Response to ED [egusphere-2024-1012]

Black: Editor's comments. Blue: Authors' response.

ED: Editor comments

Dear Author,

Both reviews are in general positive but do make constructive suggestions that will help you prepare an improved revised version. In particular:

Dear Editor,

Thank you for handling the manuscript. I hope it is appropriate for me to post this reply as my *Final Response* in the interactive review process, as I have replied to the two reports RC1 and RC2, responding in detail to their points (except those on minor corrections regarding typos, local precision in wording, and inclusion of references). I appreciate the detailed, constructive and insightful comments by the reviewers.

My plan of revising the manuscript consists of (i) implementing changes in response to the reviewers' points and suggestions – I think that I should be able to address most of them, and (ii) extending the text in the Introduction (probably also in Sect. 4.1 or Conclusions) to put across the rationale of the study more strongly.

I respond briefly to the bulleted items below, including your comment about fast diffusion along small-angle boundaries.

- Please ensure that all hypotheses and simplifications that you use are explicitly stated. You may also briefly discuss their limitations.

  Yes.

- Please ensure that all your equation developments are reasonably easy to follow and to reproduce by scientists in the field. Your choice of parameter values must be justified. Reviewer 2 makes a number of remarks on this aspect that deserve your attention. Among these, your choice of grain size, and the impact of choosing other grain sizes, should be discussed.

  As described in my response to the RC1 and RC2 reports, I will (i) give more background behind the chosen ranges of wavelength and vein-water flow velocity, (ii) say more about the impact of grain-size variations on the isotopic pattern and the enhancement factor, and (iii) explain Figure 2 better in order to link the experimental and model values of D_b (grain-boundary diffusivity) more clearly.

- The relationship to ice core measurement must be improved, as recommended by Reviewer 1.

Yes, I plan to follow Reviewer 1's advice of illustrating the study with computed results for a signal of longer wavelength of 10 cm or so. Accordingly, in Sect. 4, I will pitch the inferences regarding the amplitude of the predicted patterns and the required experimental measurement sensitivity to detect them in terms of those results (rather than results for a 2 cm signal). As described in my reply to RC1, numerical results were computed across the parameter space so I have the relevant data at hand, and while Figs. 4–11 will be updated, their isotopic patterns and pattern transitions will not change much.

- I mentioned in my initial evaluation that the possible impact of small angle boundaries may also deserve consideration as diffusion short-circuits. Their presence is likely because of ice deformation. Please consider addressing this topic. How would considering these defects affect your equations and conclusions?

  Thank you for this idea. Yes, I can discuss this topic in the revised text. Its discussion will enrich the manuscript. This will probably be added to Sect. 4.2, where model limitations are discussed.

  The revision will probably explore a thread similar to the following. I perused the studies by Dominé et al. (1994) and Thibert and Dominé (1997), who interpreted experimentally-measured depth profiles of HCl concentration in ice single crystals for the occurrence of fast diffusion along small-angle boundaries inside crystals, i.e., sub-grain boundaries, and attributed this process as the cause of the high value and scatter of the apparent diffusivities of their samples. Dominé et al. (1994) estimated the HCl diffusivity along the small-angle boundaries (accounting for segregation of HCl there), at -5 to -15 °C, to be ~ 10^7 times greater than the "true" HCl diffusivity in the crystal lattice (away from the defects), which the two studies estimated to be probably ~ 10^{-16} $m^2\,s^{-1}$ at -5 to -35 °C. Therefore, when considering oxygen and deuterium isotopes, it is possible to conjecture that fast diffusion along small-angle boundaries could raise the amount of excess diffusion and complicate the isotopic patterns, by extending the short-circuiting network of grain boundaries and veins further into crystals; the outcome would depend on the density of small-angle boundaries. In exploring such a conjecture, a key question of whether (or how reliably) the findings for HCl translate to the problem of water self-diffusion, and one way to examine this question is to repeat the kind of experiments performed by these authors on water stable isotopes, instead of HCl.

  Given that my study's purpose is to compute the predictions of a short-circuiting model encapsulating the theories of Nye (1998), Johnsen et al. (2000), Rempel and Wettlaufer (2003) and Ng (2023), for informing the testing of those four theories, I think that adding other processes to the current mathematical model should not be necessary (in any case, this is difficult to do when the self-diffusivity of H_2O along small-angle boundaries and the thickness of these are not well constrained).

Please explain how you plan to respond to these suggestions, as well as the other Reviewers' comments.

I look forward to reading your responses.

Best regards,

Florent Domine

Editor

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Thank you for your consideration. Please let me know if further responses from me is needed.

Best wishes,
Felix Ng

References

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