

The influence of layering and barometric pumping on firn air transport in a 2D model

Benjamin Birner et al.

General comments: The submitted manuscript analyses the influence of impermeable layer and barometric pumping (driven by surface pressure variability) on firn air transport using a 2D trace gas advection-diffusion-dispersion model accounting for discontinuous horizontal layers of reduced permeability. The simulated results are compared with field measurements from WAIS Divide and Law Dome DSSW20K and show good agreements.

Specific comments: The manuscript is well written and shows interesting results which are sufficient to be published. However, I would suggest to add some minor comments to make the manuscript clearer:

1. In the Figures, I would mention the time step you used for the plots. Are they consistent with the field measurements?
2. In the 'supplementary information' you show a table with some simulation parameters, however some information is missing or is unclear, respectively. (e.g. simulation time, time range of the simulations, resolutions, etc.)
3. I would recommend to also show plots of the boundary conditions at the surface, like temperature, pressure, etc.

Detailed comments manuscript:

Page 3, Line 5 – 6: I would recommend to make 'z', 'T', and 'R' italic to make it consistent.

Page 7, Line 2 – 3: Have you checked the influence of airflow due to temperature changes, especially in the convective zone? Normally, in the top 10-15 meters you have a high variation in the temperature profile due to the changing temperature at the top. This variation in the temperature profile can cause an airflow.

Page 11, Line 4: '... assumed to be temperature independent if the temperature sensitivity is unknown.' -> Where does this temperature sensitivity appear?

Page 11, Figure 7: There are two outliers in the observed CO₂ concentrations at around 15 and 50 meters. Is there a reason for this?

Page 11, Figure 7 caption: You refer to Fig. S9 to illustrate the differences in the CO₂ and CH₄ profiles between the 1D and the 2D model with or without barometric pumping which is not visible at the resolution of this Figure 7. However, Fig. S9 shows the same figure like Fig. 6 but only for Law Dome DSSW20K. Where can I find the Figure of the differences in the CO₂ and CH₄ profiles between the 1D and the 2D model with or without barometric pumping?

Page 12, Line 10: See my comment to Page 11, Figure 7 caption.

Page 17, Line 13 – 14: What could be the reason that the simulated ^{86}Kr excess is significant lower than the observed one?

Page 18, Line 6 – 7: 'Heavy, slow-diffusing isotopes approach gravitational equilibrium more slowly than lighter, faster-diffusing isotopes.' -> Maybe it is a silly question but is it not the opposite around? If the isotopes are heavy you have a faster settlement due to stronger gravitational force?

Page 22, Line 24: 'However, our experiments fail to ...' -> Which experiments? I cannot see in your manuscript that you did experiments, just simulations.

Page 24, Line 3 and 9: I think you want to refer to Eq. (A3) instead to Eq. (A4).

Detailed comments supplementary information:

Page 2, Equation S5: 'q' on the left-hand side of the equation is missing.

Page 4, Line 15 – 20: Does it mean that snow accumulation is included?

Page 10, Line 4: How long does it take to run one simulation with time steps of around 3 days?

Page 11, Section 'Thermal model': Can you show a figure of the temperature profile to get an impression of the boundary condition?

Page 11/12: The line break is wrong.

Page 12, Line 4: The line break is wrong and it should mean 'firn'

Page 12, Line 10: Please show a figure of the surface temperature histories.

Page 13, Table S1: Are the parameters the same for WAIS Divide and Law Dome DSSW20K if you only show one number, e.g. the 'Horizontal' or 'Vertical grid spacing'?

Page 13, Table S1, Row 'Width': Does this mean there is a variation of the width? What are the exact values for WAIS Divide and Law Dome DSSW20K you used in the simulations?

Page 13, Table S1, Row 'Depth of first layer': Can you provide an exact value?

Page 13, Table S1, Row 'Temperature': Did you use a fix temperature value at the top? No daily or seasonal variations?

Page 13, Table S1, Row 'Surface Pressure: Did you use a fix pressure value at the top? No daily or seasonal variations?

Page 13, Table S1, Row 'Free air relative diffusivities to CO₂': Can you show the value you cited from the Paper?

Page 15, Line 5: '... using q-values.' -> please change it to '*q*-values'.