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Comment on egusphere-2022-718

Anonymous Referee #1

Referee comment on "A modern-day Mars climate in the Met Office Unified Model: dry simulations" by Danny McCulloch et al., EGUsphere,
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This manuscript provides an introduction to the modern Mars version of the Met Office United Model (UM). The paper describes the foundational adjustments that were made to the model to adapt it to modern Mars and then evaluates its performance relative to the LMD Mars Planetary Climate Model (PCM) and compares UM simulations with (RA) and without (RI) radiatively active dust. The model is still in development and currently lacks CO2 and H2O cycles. The model broadly reproduces the martian dust cycle and annual thermal and dynamical conditions. It will be useful to the scientific community to have another Mars GCM, but with terrestrial-derived physical parameterizations to help better understand the physics of the martian climate. I recommend the manuscript for publication after a moderate revision.

General comments:

- Substantially more discussion is needed regarding several aspects of the modeled dust particles and dust cycle in general.
  - First, only a single sentence is used to describe the dust optical properties used. Based on the reference, I assume this implies that a terrestrial dust composition and optical properties are used. But that reference also refers to other references with those details. The authors should summarize the relevant information in the text and also compare and contrast that with known properties of martian dust (chemistry, optical properties, albedo, etc.). Additionally, discuss how these differences could impact the simulated climate.
  - Second, how is dust lifted in the model? It seems (based on a few sentences throughout the text) that the model only lifts dust through wind stress-driven saltation. Is that correct? Observations have shown that dust devils likely supply

~50% of dust into the atmosphere, so it should be mentioned explicitly if there is no parameterization for dust devils. I have some additional comments below that relate to this.

- Given the paper is focused on the dust cycle and its impact on the climate, I think another figure or two on the modeled dust cycle would be quite helpful. Specifically, a figure showing the globally averaged aerosol optical depth as a function of season for RA and RI simulations, perhaps with the PCM overplotted, and a second figure identifying model grid points favored for dust lifting and deposition. See Gebhardt et al. (2019) for similar figures: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019JE006253. I think such figures could replace Figures 1 and 2 if desired.
- I don't think Figures 6-9 are structured in the most effective manner. The difference plot in the center is intuitively for the differences between the left and right columns, but that isn't the case here. And differences between the RA simulation and the PCM are discussed in the text, which leaves the reader having to mentally try and create such a difference plot. I don't think the authors need to double the number of plots necessarily (one set comparing RA and RI, another comparing RA and PCM), but I do think the visual comparison between RA and RI and RA and PCM should be separated.

Specific comments:

Line 98: Are spectral files for the ancient Sun (3.8gya) being used here?? Or is that just a typo?

Table 1: Maybe change the title from 'orbital parameters' to 'physical constants' or something else as the gas constant and scale height are mentioned? Additionally, is the scale height prescribed as a constant? How does that work? That value seems high relative to Mars (~11 km).

Section 2.3: There's no mention of surface albedo or thermal inertia here or elsewhere. Are martian values used as boundary conditions? Something else?

Line 155: Is an effective dust radius of 3um assumed as it was in Madeleine et al. (2011)? Some other value? Specify it here.

Line 167: Does it really take 40 years to reach steady state? Why so long, especially without H2O or CO2 cycles?

Line 221: "meaned" reads oddly to me. "Averaged"?

Line 237: should "to" be "in" here?

Lines 239-240: it looks like 1-2 m/s and 1 K differences to my eyes?

Line 251: "in each month" should be "in this month"?

Line 252: This difference perhaps could be somewhat ameliorated by tuning the dust cycle, however? Was any tuning done to the dust cycle? This goes back to general

comment #1. Lifting efficiency factors, etc., are typical tuning parameters for Mars GCMs.

Line 256: “reverse” should be “reverses”

Figure 7 caption: specify that negative values indicate southward winds.

Section 4.2. titles: include Ls range with each month title (e.g., “Month 9: Ls 270-300°”).

Line 314: “RI” here should be “RA”

Figure 9: I appreciate the reason to use different color bar scales for RA and PCM here, but it’s still quite confusing by eye when the RA plots have deeper red colors. Can the color bars be adjusted to help the reader visually intuit that RA often has less dust? Additionally, percent difference (as is used in the text) might be more intuitive for the difference plot in the center in this case.

Section 4.2.3 and Figure 9: One consistent difference (at least for months 6-12) between RA and RI seems to be that RA lifts dust farther south than RI? Is that correct? Is that a feedback effect between radiatively active dust and the Hadley circulation perhaps? This

may be worth some discussion in the text.

Line 322: I'm confused by the sentence beginning with "The high vertical uplifting…". This sentence makes it sound like the UM has a "rocket dust storm" parameterization, which I don't think is true. So what is really meant by "high vertical uplifting"? What physical mechanism is bringing higher dust mixing ratios to high heights in UM-RA? Months 6 and 9 seem to natively produce a high altitude dust layer (Heavens et al., 2011; Guzewich et al., 2013), which I think would be quite novel for a free-running dust simulation! More discussion is needed here.

Section 4.2.3: calling back to my general comment #2, does dust opacity peak in month 9 in UM-RA and UM-RI? That is the typical pattern for free-running dust simulations in Mars GCMs, but the real Mars often has a "solstitical pause" in activity near southern summer solstice outside of years with solstitical global dust storms. I imagine PCM reflects this since it uses the Montabone dust climatology.

Line 347: The sentence beginning with "Dust abundance is higher…" is essentially repeated in the next paragraph. Similarly, saying a simulation is "higher" by a negative number is confusing.

Line 378: "Once again there is a difference…" of zero?

Line 380: Missing "Fig."

Line 381: specify this difference is only in RA and RI, not in PCM simulations

Section 4.3.3: Dust devils aren't mentioned at all! The most likely reason for this disparity, in my opinion, is that UM doesn't have a dust devil parameterization. Wind stress lifting is very low during the early portion of the year, while real Mars (and hence the PCM) maintains a background dust haze through dust devils. Kahre et al. (2017) and references therein discuss this in detail.

Line 471: typo "whata"