

Review: “Doomed descent? How fast sulphate signals diffuse in the EPICA Dome C ice column”

by Ng et al.

Submitted to *The Cryosphere*

1 General

In this paper, the authors analyze the diffusion of key climate signals in ice cores, taking sulfate as the primary molecule of interest. They pick up the thread of the recent analyses by Fudge et al. (2024) and Rhodes et al. (2024), where the results of those papers differ, in part, due to their distinct methods for estimating the diffusivity. Felix Ng and company describe these differences and place their origin on a firmer theoretical foundation. The current authors then take the new theory inference and perform a new inversion. The results of this effort are sort of mixed and could be clearer (but maybe the answer is that the data / inversion is just inconclusively unclear). They then perform a forward simulation, which matches the data nicely and gives new insight. Then there is a discussion about the rate of diffusion through the firn. This part of paper is a little speculative and lacks some of the clarity from the earlier part of the paper.

Overall, this is a really well-written paper – Felix and team are articulate, poetic, and precise in their wording – a masterclass in writing. I like that this is an all-star team – with 3 recent papers on the subject – joining forces to get to the bottom of this question. I also like that this paper is eminently readable. There is a nice description of the physics of the $t - z$ transformation to $\psi - \zeta$. With a few minor changes, I am happy to support publication.

2 Remarks

1. I think more discussion of D_R is warranted – it turns out to be important and having not read Rhodes et al. (2024) in enough depth, I am wishing that it was clearer in the text.

3 Specific comments

1. Section 2.2.1 - it could be worth making the connection to the method of characteristics as motivation for the change of variables.
2. Line 192: what is the 4.2919 factor?
3. Lines around 320: is D_E the same as D_{eff} from before? I am missing the subtle difference.
4. Figure 4a: a legend or arrows could be helpful. It took some time for me to see the exponential curve.

5. Where is the first inversion approach plotted? Figure 5 is the second approach only, correct?
6. I am very confused by the oscillations in $D(t)$ shown in figure 5. Is some sort of regularization required?

References

- T. J. Fudge, R. Sauvage, L. Vu, B. H. Hills, M. Severi, and E. D. Waddington. Effective diffusivity of sulfuric acid in Antarctic ice cores. *Clim. Past*, 20(2):297–312, 2024. doi: 10.5194/cp-20-297-2024.
- R. H. Rhodes, Y. Bollet-Quivogne, P. Barnes, M. Severi, and E. W. Wolff. New estimates of sulfate diffusion rates in the EPICA Dome C ice core. *Clim. Past*, 20(9):2031–2043, 2024. doi: 10.5194/cp-20-2031-2024.