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Climate of the Past Discussions

Interactive comment on "Spiky Fluctuations and Scaling in High-Resolution EPICA Ice Core Dust Fluxes" *by* Shaun Lovejoy and Fabrice Lambert

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By using non-standard approaches, the authors analyze in this paper the 320.000 cm-long EPICA Dome C dust flux record published in Lambert et al., 2012. I cannot judge on the statistical techniques adopted for characterizing the cycles – that I leave to expert reviewers in this (mathematical/statistical) field. Glacial-interglacial cycles that are present in the EPICA record are subdivided into 8 phases showing systematic variations of their statistical properties. The interpretation of the variability of four key indicators (H, C1, qD, A) provides some interesting paleoclimatic information. I have only some concern about the interpretation of A and H exponent and their link to the size of the Patagonian ice sheet (see below), as well as some minor comments/questions. If the statistical part is duly revised by an expert in the field, this paper is worth to be pub-

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lished in CP after some minor revisions. Author Response: Thank you for the positive comments.

********** Page 2, lines 17 to 29: they refer to figure 2 which is (according to the figure caption) redrawn from Lovejoy, 2017 – please reference to that paper in this paragraph. Author Response: Added Page 6, lines 25-27: if you consider every cm of core, also the dust record can be somewhat affected at depth. Is this something which should be mentioned here? Probably not. But keeping this in mind, please re-structure this first sentence and state that you just take published data from Lambert et al., 2012 and discuss them as they are. Author Response: The worsening of the resolution with depth of the dust data is discussed in lines 27-30. In our opinion, the sentence is clear that the dust data is not a product of this publication. Page 7 , line 1: dust CONCENTRATION measurements, please specify. Author Response: Changed to "dust flux measurements" Page 7, lines 1-4: dust production depends on the source "intensity" that includes also the areal extent of the source which is variable depending on the exposed continental shelf. Author Response: Original text changed to "The amount of dust deposited in East Antarctica will depend on the size and vegetation cover of the source region. . ." Page 7, Lines 5-9: dust depositional flux variability is also related to the hydrological cycle at low frequencies.. and to temperature. . .this explains the high correlation between dust and stable isotopes in ice cores. Please restructure this sentence. Page 7, Lines 8-9: "at high frequency dust deposition variability depends on wind and hydrological cycle": which is the reference for this assumption? Dust concentration/flux depends on the hydrological cycle at different timescales. . . And wind (transport) influences mostly size rather than concentration. I think the sentence " at high frequency dust deposition variability depends on wind and hydrological cycle" is more a conclusion of your study, as written in lines 17-20, page 13 "At higher frequencies. . .[. . .] . . .dust deposition in Antarctica will be more sensitive to temporary atmospheric disturbances in the winds and hydrological cycle" Page 7, Lines 9-10: As above, the sentence "..a single peak within a low background may reflect short-term atmospheric disturbance like drought over South America or

low precipitation over the S.Ocean. . .” is more a conclusion of your work rather than a literature assumption. But in any case, why not an eruption? Why not an impurity (contamination) within the core? And at depth, why not a level where particles aggregates are present and to some extent perturb the signal? Is it certain that every spike registered in the core represents a climatic signal? It would be a huge work to analyze every sample where dust levels are above background, but I feel confident that many of these spikes can be attributed to these causes. Author Response: Indeed, this sentence contains some results from our analyses. We have changed these sections to “High and low frequency variability in the dust flux record is likely driven by different processes. For examples, dust source conditions related to glaciers and vegetation cover may not have influenced high frequency variability due to their relatively slow rate of change. On the other hand, volcanic eruption or extreme events related to the hydrological cycle may produce high-frequency signals in the record.” Indeed, analyzing every sample of the EPICA Dome C Continuous Flow Analysis data was a huge task and took F. Lambert over 2 years during his PhD. But thanks to this work we can be sure that most contamination peaks were cut out of the signal. Large volcanic eruptions usually saturated the dust signal and were cut out as well, but smaller more distant eruptions may produce a particle peak similar to a climatic event. Since we didn’t check each dust peak for a corresponding sulphate peak, we have added in the text volcanoes as another possible high-frequency contributor. Aggregates did change the size distribution in the data quite a bit, but not the particle count. And since the dust flux record used here is a merged signal of particle concentrations and Ca and nssCa data, we feel confident that dust aggregates did not produce any sharp peaks. Page 10, line 22: replace “compares” with “compare” Author Response: Corrected From Page 11, line 31, to page 12, line 24: the whole paragraph is very interesting as figure 12 is also interesting. But with so many acronyms or indices, would it be possible to write for example “DRIFT” over the first plot (H), “SPIKINESS” over the second (C1) . . .etc? And also, maybe draw a horizontal arrow in each plot, going from right to left with “TIME” written on it. And why not, close to each number 1,2,3. . . the informal

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name of the phase (“interglacial”, “glacial maximum”,. . ..)? This just for clarification, and for helping this figure to give an immediate message to the reader; I think this is one of the most important figures in the paper, so put it into value. Author Response: We have followed the suggestions and updated the plot. Page 12, lines 26-29: I would not say that the precise climate significance of dust flux is hard to nail down. Rather, maybe you can find an elegant way to say that dust fluxes result from several synergic variables and dust flux alone does not allow distinguishing the contribution of each of these variables in detail. Author Response: We agree and changed this sentence to “First, their dynamical interpretation is not unambiguous: because they depend on temperature, wind, and precipitation, and so are holistic climate indicators, dust flux variability is hard to attribute to a specific process.” Page 13, lines 5-8: is the broadness of the peak really indicating irregularities of the eccentricity-forced Milankovitch cycles or, as I think, you probably mean it is indicating the irregularities in the continental response, including sea level change and shelf exposure, vegetation, glacial activity. . .and so on? Author Response: Correct, we changed this to “The broadness of this peak already indicates the irregularity of the Earth system response to the eccentricity-forced orbital cycles.” Page 13 lines 15 to 20: this is an important consideration and conclusion of this paper that needs to be hemphasized a bit more. Author Response: We expanded the corresponding section in the conclusion and added a sentence in the abstract. Page 14, lines 1-2: after saying on page 12 that it is complicated to associate the dust flux increase or decrease to one variable, you are now associating high dust supply during phases 6-7 to the size of the Patagonian ice cap. That is not correct, first of all because dust influx to Antarctica does not depend solely on source production. Yet, even considering only dust availability at the source (source production), and only solely glacial dust sources, then you must consider that dust production is not one-to-one related to the size of the Patagonian ice sheet, but to the intensity of all glacial and periglacial processes potentially involved in dust production, which change in time, of course. Therefore, not only glacial processes related to the size of the ice sheet (involving erosional processes related to the movement of

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ice and pressure on the underlying surface leading to great amounts of erosion) are involved. Also transport and deposition of glacial debris and formation of tills, outwash sediments (glacio-fluvial process), glaciolacustrine deposits, glacioeolian deposits, can act as dust sources; in addition, dust can derive also from periglacial processes related to nivation, frost action, mass wasting, fluvial processes and eolian processes that are enhanced by freeze drying of surface sediments, scarce vegetation cover and exposure to strong winds. So I think it is too simplistic to relate the A and H exponent to the size of the Patagonian ice sheet... please consider the possibility to relate these indices to the intensity of glacial and periglacial processes in South America. Author Response: We agree that was too simplistic and we removed that passage from the abstract. We have changed that section to "The higher amplitudes in phases 6 and 7 indicates that dust supply became abundant then. Since the Argentinean continental shelf was still submerged at that moment and the outwash plains not yet fully extended, the higher dust emissions may have been due to a transformation in vegetation cover about 30 kyr after glacial inception, possibly accompanied by changes in glacial and periglacial processes in the Andes." About interpretation of C1 and qD exponents, related to short-term events. You cite possible short-term disturbances in the atmosphere. Why you do not consider volcanic eruptions? Probably because of the short-term atmospheric disturbance of these events? Or because you do not have a corresponding sulphate signal in the core? Please clarify introducing one or more sentences before the conclusion paragraph. Author Response: Identifying volcano eruptions using the sulphate record alone is tricky because many large sulphate peaks do not have a corresponding dust peak. This means that even if you do have matching dust and sulphate peaks, it could be an eruption or a coincidence. Unfortunately, tephras in the EDC ice core were measured only at very low resolutions to get an idea about eruption frequencies, and we do not have that data available to unequivocally identify single events. But you are right, this means we cannot exclude volcanoes. A paragraph was added explaining this. " "Finally, we could mention volcanoes. Volcano eruptions usually saturated the dust measuring device and were mostly cut

from the record. Using the sulphate record to identify eruptions is tricky because many large sulphate peaks do not have a corresponding dust peak. This means that even if you do have matching dust and sulphate peaks, it could be an eruption or a coincidence. Therefore, the influence of volcanic variability on the results cannot be completely eliminated, although our key results are fairly robust with respect to the phase of the cycle and are therefore unlikely to be influenced by volcanic eruptions."

Please also note the supplement to this comment:
https://www.clim-past-discuss.net/cp-2018-171/cp-2018-171-AC2-supplement.pdf

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