General comments

This study takes an in-depth look at how kilometer scale regional climate models (RCMs) resolve the interactions between atmospheric rivers (ARs) and complex topography in a couple case studies centered around the Amundsen Sea Embayment. Their most consequential results indicate that the boost in resolution in these three RCMS (MetUM, Polar-WRF, and HCLIM) leads to the resolution of non-trivial rainfall quantities over the Thwaites and Pine Island ice shelves, especially during the summer AR event. The ERA5, normally considered the gold standard for Antarctic precipitation studies, is unable to depict the rainfall quantities from these AR events. The final experiment of using the MetUM shows that even model resolutions considering high (12 km) are too coarse to simulate topographically influenced rainfall on the Antarctic coastline.
The authors make a great effort using SNOWPACK to calibrate the ground observations for a better comparison with the RCMs and ERA5 instead of just comparing the models directly with the station observations. Despite the consideration, there remains a great deal of uncertainty in validating the performance of the RCMs and ERA5 at this high resolution where the authors meticulously highlight the potential shortcomings of studying this remote region. Other efforts like incorporating IMERG rainfall data and the discussing its shortcomings emphasize the level of detail that went into this study. From my perspective, all the most relevant research was cited and is usefully employed to place the results in context with the existing literature. I believe this study conveys the potential unrealized threat of heavy rainfall on Antarctic coastlines and the need for advanced modeling and observations to further realize this problem. I've made specific and technical comments below thar hopefully help the authors clarify a few details, but I believe this manuscript will be an important contribution to the field after some minor revisions.

-Jonathan Wille

Specific comments

Line 23-25: Can you specify that you used the MetUM for the resolution experiment here?

Line 33-34: Can you elaborate on this mass loss from ice shelves? Like are the ice shelves themselves shrinking in mass or is something else happening? Also please include a reference for Smith et al. (2020)

Line 39: The wording is a bit confusing here. If accumulation is not compensating for SMB losses on the ice shelves, then perhaps instead of saying "constrain", try "… but snowfall still modulates (or controls) the timing and characteristics of ice shelf collapse, or recession and thinning"

Line 70-80: This rainfall paragraph is well-written but it could be beneficial to cite (Vignon et al., 2021) which characterized rainfall patterns around Antarctica (i.e. it happens more often than you'd expect) and uses GCMs to show increased rainfall in the future.

Line 158: Can you state how deep convection is treated in the HCLIM? This is described for the other models so it would be good to know here as well.

Section 2.3: Since this becomes relevant later in the results, can you describe the topography surrounding the stations so that the reader can get a feeling for how orographic lifting might behave here? Also it might be important to state any potential snow measurement issues at these stations like blowing snow?

Section 2.4: Is this method of diagnosing snowfall using SNOWPACK sensitive to blowing snow related errors or would it actually reduce the impacts of blowing snow?

Section 3.1: It would be helpful if you gave more details on the temporal evolution of both case studies. Like providing dates for the AR landfalls. Also at the risk of self-advertising, it could also be helpful to state that these events were detected AR events from the Wille et al. (2021) detection algorithm (I already verified this).

Section S2.1: It was instructive to see IMERG data being applied for this study even if it just highlights the unreliability of IMERG data over Antarctica. Does the IMERG data used in this study have a quality control variable that can be used to mask out unreliable data? From personal experience, I know the IMERG Final Run has this variable. If this is something you didn't consider, I wouldn't recommend rerunning your analysis of the IMERG data, but perhaps just mentioning that the quality control wasn't implemented since this isn't an important aspect of the study.

Figure 2: Can you add date labels to the two panels in this figure?

Line 285: From the sentences that follow, this seems dependent on which station you are describing. Like you say the RCM estimates at Channel are quite accurate in the next sentence.

Line 299-300: Careful with the terminology here. The way this sentence is structured, it sounds like you are making a general statement about RCM performance during the winter and summer. When addressing your case studies, perhaps it is more intuitive to say, “winter event” and “summer event”.

Lines 364-372: I suggest reorganizing this paragraph so that you discuss all the summer event results first and then finish with the couple results on the winter event rainfall or the other way around.

Line 432-433: Perhaps rephrase to “which may indicate that in the most extreme AR conditions during winter, liquid precipitation can still occur”. It’s not very surprising it rains during summer AR events, but the winter rain is more impressive.

Figure 5: Can you add date ranges to the figure caption?

Figure 6: Similar comment as before, please mention which date the transects are from.

Figure 7: Same as previous comment.

Figure 8: Same, a date range would be helpful in the caption

Section 3.4: This section does an excellent job at covering many different facets of rainfall behavior during the two AR events. There are some details about the influence of the foehn wind on increasing temperatures and altering the precipitation patterns, but it would be helpful to see an organized paragraph discussing the timing of the foehn relative to the rainfall and whether the foehn leads to enhanced sublimation of precipitation. In its current form, it appears the foehn helps warm the surface allowing more rainfall to happen even though one would expect greater sublimation. Are there differences between the RCMs in how they resolve the timing of the foehn and magnitude of sublimation?

Line 473-475: These sentences could be shortened and combined for simplicity. Like “… indicate the maximum height of the 0 C isotherm which can be considered the melt layer”. It’s obvious that below the melt layer, precipitation would fall as rain or sublimate.

Line 484: Do you mean sublimation instead of evaporation?

Lines 544-547: I feel like this message about “the difficulty of verifying rainfall but that the RCMs are simulating it” is repeated a few times already like in lines 401-404 and 431-433. Especially here this message doesn’t need to be repeated but do keep the interesting discussion on liquid precipitation at low temperatures.

Lines 558-559: It might be worth mentioning that ARs are shifting poleward along with the general storm track (Chemke, 2022).

Technical corrections

Line 68: “the precipitation phase” or “precipitation phasing”. Also the Gehring et al. (2022) study is perhaps one of the more closely related studies so it could be worthwhile spending another sentence describing how they found that local foehn winds and orography can completely sublimate the precipitation in some AR cases while AR orientation is crucial for controlling snowfall amounts

Line 114: Don’t forget about the oxford comma.

Line 115: Do you mean the models have 16, 20, and 14 levels in the 1km nest?

Line 187-188: This sentence repeats itself, “Then, the observed snow height is compared to the observed snow height to determine the accumulation terms.”

Figure 3: It could be helpful if you labelled “summer” and “winter” on the figure so that the reader quickly identifies which event is which.

Line 423: “where the terrain beings to slope upwards more strongly” doesn’t sound accurate. How about “where the terrain begins increasingly steepening”?

Line 550: “ARs”

Line 568: “showed”

References:

Chemke, R. (2022). The future poleward shift of Southern Hemisphere summer mid-latitude storm tracks stems from ocean coupling. *Nature Communications*, *13*(1), 1730. https://doi.org/10.1038/s41467-022-29392-4

Vignon, É., Roussel, M.-L., Gorodetskaya, I. V., Genthon, C., & Berne, A. (2021). Present and Future of Rainfall in Antarctica. *Geophysical Research Letters*, *48*(8), e2020GL092281. https://doi.org/10.1029/2020GL092281