Title: The patterns and implications of diurnal variations in d-excess of plant water, shallow soil water and air moisture

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Interactive comment on "The patterns and implications of diurnal variations in d-excess of plant water, shallow soil water and air moisture" by L. Zhao et al.

Anonymous Referee #2

Reply to comments of reviewer 2:

The manuscript of Zhao et al presents a detailed set of investigations into the deuterium excess (dex) of waters in of plants, soils, and the surface atmosphere across a basin in central China. At five sites over a period of 1-3 days these quantities were measured at 1-2 hour frequencies, and thus present an interesting dataset with which to explore the role of vegetation in controlling the diurnal cycle. While I find the objective of this paper an interesting topic, I feel that more could be done to demonstrate the how plants, soils and meteorological conditions influence isotopic cycling in these environments. Many of the results of this study are consistent with previously understood dynamics in the soil-plant-atmosphere continuum. The isotopic enrichment of waters as it moves from soils into xylem, from xylem to leaves, and from leaves to the atmosphere has been actively studied by Farquhar, Cernusak, Ehleringer, Dawson, and many others. The authors demonstrate a diurnal cycle in leaf dex values, but no attempt is made to reconcile these observations with well-understood dynamics of leaf enrichment. In order to justify the authors conclusions about the role of plants in mediating the dex content of surface vapor, these models should be tested to see what the diurnal cycle of leaf transpiration dex would be based on theory.

Reply: We appreciate reviewer's positive comments on the scope and significance of the research. We agree with the reviewer that incorporating modeling exercise will enhance the implication of results. However, we want to note that the main body of modeling work of isotopic leaf enrichment is focusing on ^{18}O. ^{2}H enrichment is not commonly seen in literature with several unconstrained parameters. This makes the d-excess modeling difficult to be validated. For this particular experiment, we didn't measure several physiology parameters such as leaf transpiration flux required for modeling of leaf $^{18}O/^{2}H$ enrichment and consequent d-excess. We believe the major contribution of the study is to provide a comprehensive dataset of d-excess under various climatic conditions and to assess the environmental controls on the d-excess variations. Such information will be very valuable for any modeling exercise in the future, which is our plan for future experiments.

In addition, we don't think observation data alone won't be able to justify our conclusions of the role of plants in mediating the d-excess dynamics. We had done extensive statistical analyses between d-excess and environmental variables and multiple lines of evidence support our conclusions. In the revised manuscript, we have carefully revised many parts of the discussion to strengthen the logic flow.

The trend in dex of soil moisture observed at S3 is very puzzling. The limited explanation that the authors give is not sufficient nor justified by any mechanistic process know to occur in soils. Much more detailed assessment of these data are needed or this section should be removed as it is not adequately addressed. Overall, I find the analysis of the collected data in this manuscript weak. The figures (with the exception of F1 and F3) all plot observed data with respect to time, yet many claims are made about the relationship between dex and meteorological conditions are made.

Reply: We have re-wrote the discussion section for d-excess of soil moisture. The unique pattern of d-excess of soil moisture at S3 is very interesting. Multiple evidence showed that it's caused by strong evaporation and we have elaborated this by adding additional evidence. In terms of overall analysis, like we mentioned earlier, we had done extensive statistical analyses between d-excess and all the available environmental variables to explore the controlling factors of d-excess dynamics, we adjusted several sections for better flow and reduced repetition. The plots showed the observed data with respect to time and tables showed the statistical results between d-excess and all the available environmental variables.

P4434:

L9: Add in note about the ecosystem types assessed for those not familiar with the Heihe Basin.

Reply: We added more information about the ecosystem types here.

L10: This wording implies that measurements were made over multiple days (please clarify)

Reply: Yes, the measurements were made over multiple days. Please find the detailed sampling times in the Fig. 2.

L11: Change ‘plots’ to ‘values’

Reply: We changed ‘plots’ to ‘values’ according to reviewer’s suggestion.

L12: The conclusion that dex values vary between different pools, or that there is a diurnal cycle in the atmosphere is not a novel finding.

Reply: Yes, “There were significant differences in d-excess values among different water pools at all the study sites” and “there is a diurnal cycle in the atmosphere” are not a novel finding per se and they are introduction sentence of their corresponding conclusion.

L17-22: Many of these relationships are expected from classic models such as Craig-Gordon, why is this novel?

Reply: Yes, in theory, the general direction of many relationships could be predicted using models like Graig-Gordon. However, the magnitude, the variations, and the diurnal patterns are not easy to predict due to the uncertainty in ^{2}H calculations as we mentioned earlier. And field observed d-excess variations are not readily seen in literature yet, not to mention the high-resolution ones of multiple pools.

P4435 L17: Explain this with respect to the physical processes that affect dex first, then note the graphical relationship afterward.

Reply: We revised this sentence as suggested.

P4436:

L5: dex ‘in surface atmospheric vapor’

Reply: We added ‘in surface atmospheric vapor’.

L20: The theory of Merlivat and Jouzel was developed for open water evaporation where delta_ET = delta_A, why is this theory relevant here?

Reply: The soil evaporation process is similar to open-water evaporation (i.e., the application of Craig-Gordon model for soil evaporation). And the prediction of Merlivat and Jouzel is one of the few that theoretically predicts the quantitative relationship between d-excess with T and RH.

L25: This is an interesting point. What do model like those of Farquhar and Cernusak predict?

Reply: As far as we know, Farquhar and Cernusak model didn't report d-excess, though in theory they could.

P4437 L10: I feel that (2) is not addressed sufficiently.

Reply: We have thoroughly revised the discussion to provide more mechanistic understanding of d-excess.

P4439 L14: How many locations, where were they located relative to the vegetation?

Reply: We added the contents "at S1-Sep, S1-Jun, S2-Jun and S3-Aug in the upper reaches and at S4-Aug and S5-Aug in the lower reaches (Figure 1 and Table 1). At the S1-Sep, S1-Jun and S2-Jun, the sampling of air moisture were collected within a canopy and near ground (about 20cm above the ground). At S3-Aug, S4-Aug and S5-Aug, the sampling of air moisture were collected within a canopy." in L14.

P4440 L5-12: A better description of the weather stations would be helpful. What instruments were used, at what height above ground were the measurements made?

Reply: We added additional description of the weather stations as highlighted below.

At S3-Aug, every 30 min with a weather station permanently installed at the station (HMP45C for measuring T and RH, LI190SB for measuring PAR) at 2m, 10m and 24m height. At S1-Sep, S1-Jun, S4-Aug and S5-Aug, RH, T and PAR were measured every 10 min with two portable weather stations (Davis Vantage Pro2 portable weather station) at 2m. We compared the T and RH measured with two different weather stations and different height, and no remarkable differences and diurnal variations were found among them. Thus, only 2m height weather data such as T, RH and PAR were used in this paper. We measured T, RH and PAR due to their significant effects on soil evaporation and transpiration.

P4444:

L6: Much of this section is just stating what's in tables 5 and 6.

Reply: We shortened this section.

L17: Again, what at what heights were measurements made? This clearly affects your results.

Reply: Height information was added.

P4446:

L21: What is the justification for this statement?

Reply: We changed this statement as "Our results show that there are significant differences in δD and $\delta^{18}O$ among leaf and xylem water, soil water and air moisture, and different δD-$\delta^{18}O$ patterns due to hydrogen and oxygen isotopic discrimination related to soil evaporation, plant transpirations and plant physiology."

L24: Leaf water enrichment during transpiration has been understood for a long time, as is the influence of T and RH on this process.

Reply: Yes, we agree with this and we explained this in the manuscript: **"**For example, compared to that of xylem water and shallow soil water, leaf water have the highest average δD and $\delta^{18}O$ values and the largest ranges, and showing the greatest variation in $\delta^{18}O$ values in all the study sites. In addition, the δD-$\delta^{18}O$ plots of leaf water highly deviate from their corresponding LMWL (Table 2; Fig. 3), suggesting a strong transpiration enrichment effect. With the decrease of RH and increase of T, leaf water δD and $\delta^{18}O$ values increased and the δD-$\delta^{18}O$ plots gradually deviate from their corresponding LMWL due to stronger transpiration, suggesting that climatic conditions have significant effect on variations of leaf water δD and $\delta^{18}O$ and their correlations by affecting transpiration (Table 2 and Table 3)."

P4448:

L23: What does the Farquhar and Cernusak model (or something similar) predict for the effects of transpiration on dex in leaves. What role does RH and T play in this as well?

Reply: As mentioned earlier, the main body of modeling work of isotopic leaf enrichment is focusing on ^{18}O. ^2H enrichment is rarely seen in literature with several unconstrained parameters. This makes the d-excess modeling difficult to be validated. For this particular experiment, we didn't measure several physiology parameters such as leaf transpiration flux required for modeling of leaf $^{18}O/^2H$ enrichment and consequent d-excess. We believe the major contribution of the study is to provide a comprehensive dataset of d-excess under various climatic conditions and to assess the environmental controls on the d-excess variations. Such information will be very valuable for any modeling exercise in the future.

L26: Is this always true? What if the original oceanic source of some of the vapor had a low RH and the dex of entrained atmospheric moisture is quite high?

Reply: We revised this sentence to make it more accurate.

P4449 L11-21: This 'trend' in dex of soil moisture I find very confusing? You state multiple times, and is often reported in the literature, that root uptake doesn't fractionate. Then the only other mechanism to alter the soil dex is evaporation. But evaporation will result in enriched soils and result in a lower dex. How do you possibly explain the increases in dex at the end of the day? Why does only this sample show this trend? This finding is very puzzling and not explained adequately!

Reply: We re-wrote this section of discussion and aimed to better explain the pattern.

This map is difficult to read, and may print poorly in black and white. Perhaps swap the locations of the North arrow and the legend (after removing Yagan) and use a color for the rivers not found in the terrain gradient.The legends for this and other plots are very unclear. Please state which panel corresponds to which site. Please use the same tick spacing on x-axis (12hrs) on each plot so that the observational windows can be compared more easily. Also remove the minutes (here and elsewhere) since they are all zero.

Reply: We revised the legends of all figures, and we remade the Figure 2 according to reviewer's suggestion.

Combine this and figure 7 and plot as in F2. This would allow us to see the difference between sunny and shady days more clearly.

Reply: We combined mean RH and T at the sunny day in the Figure 4.

We combined RH and T at the cloudy day in the Figure 7.

Combine this and figure 8 as above.

Reply: We combined RH and T at the cloudy day in the Figure 8.

What does the shaded area and the grey arrow signify. Plot the relationship between dex in the various pools with PAR, T, and RH. Where are there strong relationships?

Reply: We added a note in the Figure 5 to explain the shaded area and the grey arrow. There will be too many figures if we plot all the relationship between dex in the various pools and PAR, T, and RH. Therefore we used tables to show their relationships. In addition, we only analyzed the relationship between dex in the various pools with T and RH. The strong relationships were indicated with P values in the Tables 6, 7, 8 and 9.

What does the relationship between dex of leaf water and dex of the atmosphere look like?

Reply: Positive relationships were found between dex of leaf water and dex of the atmosphere.