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Interactive comment on "Annual CO_2 budget and seasonal CO_2 exchange signals at a High Arctic permafrost site on Spitsbergen, Svalbard archipelago" *by* J. Lüers et al.

J. Lüers et al.

johannes.lueers@uni-bayreuth.de

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Dear Frans-Jan Parmentier, first of all we would like to thank you again for your valuable comments and also that you give us the chance to discuss the data and paper. We had some discussion about your points, especially with regards to the CO2 "outbursts". I will summarize our ideas with respect to these processes:

First case (forced CO2 emission from snow)

Usually, the partial pressure of CO2 is much higher in snow and soil (due to ongoing soil respiration, and CO2 accumulation in the snow pack caused by limited exchange with the atmosphere) compared to the atmosphere (over 1000 ppm and more). This could be the case in our first described observation: No exchange between snow and atmosphere occurred for some time, and thus the total air pressure between snow and atmosphere is in equilibrium, but the concentration of CO2 in the snow can be higher. Then a rapid, meso-scale atmospheric pressure drop (10 bis 30 hPa) happens within a short time period (hours) together with high wind speeds. This forces an exchange of gas between snow and atmosphere, the air (possibly CO2 enriched but not necessarily) is pumped out of the snow (positive CO2 flux measured above surface with EC), until total pressure between atmosphere and snow is in equilibrium again. The partial CO2 pressure concentration of the air in the snow pack or in the atmosphere (or a possible gradient between the partial CO2 pressure in or outside the snow) doesn't play the leading role here, because this effect is very small compared to the overall total air pressure change. Due to the sharp, meso-scale total air pressure drop it is very likely that within the whole footprint area of the Eddy-flux instruments air is sucked out of the snow pack (or parts of the snow layer), and due to the deep air pressure in the whole atmos. boundary layer we will have an upward directed vertical air flow (and horizontal, converging advection flows, conservation of mass) close to or above the snow surface, thus a positive vertical wind component 'w' and therefore a positive NEE-Flux (the higher the amount of the pumped out snow/soil air or the higher this air is CO2-enriched, the higher the CO2-signal measured by the Eddy-Flux-system). This observation can possibly be connected or compared to the so called free-convection events (short but strong, convectional, positive sensible and latent heat fluxes). Their existents at Svalbard could be proved by Lüers & Bareiss 2011 (Lüers, J; Bareiss, J: Direct near-surface measurements of sensible heat fluxes in the arctic tundra applying eddy-covariance and laser scintillometry - The Arctic Turbulence Experiment 2006 on Svalbard (ARCTEX-2006), Theoretical and Applied Climatology, 105, 387-402).

Second case (CO2 deposit in snow)

Overall, the CO2 production in the ground is expected to be small during winter. Since October a continuous, very small CO2 emission (diffusion) occurs. In addition, strong, rapid CO_2 emission events (first case described above) maybe deplete the overall CO_2 concentration in the snow or only in the upper parts of the snow layers. Then, the end of winter (April), an atmospheric pressure decrease is followed by a strong, rapid atmospheric pressure increase, which forces the air into the snow until equilibrium between snow and atmosphere is established again (negative CO_2 flux). Thus, if we measure (above the surface) a down to the ground directed flux in most of this cases the vertical wind component 'w' is by definition negative and all the physical properties of this air package are also transported downwards. Now, as said, first the total air pressure between atmosphere and the (upper parts) of the snow layer are in equilibrium. Then a rapid, meso-scale air pressure increase occurred. That means pressure divergence, downward vertical air flow (negative 'w') and negative NEE-fluxes measure above the surface. This could also be connected to "Counter Gradient" CO_2 and heat fluxes, and transport caused by coherent structures and gravity waves. It is unfortunately true that we currently do not know what exactly happened with the depressed air, because we do not have appropriate measurement equipment yet. Beside a divergent horizontal advection above the surface, it is very likely that within the EC-footprint area fresh air is pumped into the porous snow layer (or at least into the upper parts) and maybe released again time delayed later. But what happened (some physicochemical reactions e.g. to store CO_2 in ice or snow or during snow crystal transformation) with the CO_2 inside the crystalline ice and snow structure, is also unknown and not explainable by our measurements yet.

We will adjust the relevant text parts of our manuscript according to the above discussion.

We agree that the CO_2 concentration curve in the figure 3 and part of the associated text is misleading in the paper and we will modify accordingly in a revised version.

best wishes Johannes Lüers

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