

Referee report of gmd-2023-29 manuscript :

Interactions between atmospheric composition and climate change –
Progress in understanding and future opportunities from AerChemMIP,
PDRMIP, and RFMIP

October 6, 2023

To the authors,

I appreciate the modifications and improvements to the manuscript, and that review comments have been taken into account.

However, I repeat point (2) of my earlier review : "The study is generally well written and structured, although specific sections should be improved for better understanding. I also think that there should be an effort in making the style more homogeneous over the whole manuscript. Also, one sometimes gets the impression that some paragraphs (or sentences) do not really belong in a section : they should be brought more in harmony with the text around them. This is indicated in the detailed list below."

After reading the revised manuscript, I think there are important issues remaining concerning the text of the manuscript :

- some paragraphs contain parts that remain unclear or vague, and some sections are too long;
- ideas should be more precise, without multiple sentences containing very similar messages or information; repetition should be avoided;
- the reasoning within a paragraph should be clear, logical and well-structured; and
- the style should be more homogeneous throughout the text.

I hope the authors will make an effort to improve the manuscript. I am aware that this is a time-consuming task, but I think it is necessary in order for the manuscript to be useful and attractive. I think the manuscript does not need a structural change, but mainly an improvement in how the thoughts, ideas and reasonings are formulated. Is it clearly and concisely written? Is there no repetition? Are all the reasonings clear?

Below is a list of comments mainly related to the clarity of the text. Please take these comments into account when trying to create an updated version of the manuscript.

ABSTRACT :

- line 16 : "simulation number and length" : maybe "number of simulations and their length".

1. INTRODUCTION

- line 19-20 : "aspects" and "components" : two rather vague terms in one sentence.
- line 19-20 and line 25-27 : these sentences in the same paragraph are very similar in their message (although one gives more examples). This should be more structured, without repetition.
- line 21-22 and line 23-25 : it should be avoided that a definition of "radiative forcing" via "is called a radiative forcing" on line 23-25, comes after the first use of "radiative forcing" on line 21-22.
- line 25 : "power density" : is this the correct term?
- line 30 : "... that arise from a climate forcer, e.g., a perturbation in the atmospheric composition." This is still vague. It does not mention that IRF, in principle, is just a diagnostic, not affecting the temporal evolution of the atmosphere.
- line 34-35 : "Smaller forcings ... than larger perturbations." I don't know whether this addition is useful.

- line 35-39 : I assume that "change in atmospheric composition" is the initial perturbation, and "changes in emissions of reactive trace gases" is a consequence. For the last part, is one thinking of natural responses such as modification in emission changes from "soil NOx", "lightning NOx" and "isoprene/monoterpenes from vegetation"? Is that what is meant?

- line 42-43 : "Relevant examples are ... desert-dust and sea-spray aerosol" : maybe add "emission changes".

GENERAL : line 48-62 : This paragraph is presenting quite some ideas : ESMs, their differences, MIPs, ensembles, ... I think most of the ideas mentioned here have their place, but it should be written in a more logical and coherent way.

- line 48-49 : Understanding and quantification ... are "assessed" : that is a strange expression. I would rather use "obtained".

- line 49 : "typically" : sounds not very nice

- line 50 : "Modern" ESMs → "Current" ESMs

- line 50 : in their "design" : I would see "design" choices as high level decisions, and implementation as low-level realizations of those. For me "design" remains a strange term to use in this context.

- line 50-51 : "Modern ESMs vary in their design ... and boundary data." : the examples listed seem to refer mainly to how things are implemented at low-level, except for "concerning different parameterization schemes", which seems rather vague and could maybe fall under "complexity".

- line 53-54 : "can simulate aerosol and their precursor emissions, and transport and deposition of aerosols." What about aerosol growth and coagulation? Maybe use a general term describing that aerosol undergoes various processes in the atmosphere.

- line 55 : formation of cloud droplets and "ice" → and "ice crystals"

- line 55 : "or just part of it" : not so nice

- line 55 : "radiation" transfer → "radiative" transfer (both are used in the text; maybe choose one)

- line 55 : regularly produces : not so nice

- line 56 : "However" : I would skip it. Maybe I would build up the reasoning differently in this sentence.

- line 58 : "Ensembles of different ESM experimental setups following the same protocol ..." : this is vague

- line 62-63 : The most prominent example is the experimental "protocols" : there is an issue with singular/plural I would think. I also think that a MIP is not the same as a protocol. Finally, I would not say that the "protocol" has "informed" the "assessment reports".

2 SCIENTIFIC ADVANCEMENT

2.1 MIP'S KEY RESULTS

GENERAL : line 83-96 : I am not so happy with how this paragraph is written (the rest of this section is ok)

- line 84 : "considering structural differences" : is this the main purpose of the MIPs?

- line 88-91 : this sentence does not read very well

- line 92 : CMIP-class models : strange term

- line 92-93 : "with a certain class of models in mind" (here the reader thinks that there are 3 different ideas); "i.e., CMIP-class models in all three MIPs" (now they seem equal) and specifically AerChemMIP required (now one seems to be different) : this sentence is not very nice

- line 94 : "Taken together" : not nice

- line 95 : number : sounds strange

- line 98 : "irradiance, sulfate, and black carbon aerosols." → "irradiance, and sulfate and black carbon aerosols."

- line 105 : "." should be added at the end of the line

- line 108-109 : ... to estimate the real-world evolution and timing of emission changes ... : if this refers to anthropogenic emissions, then it is a bit strange (timing of emissions is an externally imposed factor). Should one add "natural"?

- line 112 : "(hist)" : should be "(hist)"

- line 115 : where the emissions or concentrations → where "only" the emissions ...

- line 119 : "That is ..." → "It implied ..."

2.2 MIP's CROSS LINKAGES

- line 147 : the magnitude of a perturbation "in" the radiation budget : is "in" or "on" best representing the meaning?

- line 155 : "the parallel use of preindustrial control experiments" : this is a bit confusing. Does it refer to the fact that both MIPs use the same reference simulation? Or that for most analyses two simulations are used together to

derive results? Maybe use "common use".

- line 158-161 : should one make clear that the "double calls" are used for the IRF calculation and the "triple calls" to separate aerosol direct and cloud-mediated effects?
- line 166-169 : these two sentences on AerChemMIP fall within a paragraph mainly on RFMIP. Even if these two sentences have their place here, they refer to the first sentence in the paragraph, not to the sentence they immediately follow on. So the structure might be improved.
- line 167-169 : this is already said on line 128-130. It is allowed to mention things twice, but one should be careful with it.
- line 178 : "(histSST_piX)" → "(histSST-piX)"
- line 183-184 : "... and the specialized communities for aerosols and atmospheric chemistry that do not participate in CMIP." : my impression is that part of the AeroCOM and CCMI community participates/contributes to CMIP via actually RFMIP and AerChemMIP. So I would maybe not formulate it so strongly.
- line 195-196 : "Some key articles based ... deadline." It is unclear what the authors want to stress with this sentence. Now it feels that it stresses that there was little time and some analyses were ready only just in time, whereas it is also possible that the sentence wants to express that there was good collaboration and timing.
- line 197-198 : until a quorum of CMIP7 model output "come" online : "comes".
- line 198 : "online" → "available"

3. CHALLENGES IN THE MIP'S RESEARCH

This first paragraph is ok, but there is a lot of repetition of the same words such as "model diversity" and "model differences". I think this paragraph can be improved.

- line 202-205 : I assume that I understand what the authors want to express - however it is not very clear. Is the line of thought : When a difference in climate response to emissions is observed between models, one cannot say whether it is due to : (i) same emissions give difference in radiative forcing; (ii) same radiative forcings give different response; or (iii) same climate perturbation gives different feedback. Or does one rather want to express that spreads in the radiative forcing (for same emissions), and spreads in the response (for same forcing), cannot just be combined independently?
- line 211 : "elsewhere" (general) "... in the AeroCom community" (specific) : there seems to be a contradiction between "elsewhere" (which sounds general), and the rather specific mentioning of "AeroCom" at the end. I would write : "(in the Aerocom community) (Stier et al., 2013)"
- line 213 : "model-to-model diversity" : whereas on line 207, 208, and 210 "model diversity"

3.1 COMPUTATIONAL CAPACITY ABYSS

GENERAL : This section is not very nice to read. It is also reasonably long (4 pages is a considerable part of the manuscript). I list here detailed comments, but the section as a whole should be improved.

- line 231-233 : "Simpler and multi-purpose experiments would be useful and less ..." : This sentence falls a little bit out of context. So maybe start with "Also ..." or "In addition to making Tiers, ...".
- line 232-233 : "as long as they facilitate answering the science questions laid out by the MIPs." : I don't know whether this has to be mentioned so explicitly. I would think that the reader assumes this.
- line 233-234 : "We propose ..." : I don't know whether this conclusion belongs already here.
- line 235-237 : "Simpler experiments ..." : This sentence is not very nice.
- line 236 : the example seems to suggest that implementing a diagnostic is never a difficult task, although I think it sometimes can be.
- line 237 : "Another example is an experiment design that needs to implement ..." : grammatically not ok. So maybe : "needs the implementation"
- line 240 : "and the associated scientific exploitation" → and "do" the scientific exploitation
- line 241 : "run script" : not so nice language
- line 242 : A rule of thumb ... : the message in this sentence is rather general, and I don't know whether it is useful.
- line 244-245 : "One could say ..." : this is not a nice sentence
- line 244-252 : This part of the text contains a lot of "we"/"our". I would try to limit that.
- line 253 : we "review" → we "reviewed"
- line 253 : of "the" number of experiments → of "a" number of experiments
- line 256 : "Model output to assess differences in forcing and response was, however, more restrictive" : is this expressed correctly?
- line 258 : emission-driven → "SLCF" emission-driven models (to avoid confusion with CO2 emission driven models from C4MIP)
- line 260-261 : in the "works" of the CMIP climate forcing task team → "work"

- line 267-268 : with 36 "experiments" → with 36 "models"

GENERAL line 271-275 : This should be improved.

- line 272-273 : Modelling centers perform the requested experiments "with the ESM which they support." : should this be mentioned explicitly? Isn't this assumed automatically?
- line 273 : They "contribute to the decision" ... : sounds strange. Isn't it that they actually decide?
- line 273 : "of" the ESM → "with" the ESM
- line 274-275 : "Not all ... giving modelers room to make their own choices." This seems to be a slightly different topic than the sentences around.
- line 275-276 : "Taken together, there are inevitable tradeoffs in the final experiment design." Not nice, very general.

GENERAL line 287-309 : This should be improved

- line 287 : "tradeoff" (is already mentioned on line 275)
- line 290 : "priority" : this is a new aspect, which has not been mentioned before. As it falls a little bit out of the suggested framework, it should be mentioned in the beginning or at the end (not in the main part of the reasoning).
- line 297 : "restricts the scope for increasing computing resources" → limits the attribution of computing resources
- line 300 : "by" a certain degree → "to" a certain degree
- line 300-301 : "while retaining sufficient process detail for the scientific problem that is to be studied" : can maybe be skipped.
- line 305-306 : "Similarly, ... is necessary." Why such a strong statement? Why not as in the former sentence : "... possible that are needed to split ..."
- line 306 : "the required ensemble size" : possibly also length of the simulation falls under this category.

- line 310 : "data amount" is a derived product. I would think that the amount of simulated years is the determining factor.

- line 310 : "scientific interest" → "research question"
- line 311 : maybe add at the end of this sentence : "in the current setup/experiment"
- line 314 : "exact precision" → "accuracy"
- line 314-315 : "... depends on the model due to model differences in the internal variability ..." → "... depends on the model's internal variability that induces ..."
- line 318 : in "all" regions → in "some" regions; or move it to the end of the sentence (then it can remain "in all regions")
- line 318-319 : the aerosol radiative effects : BC, OC, sulfate separately? Or together?
- line 322 : "For model responses" : vague
- line 322 : the ensemble sizes and lengths → the ensemble sizes and "simulation" lengths
- line 323-324 : content is very similar to line 326-328
- line 324-326 : very similar to line 310-314
- line 328-330 : "Typically larger data amounts ... from the internal variability." : not a nice sentence

GENERAL line 331-337 : vague, not well written. It should be improved.

GENERAL line 338-358 : vague, not well-written.

- line 341-342 : "emissions, transport, and deposition" : what about "growth" and "coagulation"? Maybe use an expression which covers all the aerosol processing.
- line 349 : "had more participation" : not nice
- line 349-251 : three times "hence" in three lines.
- line 350 : "had a different structural organization with formal experiment protocols." This sounds strange. Might the following be better : "had different structural organizations of their experimental protocols."?
- line 351 : "dynamic" in the MIP life cycle : "flexible"?
- line 352-354 : gives the impression that the emission-driven setup was the preferred one (mentioned first and using the expression "had the capability"), whereas it was the prescribed concentration setup which actually was the preferred one.
- line 354-357 : should be improved
- line 357-358 : very general sentence

3.2 PROCESS UNDERSTANDING ABYSS

- line 363 : "Moreover" : Why adding "moreover"?

- line 366 : ... for all aspects. : this is vague.
- line 366 : "Clouds and circulation are for instance outstanding challenges" : maybe add "Correctly representing ..." or "Understanding ...".
- line 368-372 : "There is value ..." : not a nice sentence. Maybe just start with "Multi-model inter-comparisons shed light on ...".
- line 371 : which model "output" they → which model they
- line 372 : since not all "experiments" → since not all "models"
- line 372 : "e.g., some models might miss processes and interactions that might be crucial to address the research question." Isn't this already mentioned earlier?
- line 373 : "Results of MIPs alone can not fully characterize the uncertainty ..." : Possibly start a new paragraph as this is a new thought.
- line 373-374 : "if it is at all possible" : I don't know if this general thought contributes something to the text.
- line 376 : or "ideally" in synergy : I would skip "ideally"
- line 380 : would allow us to quantify ... → would allow us to "first" quantify
- line 392-394 : Aren't both sentences expressing the same?

GENERAL line 413-447 : not so nice to read. Please improve.

- line 413-414 : "satisfyingly" simulated : not nice
- line 416 : model consensus → "erroneous" model consensus?
- line 419-420 : no ESM in CMIP5 "and" CMIP6 : no ESM in CMIP5 "or" CMIP6
- line 424-425 : "Winds emit" : not nice
- line 427-434 : vague, not nice

4. OPPORTUNITIES

4.1 AUGMENTED ESMS

4.1.1 MACHINE LEARNING WHERE USEFUL

- line 497 : Training emulators require → require(s)
- line 506 : ... remanins. → ... "however" remains.

4.1.2 KILOMETER-SCALE EXPERIMENTS

GENERAL : this section is not very well written. The different thoughts should be ordered better and presented more clearly, and repetition should be avoided.

- line 513 : Representing clouds ... → Representing clouds "correctly" ...
- line 518 : "These meteorological variables" : a little bit unclear what it refers to, but the reader will probably assume "clouds and precipitation".
- line 519 : "their" : also not so clear what it refers to.
- line 522 : "hold the potential for surprises in understanding climate responses" : the reader is left in doubt what to expect from this. So maybe be more specific.
- line 526 : "of a few weeks to years" : "years" (in plural) gives the impression that one can already do reasonably long simulations. Is that correct? Or should one write "weeks to months"?
- line 526-528 : "... in maintaining concentrated emissions, non-linearities in chemistry, and atmospheric transport of pollutants" : my impression is that the first two aspects implicitly assume and express a benefit from high resolution (maintaining strong gradients in concentration, and non-linearities can be resolved), whereas the 3rd aspect misses something, to what the transport improves : e.g., "and fine-scale resolved transport of pollutants"?
- line 531-532 : strange sentence
- line 531-534 : "... can be done." [in first sentence] "Such model experiments have been carried out ..." [second sentence]. That sounds contradictory between the first and second sentence.
- line 534 : "...to answer open questions concerning climate change to provide information for societal needs." Why is this rather general information mentioned here?
- line 528-529 : "... to advance the understanding of climate and air quality interactions." This is very similar to line 535-536 : "... for the understanding of interactions of atmospheric composition and climate change."
- line 536-542 : "For some questions One question that can better be answered ..." : maybe use "Another question ..."
- line 543 : "will not be able to entirely rely on" : this is an understatement I think. With more nuance : "will not be able to mainly rely on"
- line 544 : at a resolution 1 km → at a resolution "of" 1 km
- line 547 : "The first possible and computationally smart way" → "The first possible way"

- line 553 : our near-future "works" → our near-future "work"
- line 557-558 : "... UKESM2 and CESM aim also An ensemble of regional composition-climate models exists ..."
: I would not call a group of two models already an ensemble.
- line 557-562 : ... in "our" past MIPs. / As such "our" need for experiments ... / ... although "we" are not averse to the idea ... : I would avoid using too often "we" or "our".

4.2 IMPROVED DIAGNOSTICS AND ANALYSIS

4.2.1 RADIATIVE FORCING CALCULATIONS

- line 592-594 : "Differently from RFMIP, AerChemMIP found ... before calculating the ERF". This is already mentioned earlier, please indicate that.

4.2.2 SYNERGY WITH IMPACT ASSESSMENTS

- line 629 : "the opportunity" → "an opportunity"
- line 634 ; "... a smaller model spread in O3". (too general) Shouldn't it be "... in tropospheric O3 burden."?

5. CONCLUSIONS

- line 657 : "(ESM)" → "(ESMs)" (as on line 49)
- line 669-671 : this sentence is grammatically a bit unbalanced : "(i) to speed up and improve ..., (ii) to data mining ..., and (iii) to develop" Maybe add a verb to "(ii) to data mining" : "to do data mining".
- line 674 : or many ensemble members → or "sufficiently" many ensemble members
- line 681 : closer collaborations with computer "science" → with computer "scientists"
- line 686 : "a" international vibrant community → "an"
- line 689-690 : The planning of ... and ... "are" currently → "is"
- line 690-693 : sentence sounds a bit strange

FIGURES

Figure 1 : The drawing of the arrows should be improved : no intermediate arrows. Possibly the authors can modify the figure to even better represent the perturbation-response paradigm.

Figure 3 : Frederiksen et al. [2021] : not in reference list. Possibly homogenize references with the main text (adding ", " before year).

TABLES

Table 1, caption : explain "X" (as it was done in the main text); maybe explain piClim-2xEms (maybe refer to them also as piClim-2xX, but explain what it means).

Table 2, 3rd column : "little" change in aerosol forcing between 1970s and 2000s → "Little" change ...

Table 2, 4th column : O'Connor et al. (2021);" O'Connor et al. (2022) → ", "

Table 3, 4th column : The numbers on the 3 lines containing "Total number coupled experiments", "Total number histSST experiments", and "Total piClim experiments" possibly do not make a lot of sense. I assume that they are obtained by summing the individual numbers, whereas the number of studies using at least one of the experiments is probably slightly lower.

Table 4 : and their role for climate "changes" → "change"

Table 4 : Aerosol absorption substantially "differ" across ESMs → "differs"

Table 6 : Improved diagnostic for "O3" → "3" in O3 should be a subscript.