

The Cryosphere Discuss., referee comment RC1
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Comment on tc-2022-101

Sanne Veldhuijsen (Referee)

Referee comment on "Climatology and surface impacts of atmospheric rivers on West Antarctica" by Michelle L. Maclennan et al., The Cryosphere Discuss.,
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Review "Climatology and Surface Impacts of Atmospheric Rivers on West Antarctica" by Michelle Maclennan and co-authors.

This manuscript investigates the climatological conditions and the surface impacts of atmospheric rivers (ARs) in West Antarctica. The author first uses reanalysis model output (MERRA-2) in combination with an AR detection tool to examine the contribution of ARs in this region from 1980 to 2020. Then for a more detailed and smaller scale perspective the authors present a case study of three successive ARs on Thwaites Glacier in February 2020, for which they use reanalysis data, in-situ measurements and a firn model. Finally, the authors discuss how ARs may change in a future climate.

The manuscript is well written with clear figures. It is an interesting and relevant study within the scope of TC. The idea and methods are not completely new, it builds on existing knowledge from ARs in Antarctica and previous firn modeling efforts. By combining large scale model output and in-situ measurements, the results are a useful contribution for understanding the climatology and impacts of atmospheric rivers in West Antarctica. Despite being a topic of interest, there are some minor aspects especially regarding the contribution/purpose, goals stated in introduction, methodology and results that might be better represented. I elaborate on this in the comments below, which follow the order of the manuscript.

General comments/questions:

- Contribution/purpose of this study: an elaborate introduction about AIS mass balance and atmospheric rivers is given. However, the articulation of the purpose and contribution of this study in the introduction can be improved. Articulate more clearly what is new in this study compared to previous work, the added value of this study,

what is already known about ARs this region (What have Wille et al. 2019 & 2021 found about ARs in West-Antarctica, e.g. how many per year/trend)? Also the reason why is chosen for this region (Lines 123-127) would be more suitable for this part of the introduction.

- Contrasting impacts on SMB: In Lines 76-78 you state that ARs have contrasting impacts on SMB, and that it is therefore important to study them from both large-scale climatological perspective and a case study. With contrasting impacts on SMB, I understand that you mean snowfall, melt or temperature? However, the melting (and temperature) part is not studied from the large-scale climatological perspective. Nevertheless, melt could be important on e.g. Abbot ice shelf. I think it would be good to explain in the introduction that and why the focus of the large-scale climatological perspective is on precipitation. This is probably also why you use the vIVT detection algorithm.
- Lines 85-86 "Finally, we discuss the results in the context of how ARs contribute to the present mass balance of the AIS and how their frequency and precipitation may change in future climate scenarios." I don't see where the future frequency and precipitation is discussed in the manuscript? You do discuss a potential increase in melt related to AR events. Perhaps use: "Responses and impacts of atmospheric rivers to climate change by Payne et al. (2020)", and the fact that there is an ongoing increase over time of current AR events, which might continue (Fig. 3a).
- The discussion is strong and very interesting, one thing that might be added is some comparison to previous findings about ARs on the WAIS, which is mentioned above as well. (E.g. Wille et al. 2019 & 2021).
- Lines 373-375: "Limited by 1.5 years of in-situ data." I wonder why you only look at 1 AR family event, while there are multiple AR events each year?

Specific comments/questions:

- Lines 63: Why is this unique for Antarctic ARs? Is this not the same for Greenland ARs?
- Lines 66: They carry much moisture, but does the fact that the AIS is a desert not also play a role in the importance of ARs?
- Line 72: The study of Neff et al 2014 is about Greenland.
- Line 73: "ARs act to increase Antarctic SMB, as they cause significantly more snowfall than surface melting". Can you give a reference for this statement?
- Lines 81-82: "to provide key insights on in-situ conditions" this can be rephrased. In-situ is often only used to describe the way a measurement is taken, maybe replace by local conditions.
- Line 93: basal channel?
- Section 2.2: Is there a reason why you chose MERRA-2 instead of ERA-5? Perhaps you can add that both reanalysis products give similar results in Wille et al. 2021.
- Line 135: Not over the AIS but over the WAIS.
- Line 153: Actually, you use three different approaches, also the GNSS measurements.
- Section 2.4: I think it can be clarified how the firn modelling works. Perhaps add that snowfall is assumed to occur when measured snow height exceeds the modeled snow height. Strictly speaking, there can also be snowfall when the observed snow height remains stable e.g. if there is snowfall in combination with densification, sublimation or melt. The difference between the observed and modelled snow height is then added to the snowpack, which can be converted with the fresh snow density to accumulation.
- Line 190-191: Perhaps start the results section with one sentence describing the kind of results you are going to show in Figure 2, as an introduction to the reader. Also refer to panels of figures if that is the case, so Figure 2a e.g in Line 193.

- Lines 190-191: the 3.2% in combination with the reference to figure 2 is a bit confusing as I don't see 3.2% in the figure. Also I suggest to first give the definition of frequency of ARs and then discuss the numbers.
- Figure 3: Would it not also be interesting (and possible) to have a third graph with the amount of precipitation from ARs over time?
- Caption Figure 5: I suggest to add that this figure is about Thwaites Eastern Ice Shelf.
- Line 228: The temperature decrease is not only in the winter right?
- Line 228: perhaps omit: "from the mean 24 hrs before landfall to the mean 24 hrs after landfall." as this should already be clear.
- Caption Figure 6: Line 1 omit repetition of "on TG".
- Line 281: Should "different spatial resolution" not be "low spatial resolution"?
- Line 281: Perhaps include in method section 2.4 that you calculate surface melt from the SNOWPACK model.
- Caption Figure 8: Line 2: atmospheric conditions are used "to" force SNOWPACK.
- Line 306: Improve the reference formatting.
- Line 320: From Wille et al. 2021 I understand that 10% of total snowfall comes from AR events. The percentage of extreme precipitation events explained by ARs depend on the threshold but is 10% lower in West Antarctica than East Antarctica (where it is 25-45%).
- Line 356-357: "As surface-based temperature inversions are least developed in austral summer, the baseline surface temperatures before AR events are nearest the melting point in summer." And also because it is simply warmer in summer?