

## Author responses to referee comment 1 - Jesper Sjolte

In this study Nilsson et al. investigate the cohesion between the weather variability and precipitation rates in the 20<sup>th</sup> Century Reanalysis v3 (20CRv3) compared to the accumulation at the Dome Summit South (DSS) drill site, Law Dome. The sparse observational data makes it challenging to constrain reanalysis products for this region and the authors use self-organizing maps to produce weather patterns and find the patterns which are correlated with reanalysis precipitation at DSS. Nilsson et al. then compares the weather patterns and reanalysis precipitation with the annual accumulation rates from the DSS ice core. The main conclusion is the 20CRv3 performs very well after 1948 when an adequate amount of data is entering the reanalysis. The authors go on to suggest guidelines for comparing reanalysis products with Antarctic ice core data and how to improve the reanalysis data in regions with sparse observations.

### General comments.

Overall, I find this study to be interesting and relevant, and the results and conclusions contribute to an area which is sort of a white spot on the map. The science question is clear and analysis, as well as, figures, data and method description are generally well executed.

There are, however, a bit of work to be done before the manuscript is fully publishable. I have quite a few comments regarding clarity and readability, and not the least structure of the manuscript. I find that there is a lot of mixing of the results and discussion section, and basically the results section should be longer and the discussion shorter. All of the description and explanation connected to Figure 4, 5 and 6, as well as, Table 3 should be in the results section. See also detailed comments below regarding this. Furthermore, I think writing in present tense when describing analysis done in the paper is more appropriate. Historical facts and events can be referred to in past tense.

Thank you for these comments. We will move the suggested sections (descriptions and explanations of Figs 4, 5, 6, Table 3, as well as lines from the detailed comments below) from the discussion into the results. We will move some of the description of the weather systems/synoptic patterns that are associated with high/extreme and low/zero precipitation from section 4.2 to section 3.5. We note that it is sometimes a little difficult to separate results and discussion in a descriptive context (such as the self-organising map descriptions) however, we will re-organise the above sections and then review for clarity and readability.

We will also rephrase the descriptions of the analysis to be in present tense.

I do wonder if a seasonal signal can be extracted from the ice core given the high accumulation rate, and the availability of high-resolution isotope and impurity data. This could give further insights to the seasonal variability of weather patterns in the region and also regarding seasonal trends in accumulation. Maybe a point for the discussion?

Thank you for this comment. This is an important point, and it is one of the main motivations behind this study. At this point we believe this work is the initial step along the way to being able to identify and then statistically verify 'within year' signals, hopefully at the seasonal scale, which would enable the demarcation of seasonal boundaries in the ice core data. This work is the first step, because we believe this

demarcation will need to be valid over a longer period of reliable data than just the satellite era (although the satellite era will obviously always remain the more reliable verification period). We will add details about the ongoing work we are conducting in this area to try to locate seasonal boundaries and / or synoptic scale proxy signals in high resolution East Antarctic ice cores, primarily a study on stratigraphic markers in the Law Dome ice core (Zhang et al., 2023) and the implications from this work.

Detailed comments.

L12 “with increased precipitation” and I suppose thus also decreased precipitation.  
Suggestion: “variability of precipitation amount”

This is a good point, since low/zero precipitation patterns are also important for precipitation variability. We will rephrase as “precipitation variability” instead of “increased precipitation”.

L24 “These weather systems have changed in frequency over the satellite era “.  
Suggestion: “The occurrence of these weather systems have changed in frequency over the satellite era “.

We will reword based on your suggestion

L30 “satellite era, and include” suggestion: “satellite era. The most recent reanalysis products include”.

We will reword based on your suggestion

L34-35 “These reanalyses are generally considered to perform poorly “ a reference or two to support this would be in order.

We will add these references to support this:

Schneider, D. P. and Fogt, R. L.: Artifacts in Century-Length Atmospheric and Coupled Reanalyses Over Antarctica Due To Historical Data Availability, *Geophysical Research Letters*, 45, 964–973, <https://doi.org/10.1002/2017GL076226>, [\\_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/2017GL076226](https://onlinelibrary.wiley.com/doi/pdf/10.1002/2017GL076226), 2018.

Wang, Y., Hou, S., Ding, M., and Sun, W.: On the performance of twentieth century reanalysis products for Antarctic snow accumulation, *Climate Dynamics*, 54, 435–455, <https://doi.org/10.1007/s00382-019-05008-4>, 2020.

Zhang, Y., Wang, Y., Huai, B., Ding, M., Sun, W.: Skill of the two 20th century reanalyses in representing Antarctic near-surface air temperature, *Int J Climatol*, 38, 4225–4238, <https://doi.org/10.1002/joc.5563>, 2018.

L75 Add “Dome Summit South” before DSS.

We will correct this

L77 “0.69 metres ice equivalent from frequent cyclonic incursions ” I suggest to make a full stop before *from* and explain about the processes forming the precipitation in the next sentence.

We propose to comprehensively re-write this section for clarity, including adding further information which will address the comments here and below relating to lines 77-80. This will include information on how the DSS snowfall accumulation rate record was developed, which includes aspects of snow densification, layer thinning and horizontal advection at the site (both over the satellite era, and also for the past 2000 years). We will also discuss in more detail how annual layers are identified at Law Dome during layer counting, volcanic alignment with known events, and current understanding of the mean seasonal variations in trace chemical records at Law Dome. We will include details of the numerous prior publications which have developed the Law Dome chronology, and the derived accumulation rate products for this site.

L77 “annual accumulation rate of 0.69 metres ice equivalent ” I found no description how the accumulation is converted to ice equivalent. How is firnification and ice flow treated? Also, is evaporation and issue when comparing accumulation and reanalysis precipitation? I didn’t found any mention of this. Maybe not an issue for Law Dome, but for other sites with low accumulation. Could be a point in the discussion.

We will rewrite this section to include more detail on how the snowfall accumulation record was developed (see comment above).

Regarding evaporation, we have no evidence from prior studies that evaporation / sublimation is a major or significant component of the variability in annual snowfall accumulation recorded at Law Dome. Law Dome is a high snowfall, wet deposition site (Roberts et al., 2015; Morgan et al., 1997) and the bulk of the snow that arrives at the site is buried in subsequent snowfall events, without relatively minor impacts from sublimation or wind erosion (e.g. McMorrow et al., 2001; 2004). We will note this.

L77-78 “produces seasonally varying annual layers ” how can annual layers be seasonally varying? Please rephrase.

We will reword this section as per above.

L79 “Annual layers are identified ” is this done in this study or in the studies you refer to?

We will reword this section as per above.

L80 “and validated against known volcanic eruptions ” It’s the time scale i.e., dating, which is validated using volcanic eruptions as tie points.

We will reword this section as per above.

L93 “applied to weather and climate applications ” I think it should be “applied in”, but maybe better to reformulate and avoid using both “applied” and “applications”.

We will rephrase this as:

“and how it has been used for weather and climate applications, can be found in other studies”

L104-105 Maybe the correlations “can be expected” to be lower?

Agreed, we will rephrase

L107 “associated with increased precipitation at Law Dome ” if you get which patters give increased precipitation, you also get the patterns that cause low precipitation. I think it is more intuitive to generally formulate that you want to establish the relation between the SOM patterns and precipitation amount at Law Dome.

We agree using the term ‘variability’ is far more descriptive here, and will rephrase as “precipitation variability” instead of “increased precipitation”. We will also ensure this is corrected elsewhere it may occur in the text.

L112 Some kind of introducing part of the sentence should be added here so that one understands it’s a new topic. Something like “We then calculated” “In a next step”...

We will add a few words to introduce the next topic.

Table 1: The standard would be to have two significant digits for correlation and explained variance. And keep it consistent between text and table. It says “ $r = 0.8$ ” in the text L144.

We will change the  $r$  and  $R^2$  values to two significant figures, and keep it consistent with the text.

L145 For trends upper and confidence bounds can be more instructive than a p-value.

We will add 95% confidence intervals for the trends instead of the p values.

Section 3.2: All but the last sentence of this section starts with “the” which makes it very repetitive. Consider rewriting with more flow by adding a few words where it fits, e.g. “Similar to” “In contrast with”.

We will rephrase to reduce repetition.

Figure 2: Unit for accumulation in caption “miceequivalent”. Mice equivalent? I think making the DSS accumulation as a stair-type plot would improve the readability of the graph.

Apologies, it should be “metres ice equivalent or m.i.e.”, which we will define in the caption.

We will also change the DSS accumulation to a stair plot structure as suggested (see revised figure below).

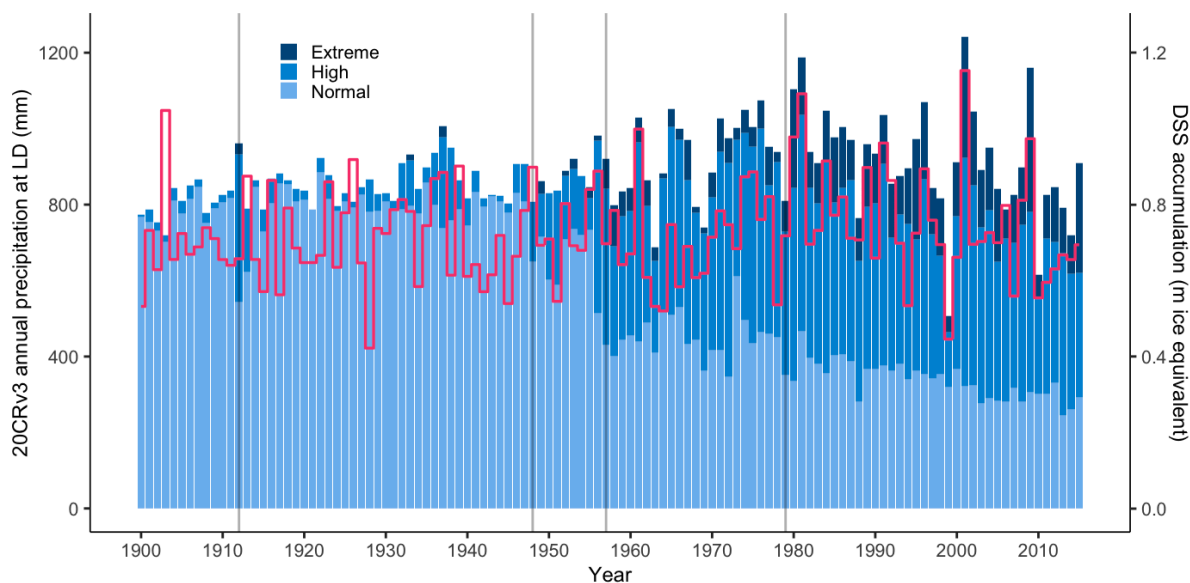


Figure 3: You could add the DSS site in the figure so the reader has something to hang onto.

This is a good suggestion, we will add the DSS site into the figure

L192-193 “Synoptic types 3, 4, 8 and 12 were associated with high precipitation at Law Dome” this is a central result. Add some text to explain why these weather patterns result in high precipitation at DSS and others not. You explain this in Section 4.2 but I think this is part of the results.

We will move most of section 4.2 to section 3.5 in the results and ensure there is good flow between section 3.5 and the discussion.

L193: Fig. 5 is referred to before Fig 4. Check so that all figures are ordered in the same way they appear in the text.

We will check the order of the figures and ensure the document is compiling correctly.

L202: Discussion. In my mind the discussion cannot start here. You are not done describing your results. You are allowed to discuss things while describing your results in the extent they are needed to explain things. For example, you can say that your results depend on the number of observations going into the reanalysis, given the topic of your study there is nothing controversial about that. In your discussion you write about uncertainties, relation to other studies, add minor results that might frame your main results and finally an outlook for future studies or recommendations.

Thank you for these helpful suggestions. We will carefully restructure the results and discussion, so that there are more explanations in the results as per the details we have provided in the comments above.

Figure 6: Use 2 significant digits for  $R^2$  in figure.

We will correct this.

L211 “that have been assimilated into ISPDv4.7 increase from” something wrong in this sentence.

Agreed, we will rephrase this sentence as:

“In the study area, the number of assimilated observations in ISPDv4.7 increased from the late 1940s (Compo et al., 2019). Some of the key locations are described here. “

L216 Byrd station also established in 1957. Although not in East Antarctica this also helps constrain the large-scale circulation around Antarctica.

This is true, although we would argue that many stations were established in 1956-1958 across Antarctica. However, we take the reviewers point, and will edit that sentence to say:

“The International Geophysical Year (July 1957- December 1958) also saw a large increase in meteorological observations in East Antarctica, as well as other parts of the continent (Wexler, 1956).”

L224-241 Keep this in discussion.

We will keep this in the discussion

Section 4.2 is mainly results.

We will move most of section 4.2 into the results as noted in the comments above.

L271-274 Results.

We will move this part into the results

L274-281 This is mainly Discussion. You might note that blowing snow is less of an issue at high-accumulation sites.

We will add that loss due to winds is less of an issue at high accumulation sites, by rephrasing the sentence in lines 279-281:

“Wind erosion is less of an issue at Law Dome compared to other sites due to an absence of frequent high winds, but there is evidence of snowfall events missing from the net accumulation record (McMorrow et al., 2001; Zhang et al., 2023).”

L281-293 Results.

We will review this section to ensure any relevant results are moved to section 3.6

L293-301 Discussion.

We will keep this in the discussion

## References:

McMorrow, A., Ommen, T. D. V., Morgan, V., and Curran, M. A. J.: Ultra-high-resolution seasonality of trace-ion species and oxygen isotope ratios in Antarctic firn over four annual cycles, *Annals of Glaciology*, 39, 34–40, <https://doi.org/10.3189/172756404781814609>, 2004.

McMorrow, A. J., Curran, M. A. J., Ommen, T. D. V., Morgan, V., Pook, M. J., and Allison, I.: Intercomparison of firn core and meteorological data, *Antarctic Science*, 13, 329–337, <https://doi.org/10.1017/S0954102001000463>, 2001.

Morgan, V. I., Wookey, C.W, Li, J., van Ommen, T.D., Skinner, W., and Fitzpatrick, M.F: Site information and initial results from deep ice drilling on Law Dome, Antarctica, *J. Glaciol.*, 43, 3–10, [doi:10.3189/S0022143000002768](https://doi.org/10.3189/S0022143000002768), 1997.

Roberts, J., Plummer, C., Vance, T., van Ommen, T., Moy, A., Poynter, S., Treverrow, A., Curran, M., and George, S.: A 2000-year annual record of snow accumulation rates for Law Dome, East Antarctica, *Climate of the Past*, 11, 697–707, <https://doi.org/10.5194/cp-11-697-2015>, publisher: Copernicus GmbH, 2015.

Zhang, L., Vance, T. R., Fraser, A. D., Jong, L. M., Thompson, S. S., Criscitiello, A. S., and Abram, N. J.: Identifying atmospheric processes favouring the formation of bubble-free layers in the Law Dome ice core, East Antarctica, *The Cryosphere*, 17, 5155–5173, <https://doi.org/10.5194/tc-17-5155-2023>, publisher: Copernicus GmbH, 2023.