RC1: 'Comment on egusphere-2022-1088', Anonymous Referee #1, 27 Dec 2022

Reviewer comments in **black**
Author response in **green**

General comments

RC1-1: The study provides a detailed look at the energy balance of Icelandic glaciers, with a particular focus on the effect of albedo during LAP events. The authors use an energy balance model and a high-resolution forcing dataset to simulate the melt energy of 6 Icelandic ice caps over the summer. Albedo observations from MODIS were used as model input to decrease the uncertainties associated with this important energy balance variable. The study is generally clear, and the results are described in detail, but could benefit from some minor additions/changes, as outlined below.

Author response RC1-1:

We appreciate the thorough and supportive comments to our manuscript, comments are relevant and will improve the work. Please see our answers and suggested modifications below.

Specific comments

RC1-2: L 2-3: It is a bit misleading to write you "developed" an energy balance model, when you use an already existing the wording to "used" or "applied".

Author response RC1-2: Agreed, changed accordingly to "applied"

RC1-3: L 30-43: this section mostly describes the study area, so consider moving this part to the "Study area" section

Author response RC1-3: This provides an overview of Iceland, climatic boundaries, and drivers of variability. We feel it fits well in the introduction whereas the study area section details in on the glaciers studied in more detail.

RC1-4: L103-108: I would try to stress the novelty of your work more in this section and the reason for your study. As I understand it, the two major novelties are:

a. other studies have investigated the energy balance of Icelandic glaciers, but these normally only focus on one ice cap or glacier. In this study, you provide a larger context on how the energy balance of Icelandic glaciers have changed. You do mention this in your introduction, but I would stress more that this is often not done.

Author response RC1-4a: Agreed – it is important to highlight this better. We add a text addressing this when we address RC1-4b comment, see author response below.

b. You use remote sensing albedo, which removes one of the major uncertainties that have previously persisted in distributed energy balance studies, as albedo is a hugely important factor for the energy balance in Iceland. Particularly that you can include the lower albedo after dust storms and eruptions is a major plus here. I would stress this more as a purpose of the study.

Author response RC1-4b:

Good comment, reviewer 2 had similar comments. We will be modifying L105-108 from:

The primary objective of this study is to understand and quantify melt season SEB for Icelandic glaciers using high-resolution meteorological climate forcing and remotely sensed glacier surface albedo from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. This adds to the previous understanding of spatial and temporal distributions of melt energy, main melt energy sources, and variability within and between glaciers in Iceland and provides insight into the melt enhancement due to volcanic eruptions and years with extensive LAP deposits. It also provides a comprehensive overview of the SEB of Icelandic glaciers since it is not limited to one glacier or glacier outlet.

To:

The primary objective of this study is to understand and quantify melt season SEB for Icelandic glaciers using high-resolution meteorological climate forcing and remotely sensed glacier surface albedo from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. The study builds on processing pipelines for albedo developed in Gunnarsson et al. (2021). This adds to the previous understanding of spatial and temporal distributions of melt energy, main melt energy sources, and variability within and between glaciers in Iceland and provides insight into the melt enhancement due to volcanic eruptions and years with extensive LAP deposits. In the case of future volcanic eruptions or extensive LAP events, the presented methodology allows for rapid assessment of glacier albedo changes in near-real time and the associated influence on surface energy balance, which can have a direct impact on hydropower production in Iceland and possibly civil infrastructure in some cases. Understanding LAPs processes and impacts on SEB also aids in parametrizations of albedo for other modelling work where remotely sensed albedo may not be available, such as for historic and future modelling studies. The study also provides a comprehensive overview of the SEB of Icelandic glaciers since it is not limited to one glacier or glacier outlet as many previous studies of surface energy balance.

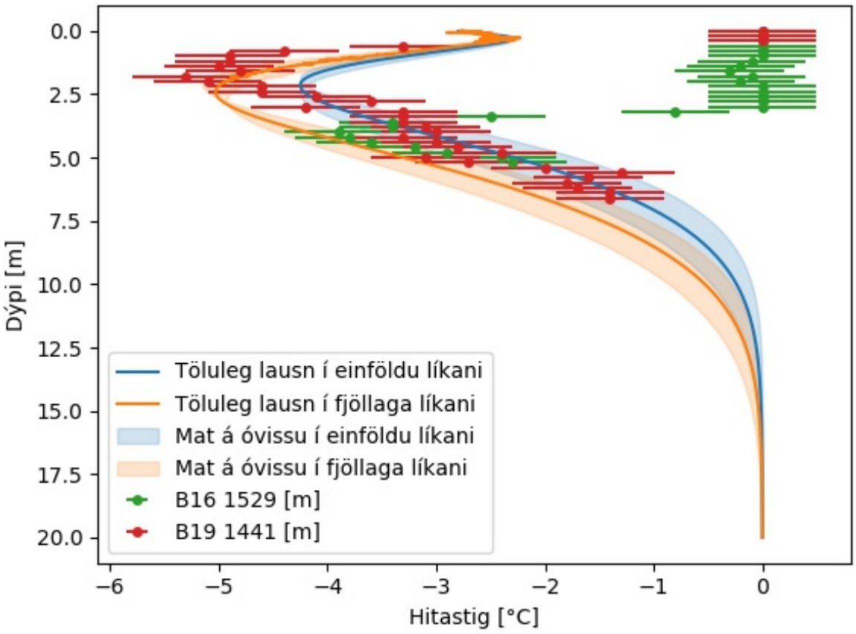
RC1-5: L178-200: Why did you not calculate the local lapse rate from the forcing data? If you have the elevation in each grid point, you could probably calculate monthly lapse rates for each ice cap for all used forcing variables.

Author response RC1-5: We decided to apply an external lapse rate from individual studies in Iceland enabling the potential use of lower spatial resolution data (ERA5 or CMIP, for example) where lapse rates from the forcing data would likely be of much poorer quality. Also, if in future work the glacier geometries where to evolve (elevation changes), we could make the relevant lapse rate adjustments annually in the model.

RC1-6: L 208: I am missing some discussion later in the text about the uncertainty of setting the ground heat flux to 0. I know that Icelandic glaciers are temperate, but surely there is a seasonal cold wave that needs to be heated to melting temperature in spring, and thus not all energy can be assumed to be melt energy?

Author response RC1-6:

This indeed is a source of uncertainty. Since we do not model the snowpack accumulation during winter the cold content is not easily tracked. To estimate in the model a vertical temperature distribution in the near-surface snow layers would be needed and the thickness/density of the snowpack. Observed temperature in spring mass balance cores indicate that cold content is not a major energy source, see figure below[1], although it provides modulation of the energy.



We will add an **Uncertainty sources** section where this would be discussed further.

RC1-7: Section 4: In this section, you only validate the forcing data against observations, but not the results of the model. Could you add a validation of the outgoing longwave and shortwave radiation (which should be available from some of the AWSs) and perhaps also the turbulent fluxes?

Author response RC1-7:

For selected sites where we have LW and SW outgoing we will add this to the summary tables in the appendix and provide a brief discussion in the relevant section.

Care must also be taken when comparing SW out from the model and AWSs, especially in the bare-ice areas where comparisons to 500 m pixels and stations footprints might not be a

[1] https://skemman.is/bitstream/1946/35967/1/BS_Verkefni_skil_2020_GBH_Final.pdf

fair comparison. Studies from Gunnarsson et al 2021 and Gascoin et al 2017 support this which are cited in the paper. Turbulent fluxes are not calculated for the AWSs.

RC1-8: L384-394: consider moving the info about the different eruptions that occurred during the study period to either the introduction or study areas section, as I think the paper would be clearer if this is presented early on (since you mention the eruptions in earlier sections too).

Author response RC1-8: L384 to L394 moved to the Study area section and incorporated into the text there.

RC1-9: L488: Could you add an "uncertainties" section where you discuss your results? What simplifications have been made, how can other energy balance components be affected by LAP events (both the turbulent and longwave heat flux must change somewhat) etc.

Author response RC1-9: Good comment, we will add a section, **Uncertainty sources,** discussing the major assumptions and how they impact the results presented.

RC1-10: L497: change "eeither" to "either"

Author response RC1-10: typo, fixed

RC1-11: Figure 3: you write in the caption that the color scale varies between months, but would it not be possible to use the same scale? It would make comparison much easier between the months.

Author response RC1-11: This could be done but the tradeoff is that the individual month distribution and energy dynamics will be lost. We have tested both versions and the current versions was thought to represent the results better.

RC1-12: Figure 4: Could you make the vertical scale the same for all columns? Then it would be easier to compare the different glaciers.

Author response RC1-12: This could be done but the tradeoff would be a lot of white space for 5 out of 6 glaciers since the vertical axis would range from 0 – 2000. In an already "tight" layout this would unlikely improve reading the graph.

RC1-13: Figure 5: change "Vatnajokull" to "Vatnajökull" in figure titles

Author response RC1-13: fixed

RC1-14: Figure 7: could you make the y-axis the same for all figures, so it is easier to compare?

Author response RC1-14: Yes, done.

RC1-15: Figure 8: The text on the figure is too small, particularly on the color bar.

Author response RC1-15: Agree, we will make years and color bar larger.

RC1-16: Figure 8: I find this figure interesting, as the different ice caps mostly follow a similar trend (years with high EB is the same for all ice caps, and vice versa) but there are some noticeable exceptions. Some of this is probably due to ash deposits from eruptions, but e.g. in 2002 and 2003, Mýrdalsjökull and Eyjafjallajökull seem to behave differently that the others ice caps, with a high energy balance in 2002 while the other ice caps have a low energy balance, and the other way around in 2003. 2014 and 2016 also seem to have some ice caps with general high energy balance while others have lower than usual. Is this difference due to dust storms or something else?

Author response RC1-16: Due to the proximity to the coast and their lower overall elevation Eyjafjalla- and Mýrdalsjökull can experience differences in climate during the melt season. Spring and early summer fresh snow fall are not uncommon, especially at Mýrdalsjökull that would lower the SEB for the season. They are also surrounded by erosive LAP dust hotspots that can contribute LAPs that other glaciers do not experience from areas such as Mælifellssandur, Mýrdalssandur and Markarfljótsaura. These areas are technically in the lowlands of Iceland and are exposed much earlier underneath the seasonal snow in Spring or late winter and in some cases do not sustain seasonal snow during winter. In 2002 the SEB is higher but also at the snout of SW Vatnajökull (Síðujökull outlet) which could originate from the same dust hotspot. Although not reported in this study, during early spring 2022 Mýrdalsjökull, Eyjafjallajökull and other smaller glaciers near the south coast experienced a LAP event not effecting the other larger ice caps. Discriminating between the impacts dust has on albedo and rain/natural snow metamorphosis is challenging only from remote albedo but remains a very interesting topic to study to further understand the impacts LAPs have on SEB. It has been done in many locations, but we have not had the time to focus on it yet.

L365 mentions this “The south-coast glaciers were also close to unstable dust hotspot areas where seasonal snow melts out earlier than in the highlands, exposing erosive surfaces.”

RC1-17: Figure B1-B5: change “jokull” to “jökull” and “Myrdals” to “”Mýrdals”.

Author response RC1-17: Yes, this will be done.