

**Review of “Evaluating the Impact of Enhanced Horizontal Resolution over the Antarctic Domain Using a Variable-Resolution Earth Systems Model” by R. T. Datta et al., submitted to *The Cryosphere***

**General comments**

The manuscript presents a systematic evaluation of the impact of using a high-resolution nest over the Antarctic within the CESM variable resolution (VR) system. The authors find that there is a general improvement associated with increasing the resolution over Antarctica when compared with AMIP and against other observational datasets. They note that the VR configuration represents a compromise between RCMs (which can fail to capture the influence of the global climate) and high-res GCMs that are often impractical to run.

It is very well presented, with suitable figures, tables and supplementary materials. The text is logically structured and contains sound arguments. The use of VR modelling is a growing area of research and will as such be of interest to readers in the cryospheric climate sciences. Although the manuscript is particularly focused on the evaluation of VR-CESM2, some of the findings may be relevant to researchers beyond the CESM2 community. While it does not introduce new concepts or results, the manuscript is a useful benchmark and an important contribution to the community.

I recommend the paper be accepted, subject to minor revisions. A few minor modifications and clarifications in the presentation of the manuscript would improve its usefulness to readers, and I have detailed these below.

**Specific comments**

**Main text**

Have you tested different VR nests? e.g. 0.1 deg or better? And is it technically possible to nest multiple VR domains within the larger global domain, for example to explore the impact of better resolution on precip and SMB over regions of interest with steep coastlines (Antarctic Peninsula, Amundsen Sea Embayment etc)? Can you speculate about the degree of improvement in the simulation relative to the resolution of the nest?

The abstract is quite long. While not necessarily an issue, the authors *may* wish to consider making it more concise.

L14-15 I would argue that some of the coupling is captured. Suggest you qualify the statement with a word like “fully”

L126 at first glance and to the casual reader it could look from equations 2 and 3 that rainfall enters and leaves the system with minimal effect (also, is there a reason you use ‘rain’ and then ‘rainfall’?). It may be worth briefly noting somewhere that rain can percolate into the snowpack and refreeze/be retained.

L148 wind speed differences from what? AWSs were not different from each other or the AWSs were not different from ERA5 / ANTSI? Clarification would be helpful here.

Section 3.1 – the heading is the same as for section 2.2. I imagine this should be something like ‘surface mass balance’

L165-167. How does ANTSI SMB compare to the models evaluated in Mottram et al? It would be good to see where it fits into that range too.

L172-173 Suggest you expand on this last point for clarity, e.g. split into two sentences: "...but not for the Antarctic Peninsula (xxx). // The higher SMB over the Antarctic Peninsula is a result of the enhanced SMB over the grounded ice sheet (xxx)."

Table 1 Do you define these acronyms (E. Ant etc.) anywhere? Apologies if I've missed them, but worth defining in the caption if not.

Fig 2 Pedantic, but you've used the notation 'GT yr<sup>-1</sup>' in the text, and 'GT / yr' on the axis labels. Suggest using just one.

L174 – 180 It kind of looks from Fig 2 like the AMIP/ANTSI SMB estimates converge over time for the East Antarctic grounded ice sheet and diverge over time for ice shelves. The latter is consistent with the negative ANTSI trend vs none for AMIP, as you note at L179. Any ideas why that might be?

L187 "discussed in results" is a bit vague... could you be more specific?

Second half of Fig 3 caption, from L644-646. I get what you're saying here – that panels c and d compare the performance of ANTSI to the Medley reconstruction and RACMO, taking AMIP as the baseline. But I struggled a bit with the wording. Is there a way you can rephrase to make it a little clearer?

e.g. something like "Panels (c) and (d) show ANTSI SMB bias relative to AMIP compared with the Medley Reconstruction and RACMO2.3, respectively, with green and purple indicating reduced/increased bias in ANTSI relative to the dataset compared against?"

L195-198 I'm finding this sentence hard to get my head around. I wonder if it would be clearer to talk about higher and lower biases rather than 'agreement', as I struggle to figure out from this sentence how the three datasets (AMIP, ANTSI, RACMO) relate to one another. Unless I've misunderstood and you're talking about how much RACMO and ANTSI dis/agree with each other??

Figure 5 caption – it would be helpful to simply state that negative values/blue colours mean that AMIP biases are larger than ANTSI and that positive values/red colours mean that ANTSI biases are larger than AMIP compared to QSCAT (I hope I've got that the right way around!)

Figure 6 –

- 1) what do grey colours mean?
- 2) Please define the acronyms in the figure labels (e.g. "relative change (%) in large-scale precipitation ('LS precip') and integrated meridional water vapor transport ('IVT')...")

L230 It might help the reader to briefly expand on why having a smaller time step impacts microphysics and hence precipitation totals.

Figure 7 –

- 1) y axes of panels a) and b) are labelled 'mmwe' – presumably this should be 'g m<sup>-2</sup>' or similar?
- 2) Again, would be helpful to state what the grey colours mean on panels e) and f)
- 3) L662-663 – it might be clearer to just say "relative difference between ANTSI and AMIP total cloud liquid water path..." (same applies to the phrasing about diffs between ANTSI/ERA5)

L263-264 “(though the latter is a product of the specific microphysical scheme)” – I think you need to clarify here, because it sounds like you’re saying it’s only a model thing. The impacts on cloud cover are also potentially seen in the real world, in which case I suggest something like “(though the latter is a product of the specific microphysical conditions)” – or you can limit it to model-world by qualifying the statement, e.g. “(though in the model the latter is a product of the specific microphysical scheme)”

L271 it isn’t immediately clear that the  $1.59 \pm 1.13^\circ\text{C}$  refers to winter biases. Suggest rewording: “...winter biases, which average  $1.59 \pm 1.13^\circ\text{C}$ ...”

Figure 9 caption – “comparing” is in the second sentence twice. Suggest removing the first.

Figure 10 – again worth noting what the grey colours mean (or just do it once and then say ‘as in fig x...’)

L332 – In a sentence or two, can you briefly summarise the key highlights of the comparison with ERA5?

L340-342 It’s not clear what the positive and negative biases refer to – presumably these refer to sensible heat biases when the flux is positive and negative (?). Please note this explicitly (the same applies later, although once you’ve stated it once I think that should suffice).

L354 It would be helpful to clarify that you mean positive LW biases.

L355-356 I understand from what you’re saying that LWP is not the only driver of LWdown. Might it be worth stating this more directly? i.e. something like “... and other factors also influence LWd” ?

L367-370 Splitting this sentence into two would help its readability. Suggest splitting after the Weddell Sea bit, eg.: “the Weddell Sea sector (nearly  $15 \text{ W m}^{-2}$  in some regions). The latter is consistent with cloud clearing...”

Second para pp 13 - Can you comment on the source of the increased LWP (and hence LW/SW) bias over the Southern Ocean in ANTSI? How does it compare to cloud + SEB biases in other models? As you say, the IWP bias has been reduced over this region, while as far as I understand in many models it is the over-enthusiastic production of ice at the expense of liquid by the microphysics (i.e. the vapour deposition & the Wegener-Bergeron-Findeisen process) that causes the Southern Ocean bias. How much of a role does the microphysics and/or large-scale cloud scheme have in driving this?

Second para pp 14 – I think it’s worth noting / emphasising that VR ESMs like this are not going to be used for the same purposes as RCMs. The strengths of a VR ESM are to simulate the coupled response of the climate and the interactions between various elements over the long-term, e.g. for sea level rise / large-scale climate factors like precip/temp and how that relates to (S)MB. RCMs are don’t have the same level of interactivity or capacity to perform extremely long simulations easily.

How much tuning is done? And does the relatively smaller improvement compared with those in Greenland reflect this?

## Supplement

Table S1 – the surface melt values are given in mmwe but the trends are shown in GT/yr/yr.

Fig S3 – Water paths in mmwe?

Table S2 “near surface” → “near-surface”

Fig S4 “near-surface-temperature” → “near-surface temperature” (for consistency). Colourbar for the top row is very small and half of the ‘d’ in ‘wind speed’ is cut off. Rogue vorticity symbol (?) above the (n) label. As with other figures, note what the grey colours indicate. Also need to be consistent in labelling of “near-surface” for wind and temperature.

Fig S5 labels on panels (j) and (f) have been cut off. Top colourbar is again too small to read. As above, need to be consistent in labelling of “near-surface” for wind and temperature.

Fig S6 “directed at” → “directed towards”?

Fig S8 see other comments re grey areas

### Technical corrections

L54 “Variable-resolution(VR) grids” → “Variable-resolution (VR) grids” (space in the wrong place)

L98 Feel like this is missing a few words, what about e.g. “while a nominal 1° (standard) grid is used in the exterior”

L117 “dycore” → “core”

L137 “drifting snow scheme” ?

L172 “but not for the Antarctic Peninsula”

L179 “an positive trend” → “a positive trend”

L213 “in” → “on” some ice shelves?

L242 extra space between “within the” and “75S”

L260 extra space before “. Cloud properties”

L295 extra space between “thus generating”

L303 extra space between “improved , ”

L324 space missing between “longwave radiation,(LWdown...)”

L327 double full stop after “coherent”.

L363 extra space between ‘W m-2’ and ‘over’

L364 “LWdown” → “LW<sub>down</sub>” (also L367)

L368 “the East Antarctica” → “the East Antarctic” / “East Antarctica”

L375 missing an “and” after the brackets?

L376 “standard” → “standard deviation”

L411 typo in “also”