Comments on reviewer #2, the original review is given in black, and author comments in **blue.**

Review of Hofsteenge et al. (2022): The surface energy balance during foehn events at Joyce Glacier, McMurdo Dry Valleys, Antarctica

Overall

This study investigates the foehn and surface energy balance (SEB) over the Joyce Glacier, where receives less attention in the previous research. This paper use SEB model simulations that driven by the AWS observation and AMPS forecast outputs. Authors suggest that SWnet is the dominant driver during the daytime with a continuous contribution from sensible heat flux. Surface sublimation offsets the positive SEB, and reduced albedo further enhances the melting. This paper also highlights the important of solar radiation penetration for the accurate estimation of SEB. This paper includes several novel findings, and the scientific part is solid. A few results will be more convincing with more data or better explanations. The Discussion section might need some reorganizations. Thus, I would suggest a **minor revision** for this paper.

We would like to thank you for taking the time to review this manuscript. We are happy to read your comments and to incorporate the suggestions you made to improve the paper. We describe below in more detail which changes have been made to the manuscript.

General

A. Structure:

The conclusion and discussion part includes lots of interesting and novel findings. I think the reader will appreciate that if it is better organized. Authors first talked about SEB, then back to foehn (which contributes to the increase SWD via foehn clearance, SH via turbulence/downslope wind on the leeside, etc). The comparison between Joyce Glacier and AP is great. However, the connection between each topic is kind of loose.

We agreed that the discussion and conclusion part could be structured better. We have in the revised text chosen to separate it in three sections, highlighting first (Section 5.1) the differences in foehn mechanism in the complex MDV valleys, then (Section 5.2) the steps that have been made in simulating the energy balance of Joyce in relation to previous SEB studies in the MDV, and closing (Section 5.3) with the role of foehn on the SEB & melt of Joyce glacier in comparison with studies for the AP. We hope that this will guide the reader better and helps to highlight the main findings of the paper.

B. Data:

AMPS provides reliable forecast data for operational use. However, it has difficulties simulating the cloud conditions partially due to the microphysical scheme it is using (WSM5). This can lead to cold bias on the surface and compromise its ability to describe the SEB. Has author evaluated AMPS data with reanalysis data like ERA5 (31km) or ERA5 Land (9km)? It is not a serious problem, since this paper mainly analyzes SEB based on the SEB model. The surface variable (2mT, 10m Wind) needs a brief evaluation observation or reanalysis data. Also, can author explain why using a 12-h spin up instead of 24-h (more common)?

Thanks for your comments. As you mention, AMPS output is indeed not used for SEB simulations, but only for evaluation of the foehn detection methods and to describe the larger-scale meteorological setting during foehn events. At the start of section 3.1, AMPS output is compared to local observations. However, we mainly discuss differences in wind direction there and we have added a brief evaluation of Tsfc, RH, and 10m wind against observations in that paragraph, as follows: 'The AMPS 2m temperature shows a strong correlation with observed 2m temperature (0.97 using hourly data and 0.86 for hourly anomalies from the monthly mean to remove the impact of the annual cycle). The 2m temperature has a mean bias of -1C, with a larger negative bias in summer months (down to -3C) and a smaller bias in winter. A lower correlation is found for AMPS relative humidity (0.45), with a mean bias of -5.7\%. AMPS 10m wind speed has a correlation coefficient of 0.5 with observations and mean bias of -1.2 m/s.'

Regarding the 12-h spinup for AMPS. Since the full AMPS output is not available anymore in an online archive, we have used a thinned AMPS product which was saved as the 12-24h forecast hours. We have in the revised text cited a paper (Seefeldt and Cassano, 2012) using AMPS in the same way who provided us with these AMPS products.

The cloud condition is important to back up some conclusions in this paper. I would suggest authors include cloud observation from satellite or simulation from reanalysis data (e.g., MODIS, ERA5, CERES, etc.) to better explain the SEB conditions (e.g., Ln 366).

We believe that one of the strengths of this study is that this is the first SEB study in the MDV that uses 4-component radiometer observations, as was also pointed out as a strength by reviewer 1. The high-quality data of incoming longwave radiation gives us the opportunity to calculate the equivalent longwave cloudiness. Since Lin is used for the SEB model as well, it gives a consistent way to analyse the impact of clouds on the radiation and ablation terms. We believe that this cloud estimation is the most accurate measure of cloudiness to represent the SEB at the AWS at Joyce. We decided not to include satellite and reanalysis data in this study as they are less likely to accurately represent the conditions at Joyce glacier, while they might be of value in studies focussing on the spatial impacts of clouds on the SEB.

Minor:

1. Echoing another reviewer's suggestion. Need more labels for the local topographic features in Fig. 1. Plus, the current labels are also hard to see.

Thank you for your comment, we have adjusted Figure 1 to clarify the valleys/topographic features that are mentioned throughout the paper. We hope this gives the reader more guidance.

2. Terms like foehn warming, isentropic drawdown, internal melting might need some brief description.

Thank you for pointing this out, we added a line explaining foehn the first time its mentioned: 'Foehn winds typically occur through topographic modification of flow in the lee of mountain barriers, resulting in strong and warm winds'. Isentropic drawdown is explained in Section 2.4.3 the first time it is mentioned, as follows: 'Isentropic drawdown is the drawdown of the potentially warmer and drier air from higher elevations when airflow is forced over a mountain range and down the leeward side'. We explained internal melt shortly as follows: 'Subsurface melt in the snow or ice pack (hereafter called internal melt) ... ' .

3. I would suggestion authors use forecast output/forecast for AMPS, and simulation for SEB model outputs.

Thank you, we agree the use of simulation was confusing and we adopted your suggestion to use 'simulation' when referring to SEB model outputs and 'forecast' to refer to AMSP output.

4. Are you able to differentiate the foehn wind with katabatic wind in your study?

The wind events that we detect as foehn events are unlikely to be katabatics as they are associated with cyclone activity and synoptic flow that leads to foehn events rather than air originating from the Antarctic plateau. We have checked the individual pressure fields that compose the composite plot of sea level pressure anomaly during foehn and see that these wind events consistently occur with cyclones over the ross sea and an associated synoptic flow towards the MDV. We have adjusted the structure of the Discussion & Conclusion section and have included more discussion around the katabatic vs foehn origin of these winds here to clarify this point.

Ln 300: Have authors checked the vertical wind profile or calculated the Fr number to confirm the low-level blocking? How strong the blocking is?

We do not have the vertical wind component in the AMPS product that is used in this study, therefore no wind vectors are included in the cross-section plots. We have checked the horizontal winds in these profiles, and they showed reduced windspeeds at the low levels on the windward side of the Royal Society Range, indicating blocking. We have calculated the Froude number from the AMPS fields, which confirms that the low-level flow is blocked. We have extended the description around the flow blocking in the paper with the description of the Froude number, as follows: 'To confirm the blocking flow regime, the Froude number is calculated as Fr = U/Nh, with h being the height of the Royal Society Range (~ 2.5 km), U the average windspeed of the upwind flow until mountain height and N the Brunt Väisälä frequency. We find an average Froude number of 0.2 during foehn and it never exceeds 0.7, indicating that the low-level flow is blocked and the flow cannot ascend over the Royal Society Range, but rather diverts around it.'

Ln 385: Some satellite or reanalysis data can be used here to provide some cloud information, such as cloud cover, phase, height, and thickness. Also, I am curious if there is any cloud formation, where is the moisture source?

We refer to our response to your comment around Ln 366 for our decision to not use satellite or reanalysis data. Figure C1 in the Appendix shows the average diurnal conditions during overcast and clear sky days and indicates that the moisture source is likely from McMurdo sound, evident from the steady sea breeze on overcast days. We do think it is interesting to study further the role of clouds and cloud formation in the MDV, since glacial melt is so strongly radiation driven. However, including this is outside the scope of this current paper.

Ln 425: Does the solar radiation penetration associated with the duration of the clear-sky conditions? Will the accurate description of the changing surface (wet snow, melting pond, refreeze) benefit the estimation of solar radiation penetration?

The solar radiation penetration in the model is wavelength dependent, and parameterized with the zrad parameter, which in practice regulates the fraction of solar radiation that is considered for surface temperature calculation and the part that goes into the subsurface. The solar penetration is dependent as well on the grain radius, which is different for snow and ice. It is therefore mainly important to represent in the model well whether the surface is covered by snow or an ice surface, which is dependent on the precipitation forcing. We have checked if the snow/ice cover is represented accurately by comparing it to the observed albedo and see that the main snow events are captured well in the simulation. We included some more information on the difference between snow/ice cover and the radius used for snow and ice in the methods section, as follows: 'Solar radiation can penetrate to considerable depths when the surface is ice and is reduced when snow-covered. A snow grain radius of 0.2 mm and an ice grain radius of 2.8 mm (based on measurements at Taylor Glacier, Hoffman et al. 2018) are used for the solar radiation penetration routine.'. The representation of liquid water in the snowpack or at the surface is not evaluated as we don't have observations that allow us to do so.

Ln 475: I think whether the downslope wind is able to reach the ice surface is highly associated with the mountain waves on the leeside, stationary orographic gravity, hydraulic jump, or breaking waves? This is not only associated with the magnitude of foehn, but also the detailed mechanism.

Thank you, we think you are right that the strength of foehn warming/drying at the surface is highly linked to the ability of the foehn air to reach the surface, which is in turn linked to the wave activity and occurrence of hydraulic jumps. We have elaborated on this as follows: 'In addition, the strength of the foehn warming and drying at the surface relates to the ability of the foehn air to reach the ice surface, which is likely associated with lee-side wave activity and occurrence of hydraulic jumps.'.

Fig. 5 the wind vector reference is hard to see. Which AMPS domain is used here (02?) at what resolution (15km)? what is the baseline for the anomaly? I would suggest including those info in the caption.

We have clarified the caption of Figure 5, explaining better how the anomaly is calculated and including the resolution and domain of the AMPS fields, as follows: 'The foehn anomaly is calculated as the mean of the AMPS fields during foehn hours at Joyce Glacier minus the mean during hours without foehn.'. The wind vector reference is not placed outside the figure to make it easier to see.

Fig 10&C1. Just a suggestion. Will that be better to use wind barbs to indicate the direction instead of different colors?

In line with the comment of Reviewer 1 that the colormap is not colourblind friendly, we have indicated the wind direction with wind vectors now.