General Comment:
1) The central message of the manuscript is still hard to determine in this revised version despite the new text providing more motivation and stronger conclusions from the presented results. Consider making the central message of the paper more explicit in the abstract and other relevant sections, and revising the title to reflect that central message/big takeaway from your results.
We agree and change the title to: "Emulating the expansion of Antarctic perennial firn aquifers in the 21st century."

The abstract is rewritten as:
"Perennial firn aquifers (PFAs) are year-round bodies of liquid water within firn, which modulate meltwater runoff to crevasses, potentially impacting ice-shelf and ice-sheet stability. Recently identified in the Antarctic Peninsula, PFAs form in regions with both high surface melt and snow accumulation rates, and are expected to expand due to the anticipated increase in surface melt and snowfall. Using a firn model to predict future Antarctic PFAs for multiple climatic forcings is relatively computationally expensive. To address this, we develop an XGBoost perennial firn aquifer emulator, a fast machine learning model. It was trained, using a scenario and spatial blocking evaluation approach, on PFA output of simulations from the firn densification model IMAU-FDM, which was forced by the combined regional climate model RACMO2.3p2 and global climate model CESM2 for three emission scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5). The trained emulator was applied on nine additional forcings (2015-2100) from the regional climate models MAR and HIRHAM in combination with five global climate models. We show that the emulator is robust, explaining at least 89% of the variance in PFA presence and meltwater storage. Our results indicate that for the SSP1-2.6 and SSP2-4.5 scenarios, PFAs remain mostly restricted to the Antarctic Peninsula. For SSP5-8.5, PFAs expand to Ellsworth Land in six out of the seven simulations and to Enderby Land in East Antarctica in five out of the seven simulations. Furthermore, the emulator predicts PFAs for similar surface melt and accumulation conditions when forced with MAR or RACMO data. For HIRHAM these conditions are slightly different, due to the different relationship between temperature, accumulation and melt in HIRHAM compared to RACMO. Overall, our findings show that PFAs are likely to expand in a warmer Antarctica, irrespective of the emission scenario, increasing the risk that an ice shelf collapses due to hydrofracturing."

The conclusion is rewritten as:
"An XGBoost machine learning emulator was set up to predict future Antarctic perennial firn aquifers (PFAs) (2015-2100) for an ensemble of 12 simulations from three regional climate models (RCMs) (RACMO, MAR and HIRHAM) in combination with five global climate models (GCMs). The emulator was trained with simulations of three scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5) from IMAU-FDM forced by RACMO-CESM. For training and testing, we used a scenario and spatial blocking evaluation approach and not random selections of training, testing and evaluation data, as the latter approach is vulnerable for overfitting. We firstly demonstrate that the emulator successfully estimates PFAs, it explains at least 89% of the variance in PFA presence and perennial liquid water content. Secondly, we project, based on the available model simulations, that for SSP1-2.6 and SSP2-4.5, PFA presence remains restricted to the Antarctic Peninsula (AP). For SSP5-8.5, PFAs expand within the AP, and expand to Ellsworth Land in six out of the seven simulations, and to Enderby Land in East Antarctica in five out of the seven simulations and to Marie Byrd Land in two out of the seven simulations. Lastly, we observe a large spread among the RCMs and

GCMs emulator predictions, related to differences in the climatic input, which highlights the necessity of analyzing multiple RCM and ESM combinations and usefulness of the emulator that make such analysis feasible. Further analysis of the results shows that the emulator projects, while using RACMO and MAR simulations, PFAs for similar surface melt and accumulation conditions. When the emulator is fed with HIRHAM data, these conditions are slightly different, caused by different relation between temperature, accumulation and melt in HIRHAM compared to RACMO. Conclusing, our results show that, irrespective of the emission scenario, firn aquifers are likely to expand in a warmer Antarctica. This highlights the importance to understand the impacts PFAs have on ice sheet hydrology, instability and ice-shelf instability."

Technical/Line-specific Comments:
*line comments made with respect to line numbers on the track changes version of the manuscript

L11: no space needed between 89% (and every other percentage value reported in the manuscript).
Done, thank you.

L11-13: consider rearranging this sentence to avoid repeating 'Using' in two consecutive sentences: 'We predict future PFAs (2015-2100) using the PFA emulator for…'
We rephrase this as: "Using a scenario and spatial blocking evaluation approach, we found that the emulator successfully explains at least 89% of PFA presence and meltwater storage variance. We then apply the emulator to predict future PFAs (2015–2100) for nine additional forcings from the regional climate models MAR and HIRHAM in combination with five global climate models."

L13: consider using a description of the two emission scenarios you name here instead to allow the reader to quickly understand the context of those named scenarios. Something like: 'Under our low and moderate emissions scenarios (SSP1-2.6 and SSP2-4.5)…'
Done.

L13: consider the same approach for the next sentence too (SSP5-8.5)
Done.

L14: you can remove 'the' from the added 'six out of the seven…'
Done, and also in other sections.

L15: like the previous sentence, you can remove 'the' from the added phrase here
Done.

L15-21: consider merging these two added sentences to improve the flow. Something like: '…conditions required for PFA formation, while those for HIRHAM are lower due to the model's different relation between temperature, accumulation, and melt compared to RACMO.' Done.

L47: I think there's a missing word here: 'Combining regional climate model (RCM) output/data with satellite data…' We rephrase this as: "Combining regional climate model (RCM) output with satellite data confirms a high probability of PFA occurrence in all these regions."

L52-55: I appreciate the added text here to expand upon the description of the motivation here, but it might be further improved by outlining how 'water storage capacity' directly contributes to 'ice-shelf disintegration events' here faster. I think the easiest way to accomplish that is to put the information about the break-ups of the Wilkins ice shelf after the description of the mechanisms that the water impacts in Lines 56-59. We agree and have rephrased this paragraph as follows: "The year-round availability of water at depth in firn aquifers can lead to hydrofracturing when stress conditions shift to favor tensile extension or reduced compression, even during the winter (Scambos et al. 2009). This mechanism can initiate cascading drainage events that cause rapid and large-scale ice shelf disintegration. The partial break-ups of the northern and northwestern Wilkins ice shelf in 1993, 1998, and 2008–2009 could well exemplify this process, as the detection of bright reflectors in airborne radar surveys indicated the presence of a firn aquifer (Braun et al. 2009, Scambos et al. 2000, Montgomery et al. 2020). These events highlight how water stored in firn aquifers can potentially accelerate disintegration. Similarly, the Müller ice shelf, which also contains firn aquifers, has lost a considerable portion of its surface area (49%) since the 1950s (Cook et al. 2010) while neighbouring Jones and Wordie ice shelves, with similar climatic conditions, have completely disintegrated (Cook et al. 2010)."

L56: I think 'extensions' should be singular here
Done.

L59-63: combine these references to ice shelf disintegration with the Wilkins ice shelf examples from Lines 53-55 here to improve flow. Done, see two comments above.

L64: a comma is needed after 'Greenland' . Done.

L78-79: I think you're missing a phrase at the end of this sentence here. Something like: 'Therefore, we developed an XGBoost PFA emulator to generate projections of future PFA extent with limited data.' We rephrase this as: "To enable projections under a wide range of climate forcings, we developed an XGBoost-based PFA emulator to estimate future PFA extent."

L99: either add 'just' before 'firn temperature' again here, change the wording to highlight that the updated densification rate depends on firn temperature like before but also grain size and overburden pressure. We rephrase this as: "The updated expression lets densification rate depend on firn temperature, grain size and overburden pressure, whereas previously densification rate depended on firn temperature along with averages over the past 40 years of accumulation and surface temperature."

L106-107: The wording in this added sentence is awkward. Consider rewording to something like "Since perennial firn aquifers (PFAs) are defined as saturated firn, IMAU-FDM cannot simulate them." Done.

L132: add 'because it' to the sentence here: '…and because it has been shown…' Done.

L136: there is a missing connecting phrase or word here between '…and complex models,' and 'it incorporates…' We rephrase this as: "Additionally, XGBoost is highly scalable, meaning it can handle large datasets and complex models. Furthermore, XGBoost

incorporates regularization techniques to prevent overfitting and it has built-in mechanisms to estimate feature importance."

L163: I think you mean 'ultimately' or 'also' here instead of 'therewith'. We rephrase this as: "These input features describe the most important mass fluxes and boundary conditions governing firn density, temperature and LWC, and ultimately the presence of PFAs."

L190: you can remove 'part of the' here. Done.

L230: while I think that your description of the target variable (annual perennial LWC) is much clearer, I still think that the reviewers' comments about reporting the RMSE and bias in mm and days being confusing, is still valid here. Can you include a phrase or sentence to quickly clarify that the mm units refer to the positive values and days refer to the negative values? We rephrase this as follows: "The RMSE is 86 (mm for positive values, days for negative), and the bias is 0.4 (mm for positive values, days for negative values)."

L238: two commas needed here: 'When randomly, instead of strategically, …' Done.

L240: remove 'using' here. Done.

L251: 'onset of aquifers' ◊ 'onset of aquifer formation' Done.

4.1 Section title: 'PFA predictions…' Done.

L266: 'arises by' ◊ 'arises from' Done.

4.2 Section title: 'PFA predictions…' Done.

L276: add 'the' after 'yields'. Done.

L278: add 'to be' after 'predicted' Done.

L288: the original formulation of the sentence was correct: 'For example, MAR-NorESM predicts the smallest…' Adjusted accordingly.

L308: 'appear thus' ◊ 'thus appear' Changed.

L309: remove 'a' Done.

L313: '…, and henceforth will be referred to as…' Done.

L349-350: the phrase 'in addition to' here makes the sentence awkward and hard to interpret. Reword to clarify the sentence. We rephrase this as: "The mismatch can be explained by underestimation of observationally detected aquifers by e.g. widely spaced radar data, resolution and process limitations of the firn model, e.g. drainage of meltwater into crevasses that is not included in the model, other above-described firn model limitations, and/or biases in the climatic forcing."

L386: add 'in' after 'resulting' Done.