelling and scientific community where they identified four main issues to the overall CMIP structure: (1) Model Intercomparison Projects (MIPs) were increasingly being organised independently of CMIP, resulting in inconsistencies in data structure and output requirements, (2) the scope of CMIP being too large for certain modelling centres which meant that many could no longer consider contributing to all proposed experiments, (3) the then punctuated structure which had begun to distort the model development process and (4) a desire to reflect the strategic goals of the community rather than simply just a collection of MIPs.

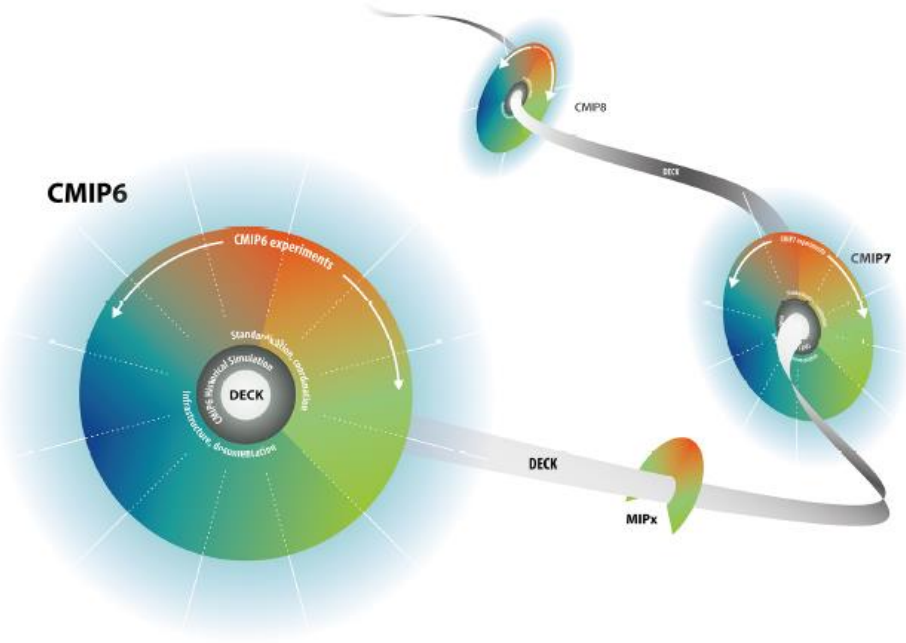
In response to this feedback, CMIP6 was designed with three major components. The first involved the identification of a handful of common experiments, the Diagnostic, Evaluation and Characterisation of Klima (DECK) experiments along with the CMIP historical simulations. The second component was the adoption of common standards, coordination, infrastructure and documentation for model output distribution and characterisation of model ensembles. Lastly, the implementation of a more federated structure to build on more autonomous CMIP6-endorsed MIPs. Together, these three components will contribute towards CMIP6's goal of addressing three broad questions:

- How does the Earth system respond to forcing?
- What are the origins and consequences of systematic model biases?
- How can we assess future climate changes given internal climate variability, predictability, and uncertainties in scenarios?

The current CMIP6 timeline and CMIP future evolution are summarised in the following two figures.



CMIP6 timeline (Eyring *et al.*, 2019).

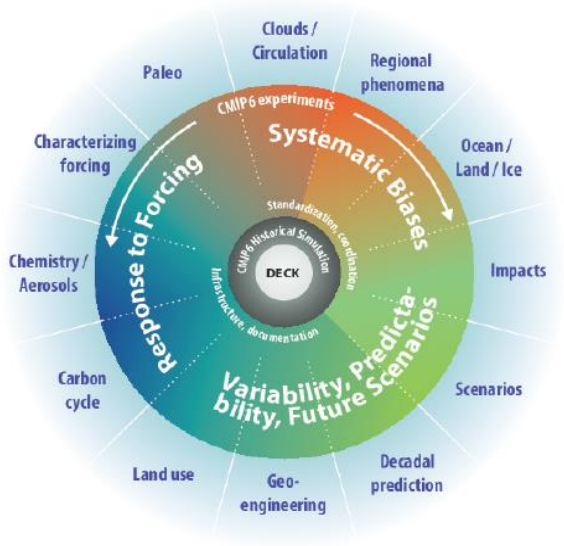


Proposed CMIP future evolution with DECK to facilitate continuity across phases (Eyring *et al.*, 2016).

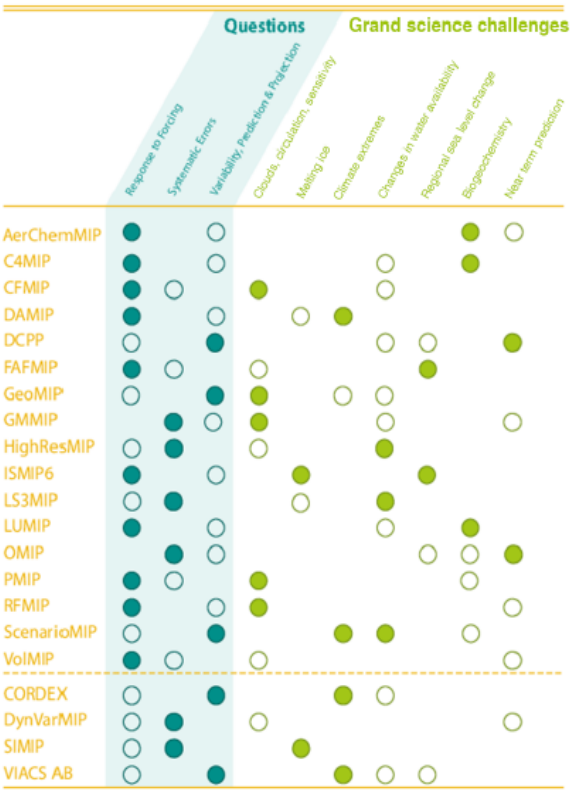
The DECK experiments were chosen to remain relatively unmodified and provide continuity across CMIP phases. The DECK is composed of four experiments: (a) a historical Atmospheric Model Intercomparison Project (AMIP) that uses prescribed sea surface temperatures (SSTs) and sea ice concentrations (SICs) derived from observations, (b) a pre-industrial control simulation, (3) a simulation forced by a 1% CO_2 concentration increase per annum and (4) another forced by an abrupt quadrupling of CO_2. On the other hand, the CMIP historical simulation covers the period of extensive instrumental temperature measurements from 1850 to now.

A big step towards improved data standardisation and coordination was attributed to the setting up of the WGCM infrastructure panel (WIP) which provides guidance and establishes specifications for model output, model and simulation documentation and archival and delivery mechanisms for CMIP6 data. These improvements were complimented by ESGF taking on the role of providing access to CMIP model output hosted by international institutions. CMIP5, with over 1000 different model/ experiment combinations, saw the first attempt to capture structured model and simulation metadata, an effort that has now continued under the banner of the international Earth System Documentation (ES-DOC) activity that sets agreements on common Controlled Vocabularies (CVs) for describing models and simulations. Another aspect of this improved standardisation in CMIP6 was the target of more routine benchmarking and evaluation of models through available tools such as the PCMDI metrics software and the Earth System Model Evaluation Tool (ESMValTool) to inform users about the results, strengths and weaknesses of model products efficiently.

All the DECK and CMIP historical experiments serve as pre-requisite experiments that modelling groups must perform in order to qualify as one of the CMIP6-endorsed MIPs to perform other more focused experiments. These MIPs were designed to tackle the three questions at the heart of CMIP6 and fill significant scientific gaps from previous CMIP phases. From an initial list of 30 suggestions, 21 (now 23) MIPs were eventually endorsed, with 4 being diagnostic in nature (not requiring additional experiments) and each being linked to at least one of the WCRP Grand Science Challenges. A summary of all the CMIP6 MIPs can be found in Eyring *et al* 2016; moreover, each MIP is described in detail in individual publications that complement the initial special edition publication on CMIP6.



Schematic of the CMIP6 experiment design. The inner ring and white text involve standardized functions of the DECK experiments and the CMIP6 historical simulation. The middle ring displays science topics related specifically to CMIP6 that are addressed by the CMIP6-Endorsed MIPs, with MIP topics in the outer ring. This is superimposed on the scientific backdrop for CMIP6 which are the seven WCRP Grand Science Challenges (Eyring *et al.*, 2016).



Contributions of CMIP6-Endorsed MIPs to the three CMIP6 science questions and the WCRP Grand Science Challenges. A filled circle indicates highest priority and an open circle, second highest priority (Eyring *et al.*, 2016).

Preparation of forcings for CMIP6 experiments began in 2016 but due to delays, the DECK and historical simulations only started to be available in 2018. As of now (end of Q3 2019), 48 institutions and 123 models have registered with CMIP6 (see https://github.com/WCRP-CMIP/CMIP6_CVs) compared with respectively 31 and 59 for CMIP5. Output from 25 institutions and 53 models are currently available on the ESGF portal spanning 170 different experiments. Most centres are due to complete their simulations by 2020 but CMIP6 will remain the database of reference and its use for analysis is likely go on for at least the next decade. The most recent international update on CMIP6 was provided by contributing scientists

from international modelling and research centres at the first CMIP6 Model Analysis Workshop 25 – 28 March 2019, Barcelona; the next such workshop is scheduled for 2021.