

# ***Interactive comment on “Numerical experiments on isotopic diffusion in polar snow and firn using a multi-layer energy balance model” by Alexandra Touzeau et al.***

## **Anonymous Referee #1**

Received and published: 30 November 2017

Touzeau et al. presents a detailed study on implementing isotopes into a semi-complex one-dimensional snow pack model. Unfortunately it is my opinion that the authors still need a little bit more work to allow this publication to become a significant contribution to the community. I am though positive that the manuscript will be publishable after my major comments have been taken into account.

Major comments: (The following list of comments are not ordered in accordance with importance as they are more or less equally important)

- The use of parentheses throughout the manuscript is not in accordance with good practice. It makes reading the manuscript difficult. Please rewrite relevant sentences.

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- The term 'oriented vapor transport' seems to complicate the reading. The model has already been defined as 1D and hence no need to include the word 'oriented'. Please remove throughout paper.
- 'Vapor density gradients'. Please change to 'vapor pressure gradients' throughout the paper. The use of vapor pressure is the normal term used i.e Merlivat and Jouzel 1979 and Jouzel and Merlivat 1984 etc.
- If a sentence is longer than 2 lines, it is most likely too long. Please refrain from using extremely long sentence that complicates the understanding of the manuscript. This is seen at several instances through out the manuscript, but my favorite example is section 2.1 L106-109 where I really have no idea what is being described.
- Rephrase 'mean local pluriannual value' or describe what you mean.
- Rephrase 'oriented processes' or describe what you mean
- In L113 you write "Indeed, higher temperatures correspond to higher vapor densities, and also higher diffusivities in the vapor and the solid phase". This is correct, but then you line 260 define the vapor diffusivity in air to be a constant despite that it is depending on both temperature and pressure. This needs to be corrected. You need to allow for a temperature and pressure dependence on the diffusivity.
- I have a problem with your first sentence in the introduction "Ice is a key archive for past climate reconstruction, which preserves . . . indications relevant to the temperature of formation of the snow precipitation. . . variations of the isotopic ratio of oxygen and deuterium". This sentence is problematic because you have co-authors who have published papers documenting in both Greenland and Antarctica how the isotopic composition of the deposited precipitation is changed through exchange with the atmospheric water vapor isotopes. You cite 8 publications to document your statement, but they are between 10 and 30 years old. You thereby disregard published research for the last five years. Please update.

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- In L 17: Why not study the influence of temperature and not only temperature gradients? What is the difference between “compaction” and “Wind compaction”.? Do you study the effect of amount of precipitation or the isotopes of the precipitation?
- L 52: Use another word than “Mechanical shuffling”
- L119: You write that the annual cycles generally disappear at sites with accumulation lower than  $200 \text{ kg/m}^2/\text{year}$  – but does that not depend on time scales – please be more precise.
- L120: You write that the diffusion is more intense in the upper layers – but don’t the diffusion depend on the isotopic gradient and would you not expect that to be larger further down in the snow? Please be precise! Also the word ‘intense’ might not be the best to use in this case
- Section 3.1.2: Describe why the new vapor transport subroutine is inserted after module 5 but before module 6? What are the thoughts behind this?
- L251: “. . .is the effective diffusivity of water vapor in the snow at the interface”. Do you mean effective diffusivity of water vapor in the air between the snow grains?
- Equation 6: I am not sure, but isn’t a layer thickness missing from this formula as you might not have the same layer thickness in layer  $n$  and  $n+1$ ?
- Equation 7: Why do you use an analytical approximation of Clausius-Clapeyron around zero and not a more precise empirical formula?
- L 313 : “Long time” – what do you mean – please be precise
- L334: What vapor are you referencing to?  $\text{H}_2\text{O}$  in general or  $\text{H}_2^{16}\text{O}$ ?
- L335: I believe you meant to write “we will still have diffusion of heavy water isotopes during conditions where the water isotopic gradient is non-zero.
- L335-336: The sentence is very convoluted. I believe you could also have zero flux

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of H216O but a flux of H218O in one direction and HD16O in another direction.

- L353: “Here the condensation of excess vapor occurs without additional fractionation”. Why do you make this assumption”. Whenever you have a phase change due to condensation you will have isotopic fractionation. I think this is something that needs to be updated in your code.

- L356: “The transfer of isotopes takes place from the grain surface toward the vapor without fractionation” If you assume this then the interstitial vapor will not be in isotopic equilibrium with the snow surface. This would then correct itself. Hence I think that your code needs to be set-up such that the interstitial vapor is in isotopic equilibrium with the snow surface at all time.

- Please note that you throughout the paper are mixing up GRIP and Summit. They are two different geographical places in Greenland albeit being close to each other.

- I am surprised to read that there are no density measurements for neither GRIP nor Summit and that you therefore use NGRIP. Please double-check this.

- You do not give a relationship for the isotope-temperature relationship for GRIP. Please correct.

- Figure 2: You should include a comparison with the model of Johnsen et al. 2000

- Figure 3: You write in the manuscript that the temperature is varying but on the figure you only show temperatures for the summer. Does this mean that you only use summer temperatures? I would expect you would use varying temperatures through the whole year.

- I am surprised to find that your model do not show an influence of temperature gradients at GRIP as you would normally assume that temperature gradients would force vapor to be transported between layers due to the vapor pressure gradient?

- L503: Is the attenuation at GRIP significant larger than NEEM? 86% and 90% seems

very similar.

- L511: Why don't you calculate the attenuation using Johnsen at GRIP such that you can compare with Bolzan and Pohjola?

- L526: It is unclear how Denux in 1996 can indicate that a study by Johnsen et al. in 2000 overestimates the attenuation. Time travel hasn't really been possible yet. You might write that "A study by Denux (1996)..."

- L528: You write that Johnsen et al. should take into considerations temperature gradients in order to not overestimate the attenuation. But would you not expect that temperature gradients would increase the attenuation due the vapor transport driven by vapor pressure gradients?

- I strongly suggest that you set up an experiment with Crocus that allow you compare as closely as possible the simulated attenuation with the calculated attenuation using the model of Johnsen et al. 2000.

- Section 4.2.1: I suggest to remove the detailed description of simulation of density at Dome C to a supplementary material as it influences the flow of the manuscript which should be focusing on the evolution of isotopes in the snow pack.

- L 604: You suggest that the higher diffusion at GRIP compared to Dome C could be explained by higher temperatures – but in line 260 you assume that the diffusivity is constant and not influenced by temperature.

- In general for all the figures you need to adjust the values for the color bar such that you don't have too many digits. For example in Figure 2 the color bar should go from -0.6 to 0.6 and in figure 3 it should be -1.9 to 0.8.

- Figure S1: Why not combine panel b, c, and d

Minor comments

L14 "The isotopes . . . resolution" should not be in abstract

L16 “condensation is realized” – what does this mean

L21: “model underestimates” -> modeled attenuation due to diffusion is underestimated, or that other processes, such as ventilation influences attenuation

L24-25: should be moved to conclusion

L42: Randomness in the core stratigraphy -> stratigraphic noise

L45: series of snow pits -> series of records from snowpits

L53: ice microstructure at solid state -> snow grains due to solid diffusion

L58-61: Cite Ebner et al. 2016 and 2017

L87 Missing parenthesis after Brun et al. 2011

L99: Quick survey-> brief overview

L118: Wavelength of what?

L178: What do you mean by “Permanent cycles”

L184: to get an -> to obtain an

L185: Remove the content of the parenthesis.

L224: What does this mean: “and taken to compensate yearly accumulation

L240: What about the influence of absorption of radiation energy in layers below the surface layer?

L254: “Interface”: Please be more precise on defining what interface you are referring to

L258: “interpenetrate”: What do you mean?

L296: “that are” -> being

L304: Have you defined kinetic fractionation previously?

EQ 12: typo in  $D_{eff}$

L486: “Amplitude decrease by -1.3 ‰” – do you mean amplitude increase by 1.3 ‰

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Interactive comment on Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2017-217>, 2017.

**GMDD**

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