S1 Supplement on the density changes caused by vapor transport, compaction and wind compaction

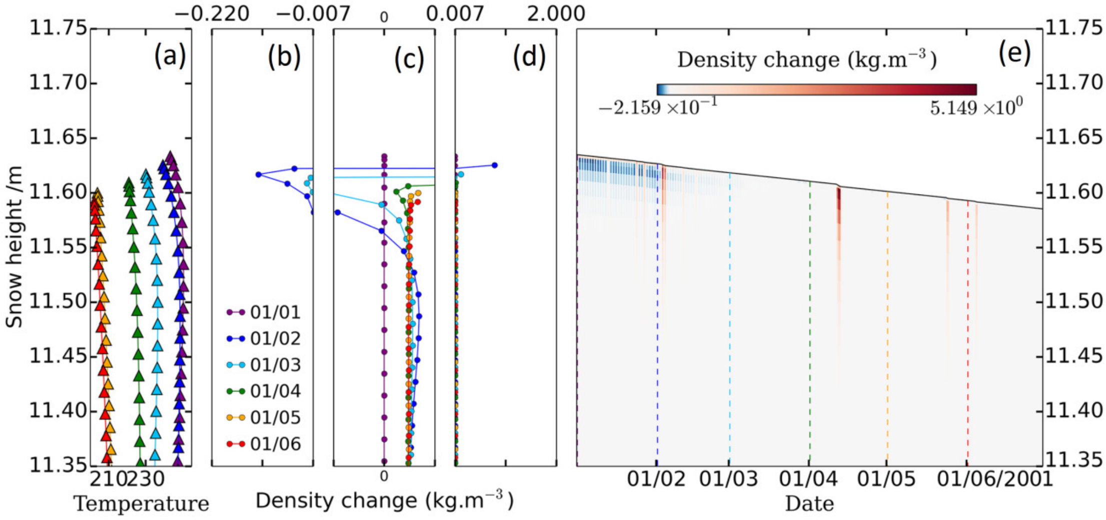

Figure S1: Density change per 12h (with vapor transport, with compaction and with wind drift).

Figure S1 presents results from the same simulation as Fig. 7 in main text, i.e. a simulation with homogeneous compaction and wind compaction, without precipitation. However we describe density change per 12h period instead of the cumulative density. Thus the magnitude of the change is necessarily reduced (shorter period). But wind compaction events become more visible (Fig. S1e). They correspond to a strong increase in density associated to a decrease of snow height (for instance on the 2^{nd}-3^{rd} of February, the 11^{th}-12^{th} of April, the 23^{th}-24^{th} of May and on the 3^{rd}-4^{th} of June). In the first two months, when the temperatures are highest, vapor transport is visible, but it becomes insensitive later on. Wind drift events are rare but lead to strong density changes (up to +5 kg m^{-3} (12 h)$^{-1}$), while vapor transport occurs every day in summer but never leads to changes larger than 150 g per 12 h. Figure S1b-d show the vertical profiles density changes at 6 dates. They show two interesting features not visible on Fig. S1e. First, positive changes of $\delta^{18}O$ are observed in the first layer (region of water arrival) at the end of January and February, indicating the orientation of water transport. Second, the layers below 11.50 m all show a slight density increase (3.5 kg m^{-3} (12 h)$^{-1}$). This homogeneous increase, constant with time, is caused by homogeneous compaction.

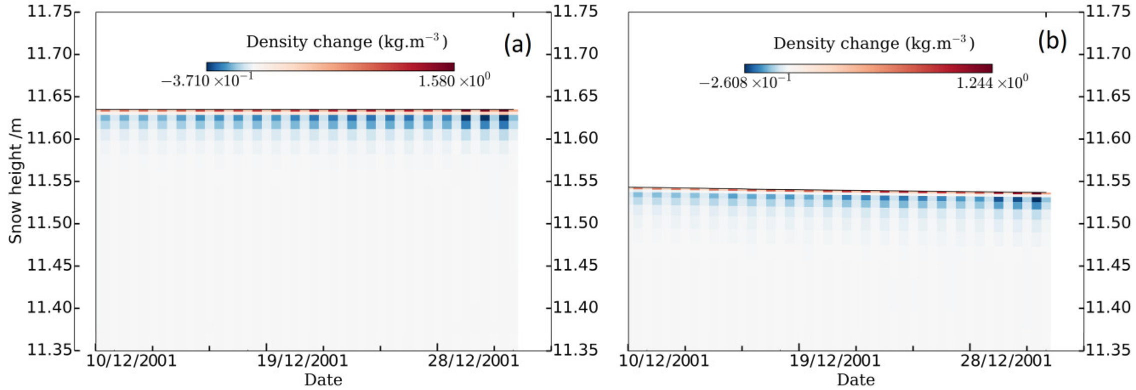

Figure S2: Density change per 12h period (caused by vapor transport only), in a case without compaction (a) and in a case with homogeneous and wind compaction (b), for the last days of December 2001.

Using the mass variation of each layer, it is possible to separate density changes caused by compaction or by vapor transport. Here we show the density changes caused by vapor transport only, per 12h period, for the case without any compaction (Simulation 3, Section 4.2.1.) and for the case with wind and homogeneous compaction (Simulation 4, Section 4.2.2.), in the last days of December (most active vapor transfer). The pattern is exactly the same, but the magnitude of the change is different. When the two compactions are active, the first layer receives less water and the layers below lose less water. This decrease in the intensity of vapor transport is expected because 1) the compaction leads to a smaller porosity, limiting vapor transport, and 2) because compaction increases the layer density and its thermal conductivity, thereby reducing temperature gradients in the snow, which force vapor diffusion.

S2 Supplement on the density changes caused by vapor transport, compaction, wind compaction, and precipitation

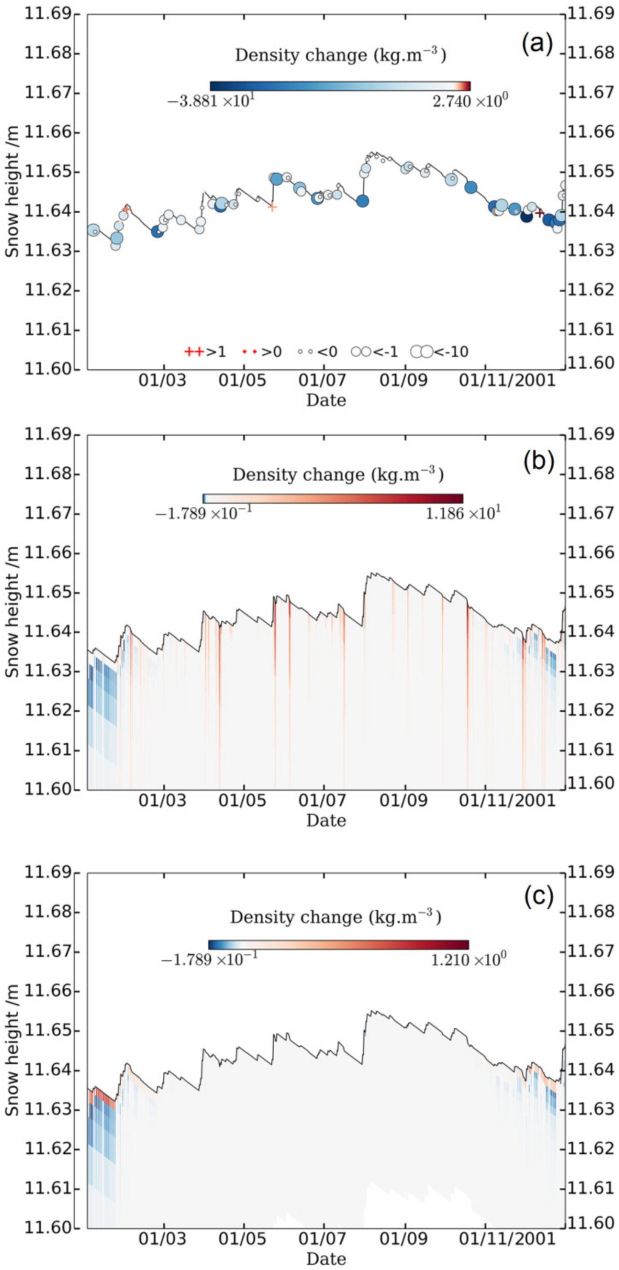

Figure S3: (a) Snow density change (12 h-period) for days with snowfall (snowpack height increases). (b) Snow density change (12 h-period): for days without snowfall (snowpack height decreases). (c) Change in snow density caused by vapor transport (days without snowfall only).

Figure 3a shows the density change per 12 h period in the first layer, only for periods with snowfall (increase of the total snow height). The values range from -38.8 kg m^{-3} to +2.75 kg m^{-3} with a mean value of -6.5 kgm^{-3} (or -2 % of the total density). Because of the low density of the new snow (304 kg m^{-3}), we indeed expect density loss during these snow fall events. Since the highest density measured in the first layer is 347 kg m^{-3}, the maximum density change on the advent of snowfall should be -43 kg m^{-3} (which is not attained here). The lower maximum, as well as the rare positive values of density change, is probably due to other processes active at the same time (compaction and/or vapor transport).

In between snowfall events (Fig. S3b), the density changes per 12 h period are mainly caused by wind compaction (with a maximum increase of 11.9 kg/m3 per 12 h period). Vapor transfer has a much smaller impact, with a decrease of density limited to 0.180 kg m^{-3} in the departure layers and a density increase limited to 1.2 kg m^{-3} per 12 h in the first layer (Fig. S3c). Thus precipitation and wind compaction are the largest contributors to density change in the first layer, and vapor transport has a limited impact. In the zone of vapor departure, the density change caused by vapor transport is visible only on the first half-summer (Fig. 9, in the main text) and overprinted by compaction in the second half-summer.

S3 Supplement on the seasonal evolution of $\delta^{18}O$ in precipitation and in surface snow (first layer)

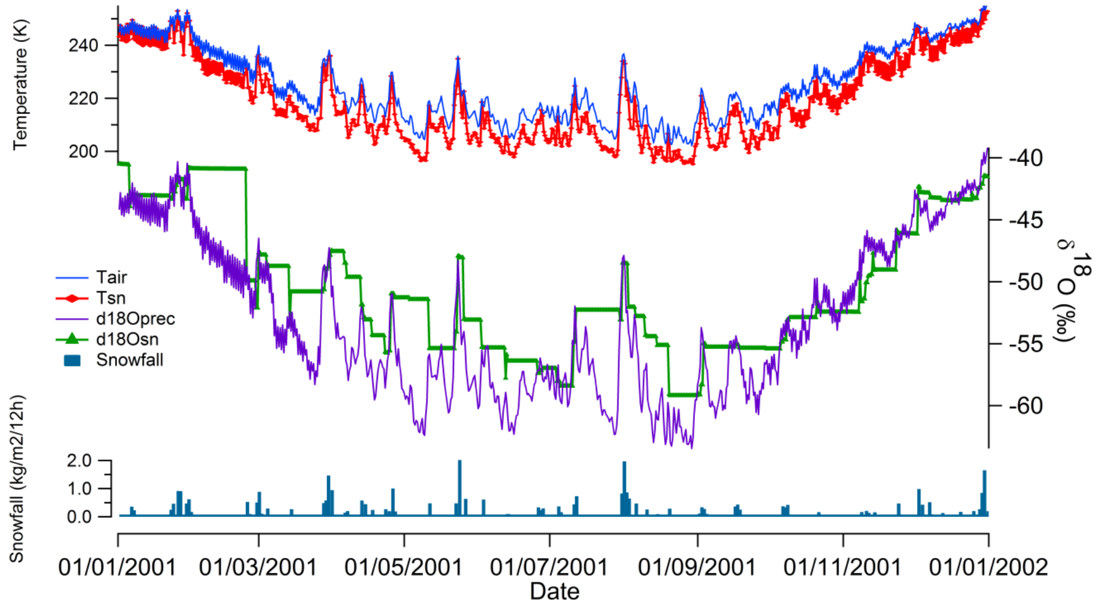

Figure S4: Seasonal evolution of $\delta^{18}O$ in the precipitation ($\delta^{18}O_{sn)}$ as well as in the first layer of snow ($\delta^{18}O_{sn)}$ as a result of variability in air temperature (T_{air}) for Simulation 5 (vapor transport, wind and weight compaction are active).

In this simulation, the same as for Fig. 10 in the main text, the temperature in the first layer (T_{sn}) closely follows the variations of the air temperature (T_{air}, 2 m) but is shifted toward lower values (~-8°C in winter; ~-4°C in summer). Snowfall events are associated with temperature increases, and therefore to peaks in the $\delta^{18}O_{prec}$ values predicted in the precipitation. The $\delta^{18}O_{sn}$ evolves mostly through brutal changes at each snowfall event, where it acquires the signature in the snowfall (new snow layer) or get closer to the composition in the snowfall (assimilation of the new snow in the preexisting first layer). The impact of vapor transport is not visible.