Response to Interactive comment on "Desiccation-crack-induced salinization in deep clay sediment" by M. I. Dragila (Referee)

By: Baram, S., Ronen Z., Kurtzman D., Küells C., and Dahan O.

The authors would like to thank the referee M. I. Dragila for the deep and comprehensive review, and the useful comments which helped us to improve and clarify our manuscript. Below please find our responses to the comments.

Comment 1: The data (Fig. 4) shows a relatively smooth enriched profile with depth and the typical near surface evaporation signature. The smoothness of the profile indicates a cyclic process of deep evaporation and infiltration. The signature is more enriched than the meteoric value but less than the expected near surface evaporation signature. The authors suggest this indicates cyclic enrichment from deep evaporation and dilution from deeply infiltrating water. Because the isotopic signature of groundwater at the site is not reported, the relative contribution to this signature from upward capillary movement is unclear.

Reply: See a detailed response to comment 2, made by I. Jolly. In short, the near-surface matric potentials, the temperature profiles, and the deep chloride profiles do not support upward capillary movement.

Comment 2: The oxygen signature shows stronger variability in winter than is summer. This could be explained by deeper evaporation during winter (data taken near end of winter, post rains). The thermal data indicates that summer gradients may be too low to sustain deep atmospheric plume invasion during summer months, especially since the seasonal thermal profile with depth generally reverses during summer to produce a stable thermal gradient. Therefore, from the point of view of deep evaporation driven by atmospheric invasion, it makes sense that the winter data would be expected to show more enriched signature locations.

Reply: We thank the referee for the comment. We added the following to the text to include that clarification: "It is possible that the higher variability in the oxygen signature at the end of the winter compared to the signature at the end of the summer, (Fig 4a, c and e) also reflects deeper evaporation during the winter, when the thermal gradients are steeper and deeper".

Comment 3: Is the variability in the del-O data real or within the expected error, considering the same variability (winter) is not seen in the del-H data?

Reply: The analytical error of the measurement of $\delta^{18}O$ and $\delta^{2}H$ in gas phase with laser spectrometry from equilibrated vapor is 0.25 ‰ $\delta^{18}O$ V-SMOW and 1.5 ‰ $\delta^{2}H$ V-SMOW. The measurement of soil water isotopes in clayey soil is less precise than measurements in other soil textures, due to the potential occurrence of intra-layer fractionation. However, intra-layer fractionation has been reported to affect mainly the isotopic fractionation of $\delta^{2}H$ at low temperatures and hardly affects the fractionation of $\delta^{18}O$. The impact of these potential and other specific fractionation processes were accounted for by 2-point calibration of standards for ^{18}O and ^{2}H in clay matrix from the same site. Including uncertainties from sampling, transport and sample preparation during equilibration, the overall analytical error is given by 0.5 ‰ for $\delta^{18}O$ and 2.5 ‰ for $\delta^{2}H$. Hence, the observed variation is the ^{18}O profile is considered natural.

Comment 4: On page 13163 the authors comment that they assume that the relative humidity of the invading atmospheric air immediately reaches 100% humidity. While assumptions such as this can be used to make first order calculation, it should be clarified for the sake of future readers that in real life evaporation of the fracture is only sustained while the relative humidity of the invading air is less than that of fracture air, and published data (Weisbrod et al., 2009, 10.1029/2008GL036096) shows that relative humidity during air invasion drops significantly within the fracture system.

Reply: We thank the referee for the comment. The reviewer is correct; the actual water vapor loss depends on the differences in relative humidity between the atmospheric and fracture air and eventually the ability of the matrix to provide water vapor becomes the limiting factor. We added the following section to the text to clarify this point: “It should be clarified that actual water vapor loss due to convection depends on the water vapor pressure differences between the atmospheric and the fracture air. As the thermal gradient increases and subsequently so do the convective fluxes, the limiting factor becomes the ability of the matrix to provide water vapor to the fracture air (Kamai et al., 2009; Weisbrod et al., 2009). Kamai et al. (2009) showed that at temperature difference (delta T) of 10 °C the water vapor loss due to thermal convection is at maximum, and increasing delta T will not result in increase water vapor loss".

Comment 5: Sec. 3.3- Thermal gradients. Please clarify the explanation of the data on page 13169-70. Diurnal changes in the thermal gradients only extend to a limited depth. Below about a meter the thermal gradient changes seasonally. For convective venting to lead to atmospheric invasion, and for atmospheric invasion to proceed downward, what is important is the magnitude and direction of the slope of the gradients that are exhibited at different times of the year. Note that during summer months, the seasonal gradient at your site may not be conducive to deep convection.

Reply: We acknowledge the comment. We agree that the thermal data collected in the field are not sufficient to quantitatively determine the exact duration and magnitude of thermal convection. We added a sentence to clarify this point and slightly revised the text: "Measurements of the temperature gradients between the land surface and the clayey sediment profile (matrix) (> 6 m BLS) (using the thermocouples on the VMSs; Table 1) showed very small daily oscillations and clear seasonal trends. The differences between the temperature of the atmospheric air and the temperature of the matrix (down to 6 m BLS) were most significant during the winter (>10° C, extending down to 6 m BLS) and were smaller but still significant during the summer (July – September) (>2° C, extending down to 1.5 – 2.5 m BLS). Weisbrod et al. (2000), Weisbrod and Dragila (2006) and Kamai et al., (2009) demonstrated evaporation and salt buildup in fractured rocks, due to thermally driven convective air flow in fracture voids. More research is needed to quantitatively link between the thermal gradient in the field and the depth and magnitude of the thermal convection".

Comment 6: This work leads to a potential future project and a very important question: what is the long term pervasiveness of these invading atmospheric plumes? Are these signatures repeated from winter to winter at the same depths? Do the same fractures (that the authors state are pervasive) vent the vadose zone in the same way from one winter to the next? If so, this may have significant implications for the physic-chemical evolution of fracture vadose zones.

Reply: We thank the reviewer for her comment. A few sentences were added at the end of the conclusions to highlight the open scientific questions which were raised by the reviewer.