Response to Reviewer 1 (author's comments in blue)

This manuscript presents a well-structured and insightful study on the role of measurement precision in enhancing the resolvable resolution of ice core water isotope reconstructions, particularly focusing on the Beyond EPICA Oldest Ice Core (BE-OIC). The research is timely and addresses a critical gap in paleoclimate reconstructions by quantifying how measurement noise limits the recovery of high-frequency climate signals through deconvolution techniques. The analytical and numerical approaches are robust, and the results are clearly presented. The manuscript is suitable for publication after minor revisions.

We thank the reviewer for their recognition of the importance of the work and their overall positive assessment of the manuscript.

The description of the Wiener deconvolution process and its application to ice core data is technically sound but could be more accessible. Figure 1 shows the conception of how reducing the measurement noise to recovery of higher frequencies. I think the legend of figure 1 should be explained in more details to aid readers unfamiliar with signal processing.

We have modified the deconvolution explanation in lines 32 - 45 to with clearer and more precise language. We have also added the following description of Figure 1 at the end of the paragraph in order to aid the reader with the concept:

Fig. 1 illustrates a simplified version of this concept through idealised power spectra. The variability of the diffused signal (black) decreases with increasing frequency, until it falls below the variability of the measurement noise (dashed lines). The corresponding frequencies at which SNR = 1 is marked by the vertical lines. It is clear to see that decreasing the measurement noise by some amount ΔP_n (orange to blue) increases the frequency at which SNR = 1 by Δf.

Line 69-73, the authors indicate that the post-depositional processes have a lesser effect on longer timescales. However, the diffusion process is one of the post-depositional processes. Here is a little confused. What kind of the post-depositional processes do you indicate?

Here we were referring to wind redistribution, sublimation, melting, etc. which are more accurately described as depositional processes, not post-depositional. This has been corrected.

The diffusion length profile (Fig. B1) is critical to the analysis but is only briefly mentioned. More details on its derivation, including sensitivity to parameters like geothermal heat flux, would strengthen the manuscript.

In the revised version, we will expand the description of the diffusion length profile and include a discussion of how the results are affected by its uncertainty. However, the main focus of the manuscript is the influence of measurement precision on the achievable resolution in ice core water isotope reconstructions. These insights are broadly applicable, rather than tied to a specific ice core or diffusion length profile. The BE-OIC case serves as one illustrative example. Therefore, a comprehensive treatment of the derivation and all associated uncertainties of the diffusion length profile, including sensitivity to parameters such as geothermal heat flux, would exceed the scope of this study.

The authors should discuss the limitations of the deconvolution method. For example, briefly acknowledge any assumptions in the Wiener deconvolution method that might affect real-world applicability (e.g., linearity of diffusion, stationarity of noise) and discuss potential biases or uncertainties in the diffusion length profile (Appendix B) and how they might influence the results.

We've added a subsection to the discussion which details the following assumptions and application limitations:

One assumption made when applying the Wiener deconvolution method across some time series segment is that the diffusion length remains constant throughout the segment. In reality, since the diffusion length varies with depth, the mean diffusion length across the segment is used, resulting in slightly biased reconstructions. In most cases, this error can be minimised by applying the deconvolution across smaller segments.

Throughout the paper, measurement noise was approximated as white-noise, which enabled more generalisation and simplified some calculations. This approximation is appropriate for discretely sampled data, such as the Dome C water isotope record, due to the independence of consecutive measurements. However, when working with isotopic data from continuous flow analysis measurements, the complications from additional instrumental memory effects should be considered.

Given the limited data, the diffusion length model of the oldest ice core used in this study makes some necessary assumptions and thus the profile has significant uncertainty. While these uncertainties impact the absolute values of f_{max} calculated at each depth/age, the relative gain in reducing measurement noise remains largely unaffected. As such, the key point which quantifies the importance of reducing measurement noise is still valid.

Finally, in this study the PSD before diffusion (P_0) for the oldest ice core was estimated from the Dome C water isotope record. The convenience of an equivalent ice core from which P_0 can be estimated before measuring the new core will not always be available, especially for deep ice cores, and as such the P_0 estimation could be more challenging in future applications of this method.