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Interactive comment on "Regional climate signal vs. local noise: a two-dimensional view of water isotopes in Antarctic firn at Kohnen station, Dronning Maud Land" *by* T. Münch et al.

Anonymous Referee #2

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The authors present two detailed horizontal (45m) by vertical (1.2m) water isotope profiles in surface firn from a low accumulation site. Isotopic values are investigated in both directions to determine spatial variability. Based on a statistical model, the authors then attempt to determine the amount of ice cores needed to reconstruct temperature from inherently noisy isotopic signals. The authors find that as many as 50 closely spaced ice cores (scales much less than a km) would be necessary to reconstruct recent temperature trends in East Antarctica.

The work is highly relevant to the ice core community, but only for very low accumulation sites. I want to congratulate the authors for their high-quality data and point out

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that the figures are especially informative. However, the main text requires additional work. After a major revision of both nomenclature and readability, as well as more in-depth discussion of assumptions used in modeling, I would recommend this paper for publication.

General comments:

The paper overall is very difficult to read. The writing is too complicated, often mixing nomenclature, or not defining it properly. The statistical model, especially, deserves more attention in the text, as well as more description in the Appendix. A major simplification of the story is needed. As it stands, the reader is lost in technical and often unnecessary writing. The paper could be as much as 25% shorter just in this regard.

In section 4.4, the authors attempt to reconstruct a 0.5degC temperature trend using a Monte Carlo approach consisting of a signal (linear temperature trend) and random noise. Although the time period is short (50 years), this is far too simplistic a model for estimating isotopic variability. The approach must also include the atmospheric component of variability, because storm tracks and moisture sources can change over decadal time periods. At the very least, this should be clearly documented as a simplifying assumption. Water isotope signals do not only depend on noise and temperature!

The results presented largely focus on isotopic analysis in the depth/time domain, but I think it would be worth pointing out that analysis in the frequency domain of isotopic profiles would be informative, and an area of much needed research. It makes sense that post-depositional stratigraphic variations alter the isotopic signal, but is the frequency component of the data preserved? That is, do the spectra of nearby isotopic profiles in the vertical direction have the same power density values? In my opinion, this would be the major test of water isotope literature. At the end of the paper, this should be suggested (note: an analysis like this would require perhaps 100 years of data from multiple cores). Table 1 would suggest there may be large discrepancies in the frequency domain, but I also think the vertical scale of the study ($\sim$1 m) prevents

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any useful conclusions.

Throughout the paper, an accumulation value for low-accumulation sites is poorly defined. The results of the paper are only valid for low accumulation sites, which I guess might mean something like less than 15 cm ice eq/year. It should be made clear at the beginning of the paper, and throughout.

Suggesting that only one injection on Cavity Ring Down Spectroscopy instruments be used for future multi-ice core studies, in my opinion, should not be included as a suggestion in the paper. Although throughput would increase, current CRMS instruments cannot give reliable results with a single injection - precision is lost - and this can alter the frequency component of the signal. Plus, the deuterium excess parameter requires good precision in both d18O and dD for useable results.

In Figure 4, seeing that the mean isotope profiles of T1 and T2 are correlated at 0.82 leads me to believe that clarification is needed in the text. Using a low accumulation site to extract temperature is problematic in many ways, and using up to 50 cores might be necessary to get some sort of temperature signal, but simply averaging a few isotopic profiles over some depth/time is still useful to pull out a common climate signal. This must be clarified to the reader.

Specific comments:

P5607-L3-4 The stated text ‘ “the strong relationship between the isotopic ratios in precipitation and local air temperature” should be clarified. This is valid at large distances (latitude scale). Variability at a single ice core site will also depend on the trajectory of individual storm tracks, and for example, the location of low pressure zones that influence meteorology. This means that there is both a local temperature effect and an atmospheric effect. This is also mis-represented later in the paper using the Monte Carlo simulation.

P5607–L13-16 It is mis-leading to say that outside of large-scale temperature shifts

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(how big? glacial-interglacial size shifts?) it is often too hard to extract climate information. There is still climate information, such as multi-year or decadal oscillations, but perhaps finding a temperature signal in a low accumulation site is too hard. Please clarify. What sort of temperature shift? What does low accumulation even mean (less than 15cm ice eq/yr perhaps)?

P5607–L21-23 What are non-climate influences? Do you mean noise, that must be averaged to get climate over something like 30 years or greater? This is at least partially explained in the rest of the paragraph. Perhaps state “short-term processes” or “small spatial scale processes” instead of “non-climate influences”.

P5608–L23 Please define low-accumulation.

P5609-L21 Please state the accumulation rate in m ice eq./yr for comparison to other ice core sites.

P5609-L27 What is a “spirit level”?

P5611-L5-14 This paragraph is excellent and useful. Describing the structure of the surface of the snow, and at what locations along the horizontal trench line, allows the reader to form ideas about how this may affect the isotope profiles in the vertical direction.

P5611-L15 Please also include a standard deviation value, in addition to mean, max, and min.

P5611-L19 What is a “high” d18O value? In the next line, please give standard deviation, not variance. This sentence is important, but very confusing. Likewise in line 23, what is a lower d18O value. Please use enriched or depleted.

P5612-L2 What is an “isoline”? Please define somewhere above this sentence for clarity. The rest of the paragraph is similarly confusing, and because of its importance, it should be carefully re-written. Give accumulation rate in m ice eq.yr. Do “lateral layer profiles” refer to isolines? The nomenclature is difficult to follow.

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P5612-L23-24 What are “inter-profile deviations” referring to? Deviations of isolines? Try to use one common description, rather than many types. In general, I can interpret what the author means over the preceding two paragraphs, but it should be defined more clearly.

P5613-L2-5 I cannot understand what this sentence means: “On the horizontal dimension of the trenches, the observed lateral variance (Fig. 3) reflects processes that are not related to variations of atmospheric temperatures as these are coherent on this spatial scale. According to the terminology adopted here, the lateral variance is non-climate noise.” Do you mean that local temperature and regional atmospheric circulation should cause variations in vertical isotopes profiles, while horizontal profiles are affected by something else, such as post depositional movement superimposed on the natural climate variability? Also, please do not use “lateral”, as this can mean “side-to-side” in the vertical or horizontal direction, and when used on its own, is confusing to the reader. Try to define nomenclature early in the paper, and stick to that nomenclature throughout.

P5613-L17-25 For this paragraph: 1) The first sentence repeats previous rationale. 2) In line 22, a mean of what? Units? It is unclear what is being discussed at this point. 3) Why do you call this “classical”? Can you include a reference? 4) In line 25, the author mentions vertical shifting, but it is not entirely clear why this is introduced? Is this peak matching with a max shift of 12cm? The entire paragraph needs to be clarified.

P5615-L5 By “independent of the signal”, do you mean the climate signal?

P5615-L24 It might be worth noting that the missing d18O winter values could have been a winter where very little precipitation fell (the seasonality effect).

P5617-L14 Spatial precipitation intermittency on scales of km’s is not relevant to this study as the trenches are only spaced at 500m.

P5618-L3 The attenuation of the signal with depth *must* be mainly explained by diffu-

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sion. Using the term ‘likely’ disregards physics. I think this paragraph can be shortened considerably to say: diffusion attenuates the signal with depth, and in the upper few meters, ventilation can cause even larger attenuation of the signal.

P5618-L26 What do you mean by “the remaining correlation”?

P5619-L22 What “criteria”? You mean, “the following criteria”? Or something else?

P5620-L1 At this point, I have become somewhat lost. While the larger picture remains clear, the details are confusing. For example, “representativity” is difficult to interpret in many instances.

P5623-L5-7 You must state in this sentence that the interpretation of firn-core-based climate reconstructions is challenging for *low accumulation sites* and state what accumulation value(s). For high accumulation sites, the interpretation is quite straightforward. As this important sentence is written, it is mis-leading.

P5626-L22 It should be clarified that low accumulation firn cores do not show a coherent signal at high-frequencies (i.e. probably at sub-decadal scales, depending on the accumulation rate).

Interactive comment on Clim. Past Discuss., 11, 5605, 2015.