

Interactive comment on “The effect of high dust amount on the surface temperature during the Last Glacial Maximum: A modelling study using MIROC-ESM” by Rumi Ohgaito et al.

Anonymous Referee #1

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Ohgaito et al., present a comprehensive set of simulations with atmosphere-only and coupled GCM simulations of the last glacial maximum dust cycle. They include glaciogenic dust, dust-cloud interactions and dust-cryosphere interactions. Their study is thorough and potentially the most complete analysis of this problem to date and provides fundamental new insight into the role of aerosols in LGM climate. This would be extremely useful for upcoming PMIP/CMIP5 analyses. The results are interesting and thought provoking, especially as they seem to partly contradict the basic premise that more dust enhances cooling.

General comments

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Overall, I didn't find this work is placed very well in the context of past studies. How does the dust-cloud scheme used differ from Takemura et al 2009, and Sagoo et al 2017? How comparable is the snow-ageing scheme to Krinner et al 2006, or Ganopolski et al, 2010? Please re-write the introduction to better place the current work in the context of past studies. What is different (or the same) as past work? What do you hope to find? What are main uncertainties etc?

The manuscript has insufficient detail on the methods used, especially on how glaciogenic dust was included. Did you tune the fluxes to the LGM dust observations somehow?

How well does your snow ageing model agree with other schemes (e.g Warren Wiscombe, 1980). Are your LGM results comparable with e.g. Krinner et al 2006?

You do not include any discussion of potential uncertainties, which would seem to be quite large, especially for dust-cloud interactions. Perhaps summarise the approach in SPRINTARS compared to other models (e.g. Komurcu et al., 2014). Are your dust-cloud effects in agreement with those presented for e.g. 'high dust' by Sagoo et al 2017? If not, could you speculate as to why.

Please also could you explain why the dust-cloud effects are so important in the southern hemisphere, but not in the northern hemisphere, and also why the reverse is true for the snow-ageing. Could you expand figure 9 to compare the radiative perturbations from the 3 separate effects of dust that you have studied.

Hence, I would recommend major revisions to the text before publication.

Specific comments

Page 3, lines 3 to page 4 line 2. This whole section could be summarised more succinctly for the reader. What is the main message from all previous work? What were the main steps? I would say, most studies simulate a cooling effect, but it is variable and that the introduction of (i) vegetation feedback (Mahowald et al 1999), and (ii) glacio-

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genic sources (Mahowald et al 2006) and (iii) dust-cloud interactions (Takemura et al 2009, Sagoo et al 2017) are the main developments.

Page 4: Lines 3-11. I find it incomplete here to only list the inclusion of the ocean. You should also mention the dust-cloud interactions and the dust on snow effects and the inclusion of glaciogenic sources in this study.

Page 5: lines 3-4: Did you reduce the imaginary part of the dust refractive index as done by Takemura et al 2009 (their page 3063)?

Page 6: Lines 5-6. More detail of the glaciogenic model setup is required. Did you optimise the fluxes from the emissions using the ice-core data, or marine data or both? What simulations did you use to calculate this? Or did you simply scale emissions in these regions to match the emissions simulated by Mahowald et al 2006?

Page 9: lines 13-16: Isn't it more likely that this small 1 degree shift, is showing that the effect is small over North America? Your argument seems to be that a much higher resolution model would be more sensitive, but I can't see why this should necessarily be the case? Perhaps I have misunderstood.

Figure 8: Can I suggest you separate this plot out into several panels for clarity?

Figure 9: It would be nice to compare the dust-radiation, dust-cloud and dust-cryosphere effects somehow?

Table 2: Takemura et al 2009 quote -0.9 Wm^{-2} for the net dust-cloud effect at the LGM relative to the PI, but your LGM.a -PI.a difference is only -0.36 Wm^{-2} . Could you comment on the differences with that older study?

Technical comments

Abstract Line 23: "for a first trial": I think you are referring to coupling with the ocean? It might make more sense to say "for testing the dust feedbacks in a fully coupled GCM for the first time" or similar?

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Abstract Line 25: Perhaps change "interaction" to "coupling"?

Page 2 line 17: "Although mineral dust aerosol is not the most significant cause of warming, its effect is not negligible because it is the most abundant aerosol." This makes it sound like mineral dust might have contributed to recent warming. Suggest to rephrase as "Mineral dust is the most abundant natural aerosol today."

Page 3 Line 13: "where supposed to generate substantial amount of moraine debris during glacial periods" Change "where" to "were". Perhaps include some of the primary references on this topic.

Page 4: Line 4: "The feedback of the aerosol to the ocean and sea ice and back to the atmosphere was not taken into account". Technically, in a slab ocean model the sea-ice can respond, only the oceanic circulation is fixed.

Page 4: Line 19: So the vegetation is not fully dynamic?

Page 5 Line 6: "that control" not "correlated to the"

Also, do these variables also control the glaciogenic dust flux?

Page 6 line 10: "The emission area is also consistent between the experiments, with little deviation following the land-sea mask of MIROC-ESM" Sorry, I don't follow this.

Page 7, line1: Is it really drier over the Sahara? I would be less surprised if it was stronger winds?

Page 7: line 3: "is probably because of the increased soil moisture, resulting in an enhancement of precipitation" Shouldn't this be "resulting from"?

Page 7 line 21: change "location" to "source".

Page 8 line 10: "It represents the total effect of the glaciogenic dust on radiation towards the earth surface" Do you mean dust-radiation plus dust-cloud plus dust-cryosphere interactions?

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Page 8 line 19: Repeated sentence.

Page 9 line 7: Refer to figure 6 here.

Page 9: 18-19: Please can you briefly summarise what these are?

Page 10 line 16: i.e. it contributes to atmospheric heating.

Page 13 line 12: "draught" should be "drought".

Page 15 line 15-16: How strong is this snow bias in MIROC-ESM? Might be worth shoing

Figure 8: This caption doesn't completely make sense to me: "Green line denotes LGMglac.naging.a-LGM.naging.a, which means the change arose from non-aging effect of snow albedo." Does this mean that the snow albedo is affected by dust but not by ageing?

Also change "Shades" to "Shading".

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