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Climate of the Past Discussions

Interactive comment on "Water stable isotopes spatio-temporal variability in Antarctica in 1960–2013: observations and simulations from the ECHAM5-wiso atmospheric general circulation model" *by* Sentia Goursaud et al.

Anonymous Referee #1

Received and published: 23 January 2018

General Comments This paper addresses novel and relevant scientific questions within the scope of CP. The authors use an impressive collection of data to assess the skill of the ECHAM5-wiso model. The main scope of the paper is to evaluate spatial, seasonal and interannual δ18O-temperature relationships, as well as deuterium excess and δ18O phasing. This information is important for correctly interpreting certain climate records in Antarctica, especially when using shallow ice core records of a few decades length.

Minor revisions are required for publication, as well as one major revision and/or clari-

fication.

Specific Comments * My biggest concern is how the authors addressed water isotope diffusion in shallow ice core records. The majority of diffusion occurs in the upper ∼10-20 meters of the ice sheet, thus this will have a significant effect on the results of this study (i.e. for ice core data from 1979-2013, or for any data extending beyond a few years in length). Can the authors clarify whether any consideration was given to the attenuation of the seasonal and multi-year variations due to diffusion?

For example, at a typical inland West Antarctic site (mean annual temp = -30.3C, accumulation = 0.23 m/yr), the annual d18O and dD signal amplitudes will decrease by about ∼50% in 30 years (calculated using a Johnsen firn model and a Herron-Langway densification model). For a colder site (temp = -40.3C, accum = 0.12 m/yr), the amplitudes decrease by 67% in 30 yrs. And for a warmer site with high accum (temp = -25.3C, accum = 0.38 m/yr), the amplitudes are decreased by 37% in 30 years. These are quick calculations, but show the importance of diffusion.

Could firn diffusion be the cause of model-data mismatch? If so, and I think this is the case, the authors should either make these calculations and include the corrections in the paper, or state a few examples of signal attenuation for different temperatures and accumulation that are relevant to the ice core sites used in the paper. On the other hand, if I have misunderstood the results, please provide clarifications and explain why.

* Please explain "nudging", and perhaps use different wording in the paper. While this may be common terminology, it is not immediately clear what it means, nor does it appear to be defined in the main text of the paper. I would also suggest a short, 1-sentence explanation in the introduction that explains the relevance of slopes for ice core isotope-temperature relationships, etc.

* Can you please confirm that for any averaged isotope data, that the same averaging was done in the model. If not, please state why, and how this could affect results. Also, please provide a clarification on how averaging could reduce the amplitude of the

observed seasonal and multi-year signals.

* The authors state once that "... a stationary isotope-temperature slope cannot be applied for the climatic interpretation of Antarctic ice core." (pg 3, line 1-2). This is an important point. I think this point should be made in the Conclusion as well, specifically that the results of this study (or atleast some of the results) may not hold in the deeper past (greater than a few decades). Please be clear in your assessment of the relevance for paleoclimate interpretations. This has the potential to be misunderstood.

* In many instances, the citations are dated. There are many more recent studies that should be cited in this manuscript. I encourage the authors to provide citations of more recent studies.

Technical Corrections

pg 2 line 7 - nudged? please explain what this means somewhere in the introduction, and possibly change the wording.

pg 2 line 15-17 - the description is unclear

pg 2 line 28 - slopes? "We show that local spatial or seasonal slopes" the relevance of slopes should be defined in the introduction so certain readers are not left wondering what this means

pg 3 line 6 - "This work valuates" - evaluates?

pg 4 line 4 - consider saying "the hydrologic cycle" rather than "water cycle"

pg 4 line 6-8: "Their climate interpretation is however limited, first by the alteration of the signal due to deposition and post-deposition processes, and second by the complexity of all parameters affecting the Antarctic snowfall isotopic composition" âĂŤâĂŤ cite sources.

For Antarctica, one of the more in-depth studies of "post-depositional processes" is Jones et al., 2017 "Water isotope diffusion in the WAIS Divide ice core during the

Holocene and last glacial"Âădoi:10.1002/2016JF003938. Also provide citations for depositional processes and "complexity of all parameters" - perhaps you mean isotopic recharge, etc?

pg 4 line 6: "Their"? Who are they?

pg 4 line 6-8: "Their climate interpretation is however limited, first by the alteration of the signal due to deposition and post-deposition processes, and second by the complexity of all parameters affecting the Antarctic snowfall isotopic composition." - please use another word other than limited. I think you mean to say that post depositional processes alter the original signal, which must be accounted for in climate interpretations?

pg 4 line 13-16, "However, recent studies cast doubt on this assumption, evidencing isotopic exchanges between the Antarctic snow surface and the atmosphere associated with snow metamorphism occurring at the diurnal and sub-annual scales (Ritter et al., 2016;Casado et al., 2016;Touzeau et al., 2016)." âĂŤ- consider citing Steen-Larsen et al.?

pg 4 line 16-18: Again, the most recent diffusion study I have seen is Jones et al. 2017, it provides important information with an Antarctic perspective, and it should be cited here. There are important points in Jones et al. 2017 that improve on Sigfus Johnsen's 2000 paper.

pg 4 line 18-19: "So far, the overall importance of such post-deposition processes on the alteration of the initial precipitation signals cannot be quantified." âĂŤ This is not true. The alteration of the initial precip signal can be determined reasonably well by fitting a Gaussian to the data. Similarly, the Johnsen firn diffusion model, to the first order, is also a reasonable model for signal alteration. However, there are physical mechanisms that are still not understood.

pg 5 line 7: "δ18O and deuterium", should be "δ18O and δD (D refers to deuterium)" - something like this would be more consistent

pg 5 line 19: is this really the only exception??? “with one exception (Lee et al., 2008).”

pg 6 line 2: what is motivating “interannual scale” research, I suggest mentioning why this matters in the introduction

pg 7 line 11: “cautious” - caution?

pg 7 line 23: nudged to, what does this mean?

pg 8 line 10: just use dD rather than deuterium to avoid confusion, and make sure to define D, see above comment

pg 8 line 18-19: unclear what this means, “the averaging period may be heterogeneous, including subintervals within 1960-2013, or longer time periods.”

pg 11 line 3-5: “While this bias is small (less than 2°C)” - this is not small, please re-word

pg 11 line 8: “above the ice sheet” - what does this mean?

pg 12 line 1-2: “despite the nudging technique (not shown).” - what exactly is not shown? As mentioned previously, please explain nudging.

pg 14 line 21-24: “The largest deviations are encountered in coastal regions, where either the model resolution is too low to resolve advection and boundary layer processes (e.g. katabatic winds), or where post-deposition processes may have a larger influence.” âĂŤ Why would post deposition processes have a larger influence? Larger compared to what?

pg 15 line 23: “We have calculated the mean amplitude of the δ18O sub-annual variations” - please clarify what amplitude you are calculating? Monthly?

pg 16 line 2-4: “ECHAM5-wiso underestimates the seasonal amplitude (by 14 to 69%) when compared to precipitation data, but overestimates the seasonal amplitude when compared to ice core data (from 11 to 71%).” âĂŤ could the seasonal amplitude over-

estimation in the model be related to diffusion? These overestimations are similar to the annual signal attenuation examples I gave above.

pg 18 line 10-11: this needs more explaining and/or a citation - “Due to the temperature dependency of equilibrium fractionation coefficients, dexcess increases when temperature decreases.”

pg 19 lines 16-18: “ECHAM5-wiso systematically underestimates the d-excess mean seasonal amplitude when compared with precipitation data, while it systematically overestimates it when compared with ice core data.” could the overestimation be due to diffusion, which would decrease the dxs amplitude? what is the range of overestimation (in percent)?

pg 19 lines 26-27, pg 20 lines 1-2: “ECHAM5-wiso always underestimates seasonal amplitude of δ 18O and d-excess in precipitation but always overestimates seasonal amplitude of δ 18O and d-excess in firn/ice cores (Table 4 and 8). Differences between the model and firn/core data might be due to diffusion processes, but no clear reason can be given for the other isotopic biases.” - it is not accurate to say “might be due to diffusion”, because diffusion must have a substantial effect

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