The Detection and Attribution Model Intercomparison Project (DAMIP v2.0) contribution to CMIP7

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Abstract. The first version of the Detection and Attribution Model Intercomparison Project (DAMIP v1.0) coordinated key simulations exploring the role of individual forcings in past, current and future climate as part of the Coupled Model Intercomparison Project, Phase 6 (CMIP6). The simulations have been used extensively in the literature for detection and attribution of long-term changes, constraining projections of climate change, extreme event attribution, and understanding drivers of past and future simulated climate changes. Attribution studies using DAMIP v1.0 simulations underpinned prominent assessments of human-induced warming in the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report. Here we describe the set of DAMIP v2.0 simulations, proposed for the next phase of CMIP, CMIP7. Detection and attribution studies rely on preindustrial control simulations and historical simulations which will be part of the Diagnostic, Evaluation and Characterization of Klima (DECK) set of simulations for CMIP7. In addition, DAMIP v2.0 identifies three highest priority single forcing experiments for CMIP7 to be run as "Assessment Fast Track" simulations in support of the Seventh Assessment Report of the IPCC - namely simulations with natural forcings only, anthropogenic well-mixed greenhouse gases only, and anthropogenic aerosols only. Beyond this, the DAMIP v2.0 experimental design includes full column ozone-only simulations and land-use-only simulations, such that the set of individual forcings experiments, when considered together, represents the full set of historical forcings. While concentration driven simulations are prioritized for attribution of past changes, emissions-driven versions of the DAMIP experiments are also proposed to support understanding of the influence of carbon-cycle feedbacks on the simulated responses to individual forcings.

1 Introduction

Research on the detection and attribution of climate change aims to identify and quantify the influence of particular forcings or subsets of forcings on the climate system, with special focus on net human influence. Such research has underpinned progressively strengthening assessments on the role of human influence in driving observed climate change in successive Intergovernmental Panel on Climate Change (IPCC) reports, including the assessment in the most recent report that 'it is unequivocal that human influence has warmed the atmosphere, ocean and land' (Eyring et al., 2021). This research generally relies on climate model simulations of the response to individual forcings or subsets of external forcings, as well as observations (Eyring et al., 2021; Stott et al., 2004). In particular, such analyses generally require simulations of historical climate change including all major anthropogenic and natural influences (historical), long pre-industrial constant-forcing simulations to characterize the influence of internal variability alone (pre-industrial control), as well as simulations with subsets of forcing agents. This paper describes the coordinated set of climate model simulations designed to support detection and attribution research that are proposed under the Detection and Attribution Model Intercomparison Project v2.0 (DAMIP v2.0), part of the Coupled Model Intercomparison Project Phase 7. In CMIP7, historical and pre-industrial control simulations will be coordinated as part of the Diagnostic, Evaluation and Characterization of Klima (DECK, Dunne et al., 2024) set of simulations which all models must complete and which serve as a basis for model evaluation. Simulations with individual forcings or subsets of forcings are the focus of this paper.

2. Applications of DAMIP v1.0 CMIP6 simulations

DAMIP v2.0 follows from DAMIP v1.0 (Gillett et al., 2016), the coordinated set of detection and attribution simulations conducted under the Coupled Model Intercomparison Project Phase 6 (CMIP6) (Eyring et al., 2016). CMIP6 included historical simulations driven with both anthropogenic and natural forcings (historical) as well as constant pre-industrial forcing simulations (piControl). DAMIP v1.0 complemented these with historical simulations driven by subsets of the historical experiment forcings. The highest priority Tier 1 simulations consisted of historical simulations driven with natural forcings only (hist-nat), historical simulations driven with well-mixed greenhouse gas changes only (hist-GHG), and historical simulations driven with aerosol and aerosol precursor emissions changes only (hist-aer). These simulations were supplemented with lower priority Tier 2/3 simulations including simulations driven with changes in stratospheric ozone only (hist-stratO3), volcanic aerosol only (hist-volc), solar irradiance only (hist-sol) and CO_2-only (hist-CO2). DAMIP v1.0 extended the individual historical forcing simulations up to 2100 using SSP2-4.5 (O'Neill et al., 2016) forcings to support analysis of the contribution of the different forcings to future changes (experiments ssp245-nat, ssp245-GHG, ssp245-aer and ssp245-

stratO3). Since the publication of the original experimental design (Gillett et al., 2016), some additional experiments were added to DAMIP v1.0, in particular: single forcing experiments with CMIP5 forcings to examine the effects of updates to the forcings from CMIP5 to CMIP6 (Fyfe et al., 2021), a simulation with ozone changes through the full atmospheric column (Shiogama et al., 2023), and a set of simulations to examine the response to COVID-induced changes in emissions (Jones et al., 2021).

Consistent with expectations, the Tier 1 simulations were carried out with the largest number of CMIP6 models, with hist-GHG simulations from 18 models, hist-aer simulations from 17 models, and hist-nat simulations from 17 models published on the CMIP6 data portal as of July 31st 2024 (Figure 1a). The simulations carried out with the fewest models were those added later in the CMIP6 cycle, namely the hist-GHG-cmip5, hist-aer-cmip5, hist-nat-cmip5, ssp245-cov-GHG and ssp245-cov-aer simulations, which were each only carried out with one model. Some modelling groups are now expanding their ensemble sizes through the Large Ensemble Single Forcing Model Intercomparison Project (LESFMIP) (Smith et al., 2022), which is particularly focussed on attribution of multi-annual to decadal changes in climate, including the effects of updates to forcing datasets. While all DAMIP v1.0 experiments were referred to in at least one publication, the Tier 1 simulations (hist-GHG, hist-aer and hist-nat) were by the far the most cited, with hist-nat referred to in 245 publications (Figure 1b). The DAMIP v1.0 simulations were also used extensively in the Sixth6th Assessment Report (AR6) of Working Group I of the IPCC, with data from these simulations used in figures in five chapters of the report (Canadell et al., 2021; Doblas-Reyes et al., 2021; Eyring et al., 2021; Fox-Kemper et al., 2021; Szopa et al., 2021). Here also the Tier 1 simulations were by far the most used. DAMIP v1.0 simulations were, for example, used in two attribution analyses of warming since preindustrial times (Gillett et al., 2021; Ribes et al., 2021), which were two of the three main studies used to assess the anthropogenic contribution to observed warming (Eyring et al., 2021), which was a headline result in the Summary for Policymakers of the report (IPCC, 2021), and was also directly quoted in the Glasgow Climate Pact (UNFCCC, 2022). Since the publication of the IPCC AR6, a selection of key climate indicators have been updated on a yearly basis (Forster et al., 2024). This includes warming attributable to human influence, calculated usingfrom DAMIP v1.0 data.

Beyond assessments of global temperature change, DAMIP simulations have been used to explore a wide variety of Earth System Changes. They have been used to explore the role of individual forcings in modelled historical and projected future changes in the Atlantic Meridional Overturning Circulation (AMOC) (Menary et al., 2020). While the CMIP6 ensemble mean Atlantic Meridional Overturning Circulation AMOC response to forcings was rather linear in the forcing, this is not true of all models (Simpson et al., 2023). In addition, DAMIP simulations have been used to assess the relative roles of greenhouse gases

95 and aerosols in historical changes in drought frequency, duration, and intensity (Chiang et al., 2021), the relative role of
96 anthropogenic and natural forcings in contributing to increasing fire weather in the western United States (Zhuang et al., 2021),
97 and the role of natural forcing, greenhouse gases and anthropogenic aerosols in historical changes in precipitation variability
98 (Zhang et al., 2024b). They have been used to attribute the observed weakening of the summertime Eurasian jet stream in the
99 historical record to anthropogenic aerosol forcing (Dong et al., 2022) and to isolate the relative role of greenhouse gases and
100 aerosols to Northern Hemisphere summertime storm track trends (Kang et al., 2024). Despite this progress, we still do not
101 adequately understand the relative role of forced changes and internal variability in observed circulation changes. Having now
102 observed forced signals emerge for longer in observations and with continued improvements in process representation in Earth
103 System Models, together with improved estimation of external forcings, further advances in this area will likelymay be
104 achieved with the use of DAMIP v2.0 simulations of CMIP7.
105
106 As well as studies attributing long-term changes in climate, another application of DAMIP v1.0 simulations is in extreme event
107 attribution, which aims to characterise how the probability of a single weather or climate event was altered by specific forcings,
108 in particular anthropogenic forcing (Christidis et al., 2023; Herring et al., 2022; Lanet et al., 2024). This is an important use of
109 DAMIP data, and allows for a wider global engagement in this field than those who have the capability to run climate model
110 experiments tailored to the specific event under analysis. However, it also presents an additional potential challenge.
111 Approaches for extreme event attribution sometimes require large ensembles of climate simulations, i.e., larger than the
112 majority of DAMIP models will have (5-10 members), and up to (for very extreme events) the order of tens thousands of
113 ensemble members for very rare events (Schaller et al., 2014). Therefore when DAMIP simulations are used for extreme event
114 attribution analysis, methods for increasing the sample size might sometimes be needed. Such methods could include using
115 model years beyond that of the specific event, combining different climate models and their ensembles (King, 2017), increasing
116 the sample size using extreme value theory (Sippel et al., 2015), or ensemble boosting (Fischer et al., 2023).
117
118 Increasingly, single forcing climate simulations are being used in hazard and impacts research. DAMIP data has been used
119 very effectively in going most of the way to explaining the observed impact changes, for both trend-based impact attribution,
120 and event-based impact attribution. In many of these studies, the authors are able to show a plausible explanation for the
121 climate-influenced part of the observed impact. This has happened primarily in the areas of hydrology (e.g. Li et al., 2024a),
122 and human health (e.g. Carlson, 2024; Chapman et al., 2022; Vicedo-Cabrera et al., 2021; Zhang et al., 2022). A challenge for
123 impact detection and attribution research is to effectively integrate the relevant different socio-economic factors into the

124   attribution framework, ~~but this can be particularly insightful~~and this is particularly relevant in adaptation, loss and damage,

125   and legal settings (James et al., 2019).

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3 Experimental design of DAMIP v.2.0

128   In most respects DAMIP v2.0 follows the experimental design of DAMIP v1.0 (Table 1, Figure 2). As in DAMIP v1.0, we

129   designate the highest priority experiments as Tier 1 experiments, with Tier 2 and Tier 3 representing successively lower priority

130   experiments (see Figure 2). There are two primary designs for detection and attribution experiments - namely individual forcing

131   simulations, and all-but-one simulations, in which all forcings except the one of interest are included (Gillett et al., 2016; Smith

132   et al., 2022). All-but-one simulations, together with historical simulations, may offer some advantages for detecting the

133   presence of one particular forcing in the observations, in particular from a causality theory point of view (Hannart et al., 2016;

134   Naveau et al., 2020), and they can be used together with individual forcing simulations to test additivity (Marvel et al., 2015;

135   Shiogama et al., 2013; Simpson et al., 2023). For example, aerosol-only simulations and all-but-aerosol simulations can be

136   used together with simulations including all forcings to test whether the response to aerosols and the response to other forcings

137   add to give the response to all forcings combined (e.g. Simpson et al., 2023). The Large Ensemble Single Forcing Model

138   Intercomparison Project (LESFMIP) proposed a comprehensive set of such simulations to investigate such questions (Smith

139   et al., 2022). However, if the objective of an analysis is to characterize the response to one particular forcing, ~~and the response~~

140   ~~to a set of forcings combined is equal to the sum of the responses to each forcing individually,~~ then individual forcing

141   simulations will lead to reduced sampling uncertainties, because they do not require a difference between two sets of

142   simulations to be taken, each of which has its own sampling uncertainties. For this reason, and for ease of comparison with

143   previous CMIP generations, including DAMIP v1.0 experiments, DAMIP v2.0 largely follows DAMIP v1.0 in being primarily

144   based on individual forcing simulations. That said, natural-only (hist-nat) simulations can be equivalently described and used

145   as all-but-anthropogenic forcing simulations, and DAMIP v2.0 links with an AerChemMIP2 simulation with all forcings but

146   aerosols (hist-piAer), which can be used to address particular questions relating to the dependence of the anthropogenic aerosol

147   impact on the climate state and additivity of the aerosol response with the responses to other forcings (Marvel et al., 2015;

148   Shiogama et al., 2013; Simpson et al., 2023).

149

150   Recognising the advances in modelling which are allowing a larger fraction of climate models to be run with interactive CO_2,

151   the new science questions which may be addressed using interactive CO_2 simulations, as well as the interest in running many

152 CMIP7 simulations with interactive CO_2 (Sanderson et al., 2024), DAMIP v2.0 is also proposing a set of individual forcing
153 interactive CO_2 simulations (Section 3.3). Such simulations could for example be used to evaluate the effects of
154 biogeochemical feedbacks on the responses to particular forcings, such as aerosols (e.g. Szopa et al., 2021), and could be used
155 in studies attributing changes in atmosphere, land or ocean carbon pools to land use change, fossil CO_2 emissions and other
156 GHG changes, and other factors. As in CMIP6, such interactive CO_2 simulations will have distinct experiment names from
157 their corresponding prescribed concentration simulations (because the prognostic CO_2 concentration will generally differ from
158 that prescribed in the corresponding concentration-driven experiments). Interactive CO_2 historical simulations will sample
159 over uncertainties in the understanding and representation of the carbon cycle within ESMs, and will allow analysis of the
160 effects of carbon cycle feedbacks on the responses to individual forcings, for instance testing the frequently-made assumption
161 that the responses to historical well-mixed GHG concentration changes are equivalent to the responses to historical well-
162 mixed GHG emission changes. However, given that direct and accurate observations of the evolution of atmospheric CO_2
163 exist, we recommend that prescribed-CO_2 simulations should continue to be used for detection and attribution studies of
164 changes in the physical climate. For this reason, our highest-priority Assessment Fast Track simulations are concentration-
165 driven, as are the other simulations described in Sections 3.1 and 3.2 (the Assessment Fast Track simulations are a subset of
166 CMIP7 simulations to be carried out first in support of the IPCC Seventh Assessment Report (Dunne et al., 2024)). If modelling
167 centres have the capacity and interest to carry out both prescribed-CO_2 and interactive-CO_2 simulations, we recommend that
168 they carry out both, allowing the effects of carbon cycle feedbacks on the responses to individual sets of forcings to be isolated
169 in each model.

171 Like the effects of an interactive carbon cycle, atmospheric chemistry also has the potential to modify the simulated response
172 to individual forcings or sets of forcings. In a model with a full representation of atmospheric chemistry, methane and
173 fluorinated gas concentrations influence tropospheric and stratospheric ozone concentration, solar and volcanic forcings
174 influence stratospheric ozone concentrations, and aerosols and aerosol precursors influence ozone and methane concentrations,
175 among other interactions. Such interactions would make DAMIP simulations from models with and without interactive
176 chemistry not fully comparable. Because of such interactions, attribution of physical climate changes to changes in
177 concentrations of radiatively active species is fundamentally different to attribution to emissions changes of such species.
178 Typically detection and attribution studies of observed changes in climate attribute to concentration changes (e.g. Eyring et
179 al., 2021), while emissions-driven individual forcing simulations may be used for bottom-up model-based estimates of the
180 climate response to emissions of individual species (e.g. Szopa et al., 2021, Section 6.4). Like DAMIP v1.0, our focus here is
181 mainly on supporting attribution to concentration changes, while AerChemMIP2 is proposing simulations to address attribution

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182 to emissions. While DAMIP v1.0 did propose an experimental design for hist-GHG and hist-aer for models with interactive
183 chemistry to try to maintain comparability with other models, we note that this was never implemented because no modelling
184 centres actually carried out the DAMIP v1.0 experiments with models with interactive chemistry. To simplify the experimental
185 design and ensure comparability between outputs from different models, we therefore suggest that modelling groups carry out
186 the DAMIP v2.0 experiments using model versions without gas phase chemistry if possible. While we note that aerosol
187 microphysics and chemistry schemes may make simulated aerosol concentrations sensitive to simulated temperatures, winds,
188 and possibly greenhouse gas concentrations, and therefore different in historical and hist-aer simulations, we note that the
189 primary sensitivity of aerosol concentrations is to aerosol and aerosol precursor emissions, and that most modelling centres do
190 not have the capacity to run their models with specified aerosol concentrations, and therefore we accept such small differences
191 as a limitation of our experimental design.

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193 If modelling centres plan to only submit simulations with interactive gas phase chemistry and are submitting historical
194 simulations including this interactive chemistry, we request that they follow the DAMIP experimental design as indicated, but
195 with the following modifications (see also Table 1). For hist-GHG and esm-hist-GHG they should specify emissions rather
196 than concentrations of all well-mixed non-CO_2 greenhouse gases simulated interactively. hist-O3 and esm-hist-O3 simulations
197 should not be carried out using models with interactive gas-phase chemistry. This is because ozone is simulated interactively
198 in response to changes in ozone depleting substances, methane and other species in such models, rather than prescribed directly,
199 and the concentrations of ozone depleting substances, and methane and other species do not change in these simulations. All
200 other simulations should be carried out as specified.

201

202 While hist-nat simulations in models with gas phase chemistry will include changes in stratospheric ozone which may modulate
203 the response to solar and volcanic forcing, we expect the effects on surface climate to be small, and such output could probably
204 be used together with historical simulations to attribute surface climate change to anthropogenic and natural forcings. Similarly
205 hist-lu simulations from models with and without interactive chemistry are expected to be comparable. hist-GHG experiments
206 are expected to differ between models with and without gas phase chemistry, because in models with interactive chemistry,
207 methane emissions will increase tropospheric ozone, while halocarbon emissions will decrease stratospheric ozone. hist-aer
208 experiments will also differ because emissions of NOx, NMVOCs and carbon monoxide (which are aerosol precursors) will
209 all change tropospheric ozone and methane concentrations. Such experiments would not be directly comparable between
210 models with and without gas phase chemistry, but analysis of the output could inform understanding of atmospheric chemistry
211 feedbacks. To facilitate analysis of the results, we request that modelling centres flag output from models with interactive

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212 chemistry with the 'f2' flag, and indicate in their metadata and documentation that the model included interactive chemistry.
213 We note that AerChemMIP2 also provides a dedicated framework for analysing the effects of such interactions systematically
214 across models with interactive chemistry.
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218 **3.1 Historical simulations**

219 **3.1.1 Increased ensemble size for CMIP7 historical and Medium scenario simulations**
220 While our focus is on historical experiments forced with single forcings or subsets of forcings, most detection and attribution
221 analyses also use historical simulations with a complete set of forcings, and such analyses generally require an ensemble of
222 such simulations, but only a single historical simulation is required as part of the DECK (Dunne et al., 2024). Therefore we
223 request at least three ensemble members of the CMIP7 CO_2 concentration-driven historical simulations (historical), and the
224 extension of those simulations to 2035 under the Medium scenario (scen7-mc, intended to represent a frozen policy scenario)
225 proposed by ScenarioMIP for CMIP7 (van Vuuren et al., 2025). Given that actual anthropogenic forcings are expected to
226 diverge only slightly from the Medium emissions scenario over the first decade or so (see Section 4), we request that these
227 historical simulations and other DAMIP experiments are extended in this way. This will allow researchers to carry out
228 attribution analyses based on contemporary data over the next decade, at least in the absence of a major volcanic eruption, and
229 will likely ensure an overlap with the next phase of CMIP. DAMIP v1.0 simulations were extended in a similar way from 2015
230 to 2020, but in hindsight this was not long enough, since at the time of writing CMIP7 simulations are not yet available, but
231 observations are available up to the end of 2024, well beyond the end of the DAMIP historical simulations. Such a need is
232 particularly apparent for regularly updated attribution analyses (Forster et al., 2024). Modelling groups should publish the
233 output data as CMIP7 historical simulations (1850-2021) and the Medium scenario simulations of ScenarioMIP (2022-2035).
234 Note that we also request an ensemble size of at least three for all other DAMIP v2.0 historical simulations, though we
235 encourage groups to runs larger ensembles if possible. Also note that all DAMIP v2.0 simulations except historical-CMIP6
236 use forcings from the CMIP7 historical/esm-historical and Medium simulations described by Dunne et al. (2024). A larger
237 ensemble of CMIP7 historical simulations will also make it easier to evaluate the consistency of simulated historical climate
238 change with that observed, though any such analysis should account for the use of historical temperature change in the tuning
239 of some models (Hourdin et al., 2017).
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3.1.2 Simulations with a complete set of forcings

We are proposing a set of CO_2 concentration-driven historical simulations driven with subsets of forcings which together sum to give the full set of CMIP7 historical forcings. This set includes the hist-nat, hist-GHG and hist-aer experiments which are designated as Assessment Fast Track experiments here (Dunne et al., 2024) and also as Tier 1 experiments, based on the extensive use of the corresponding DAMIP v1.0 simulations in the literature and in support of IPCC assessment reports (Figure 1b). For this reason, we ask modelling groups to prioritize these simulations, and to consider running large ensembles of these simulations to support extreme event attribution and other applications (e.g. Smith et al., 2022), if time and resources allow. If the climate response to these forcings is additive, then the sum of the climate responses in this full set of historical simulations (hist-nat, hist-GHG, hist-aer, hist-O3 and hist-lu) will be equal to the response in the historical experiment. We note that the variance of this sum will in general be five times larger than the variance of the response in historical, which will need to be accounted for when identifying departures from additivity. This represents involves a minor adjustment relative to the DAMIP v1.0 experimental design in which land-use and land-cover change and tropospheric ozone changes were not included in any of the original DAMIP v1.0 simulations. All these simulations should be run from 1850 to 202135 using the CMIP7 historical forcings, and the Medium scenario (scen7-mc) from 2022 to 2035, and we request a minimum ensemble size of three for all historical experiments.

hist-nat: These natural-only simulations parallel the historical and Medium scenario simulations but instead are forced with only solar and volcanic forcings from the historical and Medium scenario simulations, similar to the CMIP6 hist-nat experiment. Such simulations, when compared with historical and Medium simulations, can be used for attribution of observed changes to anthropogenic influence, as they correspond to the counterfactual world in which human influence is removed. We note that wWhile much of the time evolution of biomass burning emissions has occurred as a result of human activity, the historical simulation includes observed year-to-year variations in biomass burning partly driven bywhich includes a component related to natural variability. However, it is not easy to separate human-induced changes in biomass burning from naturally-induced changes. Therefore we, but we include that in hist-aer and request that modelling centres specify constant biomass burning emissions as in the piControl in this hist-nat simulation. In contrast with DAMIP v1.0, and consistent with our aim of ensuring a complete set of forcings across this simulation set and to simplify the experimental design, we are proposing that no ozone changes are specified in the hist-nat experiment, and that all ozone changes are included in the hist-O3 experiment.

hist-GHG: These greenhouse-gas-only simulations parallel the historical and Medium simulations but are forced by well-mixed greenhouse gas (carbon dioxide, methane, nitrous oxide and fluorinated gas) changes only from the historical and

270　Medium scenario simulations, similarly to the CMIP6 hist-GHG experiment. Both stratospheric and tropospheric ozone should

271　be held constant at piControl levels. Greenhouse gas changes are the dominant anthropogenic forcing, and these simulations

272　will allow the response to this forcing to be quantified. Moreover, historical/Medium, hist-nat and hist-GHG will together

273　allow the attribution of observed climate change to natural, greenhouse gas and other anthropogenic forcings (e.g. Gillett et

274　al., 2021; Ribes et al., 2021).

275　**hist-aer**: These historical aerosol-only simulations parallel the historical/Medium simulations but are forced by changes in

276　aerosol and aerosol precursor emissions changes only, as in historical and the Medium scenario. This includes changes in

277　sulphur dioxide, black carbon, organic carbon, ammonia, NOx and VOCs, from biomass burning, industrial emissions and

278　other sources.

279　**hist-lu:** These simulations parallel the historical and Medium simulations but are forced with prescribed land-use and land

280　cover changes only from the historical and Medium scenario simulations, with all other forcings held constant at 1850 values.

281　No such experiments were included in DAMIP v1.0, although they have since been proposed in LESFMIP (Smith et al., 2022),

282　and historical experiments without land use change (hist-noLu) were included in CMIP6 in the Land Use Model

283　Intercomparison Project (LUMIP, Lawrence et al., 2016). These experiments were used to investigate the effects of land use

284　change on surface temperature and other variables in models (Luo et al., 2024; Zhang et al., 2024a), and to diagnose land use

285　change emissions (e.g. Liddicoat et al., 2021). Note that hist-noLu is also a proposed LUMIP experiment for CMIP7, and

286　hence hist-lu and hist-noLu could be used together to evaluate the additivity of the land-use change response and the response

287　to other forcings. These experiments could also for example be used together to compare and contrast simulated historical

288　land-use change emissions with atmospheric CO_2 held constant, and in the presence of CO_2 fertilisation with CO_2 changing

289　through the historical period.

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291　**hist-O3**: These simulations parallel the historical/Medium simulations but are forced by changes in ozone concentrations only

292　from the historical and Medium scenario simulations. They will allow characterization of the response to combined

293　tropospheric and stratospheric ozone changes, which have played an important role in driving circulation changes in the high-

294　latitudes of the Southern Hemisphere and temperature changes in the stratosphere, as well as attribution studies of the response

295　to ozone change (e.g. Gillett et al., 2013; Morgenstern, 2021). Since it is increasingly understood that ozone depleting

296　substances influence ozone concentrations in the troposphere (e.g. Hassler et al., 2022; Li et al., 2024b), in CMIP7 we are

297　requesting simulations forced by changes in ozone concentrations over the whole atmospheric column, as opposed to the

298　stratospheric ozone changes only simulations proposed in CMIP6 (Gillett et al., 2016) (although experiments with ozone

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299 changes over the whole atmosphere were later proposed and carried out (Liu et al., 2022; Shiogama et al., 2023; Smith et al.,
300 2022)). Moreover, this choice simplifies the experiment design, and avoids difficulties associated with specifying stratospheric
301 ozone changes only, given that tropopause height can differ across models. (aAlthough, we acknowledge that inconsistencies
302 between tropopause height and ozone concentrations can still exist when prescribing ozone over the full column, which users
303 should be aware could impact conclusions in certain circumstances (Hardiman et al., 2019)).
304
305 **3.1.3 Other historical simulations**
306 **hist-volc**: The hist-volc simulations parallel the hist-nat simulations except that the hist-volc simulations are driven by
307 stratospheric aerosol changes only. The hist-volc experiments will allow the characterisation of and attribution to volcanic
308 influence, separate from the poorly constrained response to variations in solar forcing. Such analysis can improve our
309 understanding of the response to future volcanic eruptions.
310
311 **historical-CMIP6:** These are identical to CMIP7 historical experiments, but instead of using CMIP7 forcings, they use CMIP6
312 historical forcings to 2014 and ScenarioMIP SSP2-4.5 forcings from 2015 to 2035. CMIP simulations of past and future climate
313 changes are key to attribution as well as projection of climate change, for example in IPCC assessments (Eyring et al., 2021;
314 Lee et al., 2021), and it is important to be able to understand differences in results based on successive CMIP generations.
315 Comparing historical CMIP6 and CMIP7 simulations will beis complicated by the fact that both the models and the forcings
316 will beare different between the two CMIP generations, making it difficult to separate the influence of updates to the forcings
317 versus changes to the models. By carrying out simulations with a subset of CMIP7 models using CMIP6 forcings, it will be
318 possible to separate the influence of updates to the forcings. A similar approach was used to isolate the influence of updates to
319 forcings between CMIP5 and CMIP6 and the impact of forcing changes has been shown to be an important contributor to
320 differences between CMIP6 and CMIP5 simulations (Fyfe et al., 2021; Holland et al., 2024).
321
322 **3.2 Future simulations driven with subsets of forcings**
323 While ScenarioMIP simulations including scenarios of future changes in greenhouse gases, aerosols, ozone and land use
324 change allow the simulation of possible future climate evolution, they do not directly allow the effects of particular forcings,
325 or sets of forcings, to be isolated. Simulations of future climate change with subsets of forcings can help us understand the
326 drivers of future climate change. Moreover, the Allen et al. (2000) and Stott and Kettleborough (2002) approach to
327 constraining climate projections may be used to separately scale the future responses to well-mixed greenhouse gases and to
328 aerosols, based on regressions over the historical period, since models may over- or under-estimate the climate response to

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329 greenhouse gases and aerosols by different factors. This kind of analysis requires future scenario simulations with subsets of
330 forcings. DAMIP v1.0 included ssp245-nat, ssp245-GHG, ssp245-aer and ssp245-stratO3 simulations to address such needs
331 (Gillett et al., 2016). Similarly, DAMIP v2.0 also includes future simulations with subsets of forcings following the Medium
332 scenario from the ScenarioMIP design for CMIP7 (van Vuuren et al., 2025), which approximately corresponds to a
333 continuation of current climate policies.

334

335 **Medium-GHG**: This is an extension of the hist-GHG simulations to 2100 using the Medium scenario well-mixed greenhouse
336 gas concentrations, with other forcings kept at pre-industrial values.

337

338 **Medium-aer**:   This is an extension of the hist-aer simulations to 2100 following the Medium scenario aerosol
339 concentrations/emissions, with other forcings kept at pre-industrial levels. These simulations will also allow a more robust
340 characterisation of the response to future aerosol changes, without conflating these changes with the responses to ozone and
341 land-use changes, as would occur if the aerosol response were estimated from a difference between the Medium scenario and
342 Medium-GHG.

343

344 **Medium-O3**: These simulations are extensions of the hist-O3 simulations to 2100 following the ozone concentrations specified
345 for the Medium scenario. Stratospheric ozone is projected to recover following the successful implementation of the Montreal
346 Protocol and its amendments (e.g. Hassler et al., 2022). These simulations will facilitate a robust multi-model assessment of
347 the climate effects of this recovery on Southern Hemisphere climate and stratospheric temperature.

348 **3.3 Interactive CO_2 experiments**

349 Detection and attribution studies have typically attributed changes in the physical climate system to changes in concentrations
350 of greenhouse gases and other species by regressing observed changes onto the simulated response to changes in concentrations
351 of greenhouse gases and other species (e.g. Eyring et al., 2021), but an alternative bottom-up approach uses models directly to
352 simulate the responses to changes in emissions of particular greenhouse gases or other species (e.g. Forster et al., 2021, Section
353 7.3; Szopa et al., 2021, Section 6.4). Such approaches can quantify the respective contributions of emissions of various
354 chemical species, such as CO_2, methane, SO_2, and others. These approaches can account for feedbacks on the response to
355 emissions of particular chemical species, based on their representation in models. IPCC (2021, Figure SPM.2) contrasted
356 observationally-constrained attributable warming in response to changes in concentration of greenhouse gases among other
357 factors, with estimates of the warming attributable to emissions of CO_2, methane and other species. These estimates included
358 the simulated effects of tropospheric chemistry (Szopa et al., 2021), which strongly influence the responses to some forcings,

359 but they omitted the effects of carbon-climate feedbacks which are also expected to influence the responses to such forcings

360 (Szopa et al., 2021). In part to address this knowledge gap, we are proposing interactive-CO_2 versions of all the experiments

361 described in Sections 3.1 and 3.2, with the exception of historical-CMIP6 (where our focus is on understanding differences in

362 the concentration-driven historical experiments between CMIP6 and CMIP7). Such experiments should be carried out using

363 Earth System Models (ESMs) with interactive carbon cycles, which can simulate atmospheric concentrations of CO_2 based on

364 prescribed emissions. As noted above, we recommend that modelling centres carrying out these interactive CO_2 experiments

365 also carry out the corresponding prescribed CO_2 experiments, allowing the effects of carbon-climate feedbacks on the response

366 to each set of forcings to be quantified. These simulations should be run from 1850 to 2035, using the esm-hist~~orical~~ CO_2

367 emissions and other forcings for the period 1850-2021, and the Medium scenario CO_2 emissions and other forcings for the

368 period 2022 to 2035.

369

370 **esm-hist-nat**: These interactive-CO_2 simulations parallel esm-hist~~orical~~ simulations, but with only solar and volcanic forcings

371 varying, and all other forcings held fixed, including ozone. Such simulations can be used for example to evaluate the effects

372 of carbon-climate feedbacks on the response to volcanoes (Kandlbauer et al., 2013; Rothenberg et al., 2012), or as a true

373 counterfactual simulation reflecting the CO_2 evolution in the absence of anthropogenic influence.

374

375 **esm-hist-GHG**: These interactive-CO_2 simulations parallel the esm-hist~~orical~~ simulations, but include only fossil CO_2

376 emissions and changes in the concentration of other well-mixed greenhouse gases (methane, nitrous oxide and fluorinated

377 gas). No changes in land-use or emissions associated with land-use change should be prescribed.

378

379 **esm-hist-aer**: These interactive-CO_2 simulations parallel the esm-hist~~orical~~ simulations, but include only changes in aerosol

380 and aerosol precursor emissions. Changes in aerosols can perturb the carbon cycle not only through changes in the climate,

381 but also through deposition of nutrients such as nitrogen, sulphur, iron and phosphorous, and through changes in solar

382 irradiance and diffuse radiation at the surface (Szopa et al., 2021), and the response will depend on the representation of these

383 mechanisms in each ESM.

384

385 **esm-hist-lu**: These interactive-CO_2 simulations parallel the esm-hist~~historical~~ simulations but are forced with prescribed land-

386 use and land cover changes only, with all other forcings held constant at 1850 values. Such experiments will include the

387 simulation of CO_2 emissions based on prescribed land-use change, and will support the calculation of the net climate influence

388 of land-use change (biogeophysical and carbon dioxide effects) (e.g. Intergovernmental Panel On Climate Change, 2022).

14

389

esm-hist-O3: These interactive-CO_2 simulations parallel the esm-hist~~t~~orical simulations, but include only prescribed changes in tropospheric and stratospheric ozone concentration. Tropospheric ozone increases reduce terrestrial plant growth influencing land carbon uptake (Szopa et al., 2021). Early studies found a substantial role for stratospheric ozone in driving changes in the Southern Ocean carbon sink (Le Quéré et al., 2007), but more recent assessments find a weaker role (Garny~~, H~~ et al., 2022). These simulations will support the investigation of the effects of such processes on atmospheric CO_2 concentration.

esm-hist-volc: These interactive-CO_2 simulations parallel the esm-hist~~orical~~ simulations, but are driven with stratospheric aerosol changes only.

esm-Medium-GHG: Thes interactive CO_2 simulations are extensions of the esm-hist-GHG simulations to 2100, ~~but~~ with CO_2 emissions and other well-mixed greenhouse gas concentrations following the Medium scenario.

esm-Medium-aer: Thes interactive CO_2 simulations are extensions of the esm-hist-aer simulations to 2100, ~~but~~ with aerosol and aerosol precursor emissions following the Medium scenario.

esm-Medium-O3: These interactive CO_2 simulations are extensions of the esm-hist-O3 simulations to 2100, ~~but~~ with tropospheric and stratospheric ozone concentration following the Medium scenario.

Figure 3 shows global mean surface CO_2 concentration and temperature in a subset of such simulations carried out with CanESM5.0 (Swart et al., 2019), compared with corresponding prescribed concentration simulations for reference. The simulated CO_2 in the esm-historical simulations of this model is within 15 ppm of~~relatively close to~~ that observed and that specified in the historical and hist-GHG simulations (compare the solid and dashed black lines in Figure 3a). As expected, esm-hist-GHG shows lower simulated CO_2 concentrations than esm-hist~~orical~~, because it includes only emissions of fossil CO_2 and omits land-use change emissions of CO_2. Because of this, esm-hist-GHG exhibits less warming than hist-GHG (Figure 3b). By contrast esm-hist-lu shows an increase in atmospheric CO_2 due to the interactively simulated effects of land-use change, and hence it is warmer than hist-lu, in which constant preindustrial CO_2 is specified (Figure 3b). In this model, atmospheric CO_2 increases slightly in esm-hist-aer. While the ocean takes up carbon in this simulation in response to the simulated cooling, this is more than compensated for by the land giving up carbon, likely due to reduced photosynthesis in response to the reduced solar irradiance. However, this model lacks a representation of the vegetation response to the change

15

419 in diffuse irradiance associated with the increase in atmospheric aerosols (Szopa et al., 2021), and therefore this response might
420 be different in other models. Because of this increase in atmospheric CO_2, the cooling in response to aerosols in esm-hist-aer
421 is slightly weaker than in hist-aer, but overall these two experiments exhibit a comparable global surface temperature response
422 in this model.
423
424 3.4 Updated forcing simulations
425 As noted in Section 3.1, for the purposes of detection and attribution analyses, we recommend extending CMIP7 historical
426 simulations from 2022 to 2035 with the ScenarioMIP Medium scenario, and similarly to extend DAMIP single-forcing
427 simulations from 2022 to 2035 with the individual forcings prescribed for this scenario. However, observed concentrations
428 and emissions of forcing agents will at some point evolve differently from those specified in this scenario. While forcings have
429 evolved broadly consistently with the SSP2-4.5 scenario used to extend DAMIP v1.0 simulations since 2015 (Matthews and
430 Wynes, 2022), there have been some differencesthis has not been completely true. For example, recent aerosol emissions from
431 China have declined more strongly than those specified in the SSP2-4.5 scenario (Wang et al., 2021), a decline in marine
432 sulphur emissions resulting from new International Maritime Organisation regulations was not included in the SSP2-4.5
433 simulations (Watson-Parris et al., 2022, 2024), the COVID-19 pandemic changed emissions temporarily in ways which were
434 notn't included in the SSP2-4.5 scenario (e.g. Szopa et al., 2021), and the Hunga Tonga eruption in 2021 injected sulphur
435 dioxide and water vapour into the stratosphere, influencing the climate (e.g. Jenkins et al., 2023). In the past such differences
436 between forcings used to drive climate models simulations, and those which actually have transpired have been cited as reasons
437 for differences between simulated and observed warming trends in the early 21st century (e.g. Eyring et al., 2021; Santer et
438 al., 2014), and in the early 2020s (Rantanen and Laaksonen, 2024). For these reasons, LESFMIP proposed a set of individual
439 forcing simulations using regularly updated forcing estimates, as part of CMIP6 (Smith et al., 2022), though at the time of
440 writing such simulations have not yet been carried out and the protocols and process are not in place for the regular update of
441 forcings which would support such experiments. If this could be achieved in the future, however, such simulations could be
442 used to understand the contribution influence of updates to particular forcing estimates in contributing to observed climate
443 trends, particularly on interannual to decadal timescales, as well as to reduce uncertainties in attribution results associated with
444 forcing changes after 2021. Given the uncertainty in whether future forcings over the next decade or so will diverge strongly
445 from those specified in the Medium scenario, and if and when updated forcings datasets willould be made available to the
446 modelling community, we are not proposing additional named experiments here. However, we do note that the Earth System
447 Grid Federation (ESGF) naming convention includes a forcing index which can be used to label different forcing variants for
448 a given experiment. We recommend that this index is used to publish simulations with updated forcing variants if and when

449 modelling centres perform them. For example, if the original version of hist-nat, using the Medium scenario forcings from
450 2022 to 2035 were published with the 'f1' forcing index, and were a major volcanic eruption to occur in 2027, and an updated
451 stratospheric aerosol forcing datasets be published that year, a new version of the simulation using the updated forcings could
452 be published with the 'f2027' forcing index. Such a simulation could cover only part of the time period covered by the original
453 simulation (e.g. 2022-2035 only), as long as it is labelled appropriately. We suggest labelling such simulations with major
454 updates to forcings with the year which historical forcings were extended to e.g. 'f2027'. Alternatively a version number of
455 the forcing dataset could be used. Any such effort would require additional community coordination and documentation if and
456 when new forcing datasets were published, and would be most valuable if carried out in conjunction with updated all-forcing
457 scenario simulations as part of ScenarioMIP or DCPP.
458
459 **4. Synergies with other MIPs**
460 In CMIP6, several DAMIP v1.0 experiments were coordinated with other MIPs in order to maximise synergies and support
461 research to address a wide range of scientific questions (Gillett et al., 2016). For example, DAMIP v1.0 and the Radiative
462 Forcing Model Intercomparison ProjectIP (RFMIP) (Pincus et al., 2016) proposed coordinated coupled and prescribed sea
463 surface temperature simulations with natural-only and well-mixed GHG-only forcings, in order to estimate corresponding
464 effective radiative forcings. For CMIP7, we have again coordinated with a broad range of MIPs to maximise scientific
465 synergies.
466
467 As discussed above, all DAMIP v2.0 simulations extend beyond the end of the historical simulation in 2021, and therefore we
468 are recommending extending these simulations with the Medium scenario from ScenarioMIP. Our simulations which are
469 extended to 2100 are also coordinated with ScenarioMIP to support understanding of the roles of individual forcings in driving
470 future climate change in the Medium scenario. Similarly, we are coordinating our scenario choice with DCPP, such that both
471 DAMIP simulations and DCPP simulations will use the same scenario, allowing the contributions of individual forcings to
472 near-future climate change to be calculated and compared with initialised predictions under the same consistent set of forcings.
473
474 The AerChemMIP2 Assessment Fast Track hist-piAer experiments parallel the historical and Medium scenario simulations,
475 except that aerosols are kept fixed at pre-industrial levels. Together with the hist-aer and historical experiments, these
476 experiments will allow analysis of the extent to which the climate response to aerosols is additive with the response to other
477 forcings. For this reason we encourage modelling centres participating in DAMIP to also carry out the hist-piAer simulations.
478

17

479   The RFMIP experiment piClim-histaer (which is an atmosphere-only simulation with fixed preindustrial SSTs and sea ice and
480   transient aerosols) parallels hist-aer, except that it has fixed SSTs. This experiment can be used to diagnose the evolution of
481   the effective radiative forcing of aerosols, while the DAMIP hist-aer experiment can be used to diagnose the climate response
482   to that forcing.

483

484   High resolution climate model simulations are often able to better represent phenomena relevant to climate extremes, such as
485   tropical cylones, atmospheric rivers, and heat waves and heavy rainfall in mountainous regions (e.g. Roberts et al., 2025). Such
486   events are often the focus of extreme event attribution studies. The HighResMIP2 (Roberts et al., 2025) 1950s control (control-
487   1950), and historical simulation beginning in 1950 (hist-1950), as well as its extension to 2100 with the Medium scenario will
488   be valuable in supporting extreme event attribution for such variables, with allowance made for the fact that the 1950s control
489   is not a preindustrial control. We also encourage modelling groups to carry out DAMIP experiments with high resolution
490   models to the extent possible, but realize that computational constraints may prevent this. Finally, we note that the
491   HighResMIP2 choice of the Medium scenario to extend historical simulations to 2100 aligns with our choice of the same
492   scenario in DAMIP v2.0.

493

494   **5. Variables requested by DAMIP**

495

496   DAMIP has provided input to the process that is defining the harmonized data request for DECK and Assessment Fast Track
497   experiments through the proposal of the "Detection and Attribution" opportunity. This opportunity contains basic variables
498   that are needed for quantifying how the mean climate and its variability are changing over time, for understanding the
499   mechanisms involved, and for comparing with the observational record with a view to detecting and attributing climate change
500   signals. Many of these variables overlap with the proposed baseline variable set for Earth System Modeling (Juckes et al.,
501   2024). These proposed variables include fields for assessing the different forcings that the climate system is experiencing,
502   fields for assessing global mean temperature, hydrological, sea level, and circulation changes in both the atmosphere and
503   ocean, as well as top of atmosphere and surface fluxes for diagnosing energy balances and fields for understanding the role of
504   clouds in the climate system. With the move towards a greater role for emissions-driven simulations, we also request variables
505   that would help us understand the origins of differences in CO_2 concentration among simulations when run in emissions-driven
506   mode. A variety of daily fields are also requested to understand the time evolution of extremes and fields that can be used to
507   diagnose synoptic features and daily surface fluxes that can be used to understand the drivers of those extremes. Finally,
508   DAMIP requests zonal mean or 3D atmospheric temperature with a high vertical resolution extending deep into the stratosphere

509 to allow the upper levels to be examined with sufficient resolution to be compared with Stratospheric Sounding Unit (SSU)
510 observations (e.g. Mitchell, 2016; Santer et al., 2023). Stratospheric temperature trends are an important part of the climate
511 change signal, and are also particularly insightful for assessing ozone recovery, volcanic aerosol, and solar signals (Mitchell,
512 2016; Santer et al., 2023).

514 We propose the "Detection and Attribution" variable groups be output for all DAMIP experiments and related experiments
515 from the DECK and other MIPs shown in Figure 2. We also suggest that these be output for the pre-industrial control
516 experiments to allow the uncertainties due to internal variability alone to be quantified as well as the AMIP experiments which
517 can be used to explore the role of observed historical trends in SSTs in the evolution of the climate system and in potential
518 differences between coupled models and observations. Since most of the variables proposed as part of the Detection and
519 Attribution opportunity are basic fields needed to characterize the ~~behavior~~behaviour of the climate system, we also suggest
520 that these variables be output for the more idealized experiments that are part of DECK and Assessment Fast Track that can
521 be used to understand the ~~behavior~~behaviour of models and explore the direct effects of radiative forcings and the indirect
522 effects of SST warming on the climate system. These include: 1pctCO2, 1pctCO2-bgc, 1pctCO2-rad, abrupt-4xCO2, piClim-
523 anthro, hist-piSLCF, amip-p4k, and amip-piForcing. We also suggest that these variables are saved for the DCPP initialized
524 predictions from 2025-2036 to compare simulated near term trends in these predictions with those in free-running coupled
525 simulations, allowing for attribution of predicted~~forthcoming~~ trends in the climate system to external forcings as well as aspects
526 of variability and change that are imparted to the models through the initial conditions in this particular experiment.

528 **6. Summary**
529 This paper describes the Detection and Attribution Model Intercomparison Project (DAMIP v2.0) which will form part of
530 CMIP7 (Dunne et al., 2024) and is intended to underpin detection and attribution analysis informing the IPCC Seventh
531 Assessment Report. DAMIP v1.0 simulations in CMIP6 were extensively used in the fields of attribution of climate trends,
532 extreme event attribution and attribution of climate impacts, and they also underpinned the assessment of human-induced
533 global warming in the IPCC AR6 (IPCC, 2021), which was reported in the Glasgow Climate Pact (UNFCCC, 2022).

535 DAMIP v2.0 again proposes hist-nat, hist-GHG and hist-aer simulations as high priority Assessment Fast Track simulations
536 for CMIP7. These simulations were the most heavily used in CMIP6. We are proposing that they are extended to 2035 using
537 the Medium scenario from ScenarioMIP. However, we also propose a set of historical simulations with forcings which together
538 from the complete set of historical forcings (hist-GHG, hist-aer, hist-nat, hist-lu and hist-O3), allowing additivity to be easily

539 tested, and ensuring all forcings are covered. Given that stratospheric and tropospheric ozone changes interact with each other,
540 and to simplify the experimental design, we propose hist-O3 simulations which have prescribed ozone changes in the
541 stratosphere and troposphere, rather than just in the stratosphere as was the case for CMIP6. To evaluate the effects of
542 individual forcings on future climate evolution, we are proposing extension of key simulations to 2100 under the Medium
543 emissions scenario. Finally, for CMIP7 we are proposing a new set of interactive-CO_2 simulations, which will among other
544 things allow the net effect of land-use change on climate to be evaluated, and allow the effects of carbon-climate feedbacks on
545 the simulated response to individual forcings to be evaluated.

547 **Website of DAMIP:** Updated details on the project and its progress will be available at https://wcrp-cmip.org/mips/damip/.

554 **Data Availability:** The model output from the DAMIP simulations described in this paper will be distributed through the
555 Earth System Grid Federation (ESGF) with digital object identifiers (DOIs) assigned. The model output will be freely
556 accessible through data portals after registration.

563 **Competing Interests:** The authors declare that they have no conflict of interest.

570
571
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Table 1 DAMIP v2.0 simulations.

Name	Description of prescribed concentration simulations (forcing agents perturbed)	Interactive CO₂ equivalent simulation name (modifications)	Modifications for coupled chemistry models	Start year	End year	Minimum ensemble size
historical and Medium scenario	Enlarging ensemble size of historical (1850-2021) and ScenarioMIP Medium scenario (scen7-mc, 2022-2035) to an ensemble size of at least 3. Forcings: WMGHGs, BC, OC, SO_2, SO_4, NO_x , NH_3, CO, NMVOC, nitrogen deposition, ozone, stratospheric aerosols, solar irradiance, land use)	esm-hist~~orical~~ and esm-scen7-m~~Medium~~ (prescribe fossil CO_2 emissions instead of concentrations)		1850	2035	3
hist-nat	Natural-only historical simulations (solar irradiance, stratospheric aerosol)	esm-hist-nat		1850	2035	3
hist-GHG	Well-mixed greenhouse gas only historical simulations (WMGHGs)	esm-hist-GHG (prescribe fossil CO_2 emissions instead of CO_2 concentrations)	Prescribe emissions instead of concentrations of those WMGHGs simulated interactively	1850	2035	3
hist-aer	Anthropogenic aerosol-only historical simulations (BC, OC, SO_2, SO_4, NO_x , NH_3, CO, NMVOC)	esm-hist-aer		1850	2035	3
hist-O3	Ozone-only historical	esm-hist-O3	NA	1850	2035	3

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	simulations (ozone concentration)					
hist-lu	Land-use change only historical simulation	esm-hist-lu		1850	2035	3
historical-CMIP6	Historical simulation with forcings from CMIP6 historical and SSP2-4.5 (WMGHGs, BC, OC, SO_2, SO_4, NO_x , NH_3, CO, NMVOC, nitrogen deposition, ozone, stratospheric aerosols, solar irradiance, land use)	NA	NA	1850	2035	3
hist-volc	Volcanic aerosol only historical simulation (stratospheric aerosols)	esm-hist-volc		1850	2035	3
Medium-GHG	Extension of at least one hist-GHG experiment to 2100 using the Medium scenario.	esm-Medium-ghg (prescribe fossil CO_2 emissions instead of CO_2 concentrations)	Prescribe emissions instead of concentrations of those WMGHGs simulated interactively	2036	2100	1
Medium-aer	Extension of at least one hist-aer experiment to 2100 using the Medium scenario.	esm-Medium-aer		2036	2100	1
Medium-O3	Extension of at least one hist-O3 experiment to 2100 using the Medium scenario.	esm-Medium-O3	NA	2036	2100	1

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904   (a)

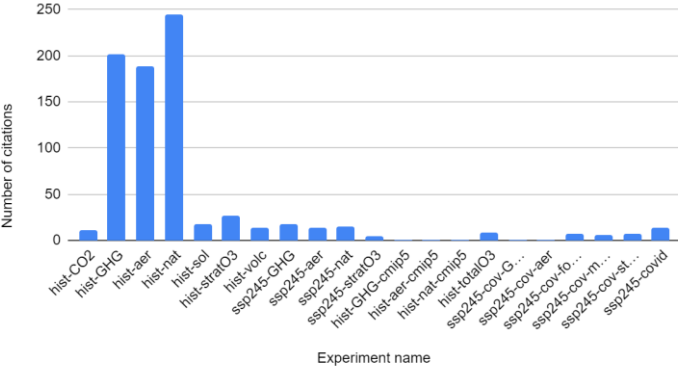## Number of models with data on ESGF for each experiment
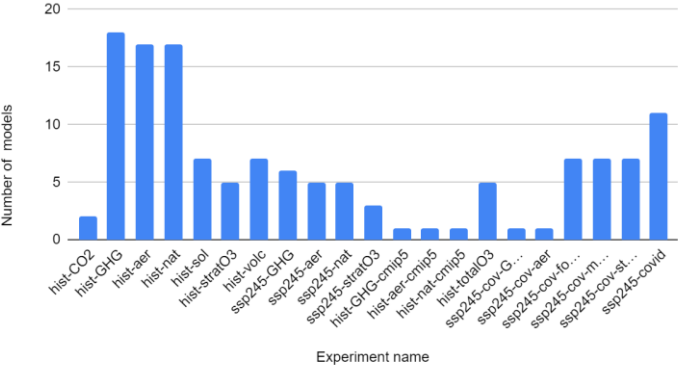
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906   (b)

Number of google scholar citations for each experiment

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908   **Figure 1.** Bar graphs showing (a) the number of models with data published on ESGF for each DAMIP v1.0 experiment,
909   and (b) the number of Google Scholar citations for each DAMIP v1.0 experiment (based on a search for 'CMIP6' and each
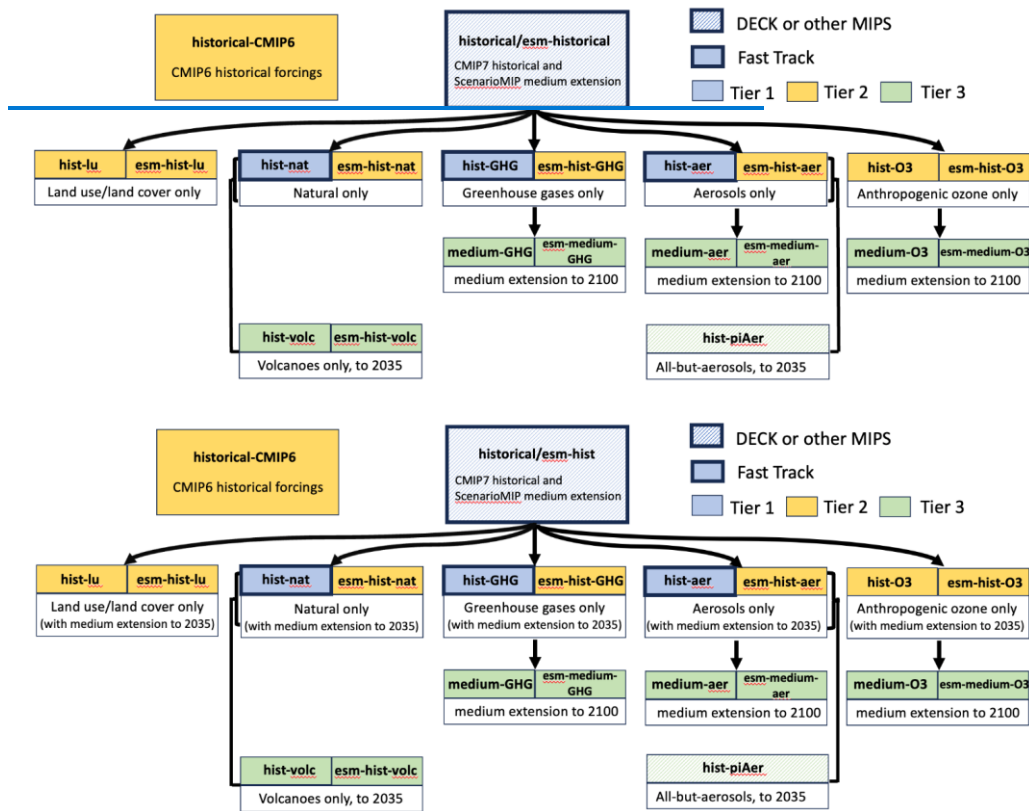910   experiment name), as of July 31st 2024.
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Figure 2. Schematic of the experiments proposed under DAMIP v2.0 for CMIP7. Blue boxes are Tier 1 experiments, yellow boxes are Tier 2 experiments, green boxes are Tier 3 experiments, and white boxes contain descriptive text. All historical simulations except historical-CMIP6 run from 1850 to 2035 using the Medium scenario forcings from 2022, while historical-CMIP6 runs from 1850 to 2035 using the SSP2-4.5 scenario from 2015. The *historical* or *esm-hist* simulation shown in the top row uses CMIP7 historical forcings which can be decomposed into the sets of forcings used in each of the

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924 simulations in the second row. Three of these simulations are extended using the Medium scenario from 2036 to 2100 as
925 shown in the third row. The fourth row depicts two additional experiments that are complementary to those in the second
926 row. ~~Solid arrows indicate the decomposition into separated forced responses.~~ Hatched boxes show simulations which are in
927 other MIPs, but which are of particular relevance to DAMIP.
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(a) CO$_2$ concentration

(b) Global mean surface temperature
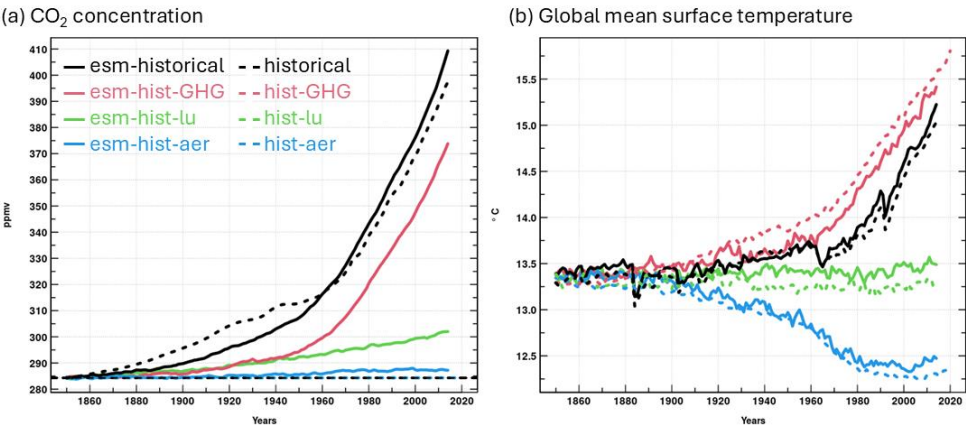
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Figure 3. Global mean surface CO$_2$ concentration (a) and global mean near-surface air temperature (b) in interactive CO$_2$
experiments performed with CanESM5.0 (Swart et al., 2019). Solid lines show results from interactive CO$_2$ simulations
(esm-historical (black), esm-hist-GHG (red), esm-hist-lu (green), and esm-hist-aer (blue)), and dashed lines show results
from corresponding prescribed CO$_2$ simulations (historical (black), hist-GHG (red), hist-lu (green), and hist-aer (blue)).
Results shown are ensemble means of at least five ensemble members. Note that the CO$_2$ concentration prescribed in hist-
GHG is the same as that in historical, and is fixed at the preindustrial level in hist-lu and hist-aer.