In blue: Reviewer's comments. [ ] = Numbering

In black: Answers to referees.
P=Page; L=Line; Track change version
*In black and italic: Modification added to text.*

**Editor:**

Dear Authors
thank you for your clarification and corrections of the revised manuscript.

I'd like to come back to my first question, which was not fully answered.

I asked for
"I would like you to show the data on the vertical stratification of the snowpack physical state (at least some examples as supplementary material) and the local D values and see whether or not there is a contradiction between the conclusion from the $CO_2$ concentration profiles (D = const.) and the D calculated for vertical strata from snow pack physical states."

You did not yet provide " local D values" and did not explain "whether or not there is a contradiction between the conclusion from the $CO_2$ concentration profiles (D = const.) and the D calculated for vertical strata from snow pack physical states."

Your answer on the local D related solely to the small effect from snow temperature but not on effects of snow and soil properties such as snow porosity and tortuosity. (see lines 226 and 227: "Once the gas samples were collected, a vertical profile of snow and soil properties was measured to calculate snow porosity, tortuosity and the $CO_2$ diffusion coefficient") .

This sentence can be interpreted in a way that you calculated local D values from snow porosity and tortuosity (see, e.g. Albert, M. R. and E. F. Shultz (2002). "Snow and firn properties and air–snow transport processes at Summit, Greenland." Atmospheric Environment 36(15): 2789-2797., where the diffusion coefficient depended on porosity, their eq(1), and not only on temperature.

I do not ask for an extension of your work, but for clarification and reformulation, if you didn't calculate $CO_2$ diffusion coefficients including the effects from porosity and tortuosity . In your discussion I'd like to ask you to comment on the apparent contradiction, that the D can be found constant in a profile with large vertical variation og porosity and tortuosity values.

I hope this is now clearer, otherwise please ask.

We propose a better idea to clarify the misunderstanding about the diffusion coefficient. The diffusion coefficient in our manuscript is the air diffusion coefficient ($D_a$ in Albert and

Shultz 2002) which only depends on air temperature. In Albert and Shultz (2002), a snow diffusion coefficient ($D_s$) is defined to include the effect of porosity and tortuosity on $D_a$. We did not use a $D_s$ since we included the explicit effect of porosity and tortuosity in our main $CO_2$ flux equation (Eq. 1). We see how it was indeed confusing. We hence clarified in the manuscript that we are referring to $D_a$ and not $D_s$. Fig. A3 in Appendix A was modified to display $D_s$ stratification instead of snow density stratification. Fig. A3 is used to support some comments on the $D_s$ stratification that were added in the discussion (Sect. 4.3 Snowpack Importance).

P5, Eq. 1: $F_{CO2} = -\varphi \tau D_a \frac{d[CO_2]}{dz}$

P5, L159-160: where φ represents the porosity of the snow medium, τ its tortuosity and $D_a$ the *air* diffusion coefficient of the diffused gas in $m^2$ $day^{-1}$.

P6, L173-175: Standard *air* diffusion coefficients of $CO_2$ (unit: $m^2$ $day^{-1}$) are available in literature but must be corrected for temperature and pressure (Marrero and Mason, 1972; Massman, 1988):

P6, Eq. 4: $D_a = 0.2020 \cdot \left(\frac{T}{T_o}\right)^{1.590} \cdot e^{-\frac{0.3738}{T/T_o}}$

P7, L219-220: Once the gas samples were collected, a vertical profile of snow and soil properties was measured to calculate the $CO_2$ *air* diffusion coefficient *from the snow temperature*, and snow porosity *and* tortuosity *from snow density*.

P7, L224-225: Examples of snow vertical stratification along with $CO_2$ concentration measurements can be found in Appendix A (Fig. A3).

P17, 487-492: *Regarding the snowpack diffusion gradient method, the snowpack is used to estimate winter $CO_2$ fluxes. An average snow density was used to estimate snow porosity and tortuosity used in $CO_2$ flux calculations (Eq. 1), which does not consider the vertical stratification of the snowpack. However, the diffusion gradient remained linear despite vertical stratification in snow density (e.g., Fig. A3 where the average ratio between the standard deviation and mean of $D_{air} \cdot \varphi \cdot \tau$ is around 10%) which points toward a minimal impact of this assumption on our results.*

P32, Fig. A3: Examples of *snow diffusion coefficient ($D_{snow} = D_{air} \cdot \varphi \cdot \tau$)* vertical stratification and $CO_2$ concentration ($[CO_2]$) gradient measurements in function of snow height ($h_{snow}$) from the ground level. The coefficient of determination ($R^2$), $[CO_2]$ gradient (m) and y-axis intercept (b) for the linear regressions on the $[CO_2]$ gradient measurements are provided. *The ratio between $D_{snow}$ standard deviation ($\sigma(D_S)$) and average ($\overline{D_S}$) is provided in percent.* The data comes from (a) Montmorency Forest balsam fir closed-crown coniferous boreal forest on 2021-02-26, (b) Cambridge Bay prostrate-shrub tundra (hydric tundra: hydric sedge fen) on 2022-04-15, (c) Trail Valley Creek erect-shrub tundra (lichen) on 2022-03-26, and (d) Havikpak Creek black spruce open-crown coniferous boreal forest on 2022-03-16.