This paper takes a very detailed look at bubble free layers in the Law Dome ice cores and their potential drivers. A particular care is given to the identification of the timing of the occurrence of these layers, with respect to the season, which is essential for the correlation with climate variables like temperature, accumulation (or hiatus), and atmospheric circulation.

I am impressed with the level of details and care given in the paper. Not much more could have been done.

In the reading, I still struggle a bit with how things are presented, and in the section describing the exploration of mechanisms, some extra care could be put on describing hypotheses more clearly, and then, what data can be brought to support them or not.

A diagram/drawing showing the potential formation mechanisms would greatly help the reading of the paper.

We do appreciate that this would add to the reading of the paper but it is not something that we think we can add to this manuscript. As described in the introduction, this is a descriptive and exploratory study. The next stage of our work is to use the SNOWPACK model to investigate possible formation mechanisms using the analysis we present in this paper as a starting point. The data we present and analyze here is occurrence of BFLs rather than formation. Currently, we don't know how frequently the mechanisms to produce BFLs occur without the preservation of a BFL (as preservation could be decoupled at times from formation, e.g. due to ablation of a newly formed layer). Equally, there could be a timelag between formation and apparent preservation. We will clarify the text throughout the manuscript to ensure we differentiate clearly between BFL occurrence (studied in this work) and BFL formation/preservation (which we are currently commencing with the snowpack model, and intend to publish as a mechanistic study).

These are mostly cosmetic comments, on what is an excellent, thorough paper. I suggest minor revisions.

We thank the reviewer for their helpful and constructive comments.

line 35: bubble number density and paleoclimate: cite Fegyveresi 2016: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015PA002851, also potentially:

Spencer, M. K., R. B. Alley, and J. J. Fitzpatrick (2006), Developing a bubble number-density paleoclimatic indicator for glacier ice, J. Glaciol., 52(178), 358– 364, doi:10.3189/172756506781828638.

Fegyveresi, J. M., R. B. Alley, M. K. Spencer, J. J. Fitzpatrick, E. J. Steig, J. W. C. White, J. R. McConnell, and K. C. Taylor (2011), Late-Holocene climate evolution at

the WAIS Divide site, West Antarctica: Bubble number-density estimates, J. Glaciol., 57(204), 629– 638, doi:10.3189/002214311797409677.

Melt layers: consider citing Keegan 2014: www.the-cryosphere.net/8/1801/2014/ doi:10.5194/tc-8-1801-2014

We will add these references in the paper in the appropriate sections.

line 97: missing space before citation.

We will add space there.

line 225: When you introduce the synoptic types, in section 2.5, you can include here the description of the two important types that you will use later, with a figure (potentially in the supplement if you feel you have too many figures) of the synoptic types, and their relationship with accumulation.

We will add the description to the introduction and a schematic plot of SOM1 and SOM2 in section 2.5.

In general, I think that a description of the relationship between synoptic type and accumulation (or hiatus) is missing in a quantitative sense.
As I understand we could make a schematic:
synoptic type --causes --> accumulation or hiatus --causes--> bubble free layer. In this causal chain, you would find a causal relationship between synoptic type and BFL, but you would not be learning anything more about their formation than when you were looking at accumulation/hiatus.

We tried to detect the relationship between synoptic type and accumulation (or hiatus) quantitatively, but the results were not as definitive as we had hoped. We think this is because we cannot (until we have done the mechanistic modelling currently underway with SNOWPACK) quantitatively define the formation date for BFLs. That is - we cannot with current data distinguish between the dates of formation and preservation. With our current investigations using the SNOWPACK model, we can investigate the BFL formation mechanism, and then we will be able to relate the conditions needed for formation to larger scale phenomena, such as the synoptic types.

Figure 5: I can't see the grey for layer 2

We will change the gray bar into more prominent colors.

Figure 7: the aws data is too tiny, Can you make it a bit thicker? parenthesis issue in caption

We will make the AWS line thicker and rectify the parenthesis issue.

section 3.4

line 330 : you mean table 4

Yes, we will make this correction.

worth adding that som1 is associated with high precip, or describing the significant modes a bit better

We agree, and will add the schematic plot to show SOM1 and SOM2 that we can refer to here.

line 340+:trend: once you have analyzed the drivers, can you say something about the trends in the drivers themselves? Would we be expecting any trend?

We will revisit this section for clarity. However, this section is only describing an apparent (possibly spurious) trend in BFLs through time. We suggest this decreasing trend is an artificially significant trend, possibly due to the surface cores being more fragile and the BFLs in the surface core being more easily broken (and thus missed in the image analysis), rather than the formation of BFLs have a decreasing trend from 1990 to 2016. That is, it is possible that more fragile firn cores closer to the surface break preferentially at BFLs. We are currently analysing longer timeseries of BFL's from other ice core sites, and will be more comfortable discussing any trends once we have the longer timeseries measured and analysed. As suggested, we can then revisit the drivers/mechanisms to see whether they also have trends, as suggested.

line 390: you have here a great comment about formation vs preservation of BFL.

I suggest that you restructure section 4 with the investigations of mechanisms, spelling them one by one, and detailing the supporting data/correlation, and the complicating factors: For instance, make a section on vapor flux upward condensing on the surface, as a formation mechanism, then show evidence for formation during snow-warmer-than-air times, during times of long surface exposure (your hiatus), seasonality, radiation, etc. And discuss evidence where it doesn't quite work.

Repeat this effort for other mechanisms of formation and preservation, aided by schematics, so that we can more clearly see where your thinking is.

We used this structure in a previous draft of this manuscript. After many re-writes, we decided that the structure suggested above was not the best way to structure the discussion. We think this is because we don't know the formation/preservation mechanism yet. We agree that the above suggestion is a nice way to think about the occurrence/formation/preservation of BFLs, however we found that it did not ultimately make for a linear and readable structure in the manuscript sense, largely because this is an exploratory study, and it is difficult to produce schematics of formation, when we have not yet explored formation in the model.

line 419 to 435: not sure it belongs in the paper. start of 4.4 to line 450: should go into the result section.

This section relates a lot to many of the comments from both reviewers requesting more quantitative analysis regarding BFL formation. As we have said, we think we need the model analysis first to do this. As this is the first paper of Lingwei Zhang's

PhD project, we think it is worthwhile keeping this section, as it demonstrates clearly the work we are doing next. However, we will revisit this section to ensure relevance and brevity.

We will revisit the first section of 4.4 to ensure any results are moved to the appropriate section.

Section 4.4: Give more info on the relationship between SOMs and accumulation/hiatus, temperature inversions, wind scours, etc..

We will give more information on the relationship between SOM1, SOM2 and precipitation/hiatuses, however the difference in spatial scales between the synoptic types and the smaller scale processes of wind scours and temperature inversions has not yet been explored (here or elsewhere).

Appendix A1: ERA is overestimating snowfall by a factor of 2. Did you consider scaling ERA, and plotting on figure A1 the scaled ERA to highlight the temporal accuracy of hiatuses, or perhaps even plot the derivative.

in A1, ERA5 is the net accumulation (in metres water equivalent) and the AWS data is the measured snow surface height (including ablation, redistribution, settling etc). They are not really the same thing, so while scaling initially makes sense, it is ultimately misleading (we tried this previously, and felt it was more, rather than less confusing). However we will adjust the axes so that the two datasets can be more easily compared in a visual sense.