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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Volatile organic compound emissions from *Larrea tridentata* (creosotebush)" *by* K. Jardine et al.

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We would like to kindly thank reviewer 2 for the many helpful comments. Our point by point responses to the comments are below.

Comment 1 The paper is merely a listing of compounds detected and emission rates measured without offering insights into the ecology/physiology of the observed emissions.

Response 2 The major objectives of our paper were to identify and quantify the complex array of VOCs emitted from creosotebush branches and demonstrate that significant ambient concentrations can be measured. Towards this goal, our paper also describes the technical methods needed to identify and quantify the wide range of structural classes of VOCs using PTR-MS, GC-PTR-MS, TD-GC-MS, as well as the required calibration techniques. While we hope that our results stimulate additional research into the ecological/physiological as well as atmospheric processes involved, we disagree that our paper provides no insights into these topics. For example, the functional role of VOC emissions by plants has been long debated with isoprene dominating the discussions. By detecting significant primary emissions of isoprene as well as several isoprene oxidation products from creosotebush, we provide direct evidence that volatile isoprenoids serve as antioxidants in plants.

Comment 3 Surely modellers need to know which compounds are emitted, but as well will they need to know which factors are governing these emissions in order to represent these in the models. In order for the diurnal courses to make sense we need to know about potential environmental driving factors such as temperature, radiation, vapour pressure deficit and so forth. In addition it would be helpful to see diurnal courses of photosynthesis and stomatal conductance – the authors used an infrared gas analyser (Fig. 1) so I presume they are able to calculate leaf CO2 and H2O fluxes. An important question to answer in my view would be the one of which role stomatal conductance plays in the observed emission patterns or are these driven simply by temperature and radiation (which will be of importance for extrapolating to dry season conditions).

Response 3 A new discussion in the results section on the role of ambient temperature and solar radiation on influencing the emissions is now included. These environmental variables were continuously measured for each branch studied. Unfortunately, we encountered a software problem in the field with the infrared gas analyzer and therefore cannot include CO2 and H2O flux data or stomatal conductance.

Comment 5 In order to get a better feeling about the magnitude of emissions it might be worth considering plotting more compounds within one panel (possibly also in a cumulated fashion).

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Response 5: We have improved the appearance of the plots and include a summary of the magnitude of emissions in Table 1 for quick reference.

Comment 6 Similar arguments apply for the ambient concentrations – here in addition it would be helpful to see wind direction and have an idea about the concentration footprint (anthropogenic sources in particular). Generally the story line on the ambient concentrations is poorly (if at all) linked to the leaf gas exchange measurements because no ecosystem-scale flux data are reported and (untested) hypothesis about boundary layer development have to be invoked. From the setup (sonic anemometer and intake for ambient air samples on tower) I suppose that VOC fluxes can be calculated using some disjunct approach. If so, I would strongly suggest to merge these data into the paper in order to make it more significant.

Response 6 We agree that this data will be very useful for understanding the atmospheric impacts of creosotebush VOC emissions. However, in this paper we did not measure ecosystem fluxes as this would require very fast VOC measurements ($\sim$0.1 sec) and a greatly reduced set of compounds (<5). The main purpose of including the ambient VOC concentration measurements is to demonstrate that the majority of compounds found to be emitted from individual branches can be detected in the ambient air above the canopy.

Comment 7 Given the claimed large total VOC carbon emissions on a dry weight basis it would be also interesting to compare these with the magnitude of CO2 fluxes - from the data you present I get the impression that dealing with stress consumes a much larger fraction of the (probably comparatively small) CO2 assimilation of this plant species as compared to temperate ones which is ecologically interesting. Whether emissions from this ecosystem are indeed significant can only be assessed when scaled up to a ground area basis and integrated over a longer time frame (at least a dry season but preferably an annual cycle).

Response 7 Regarding comparing CO2 and VOC fluxes, we agree that this is an im-

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portant step in understanding the plant physiology of creosotebush. Unfortunately, we were not able to obtain CO2 flux measurements due to a software problem with the infrared gas analyzer. We also agree that additional work is needed to determine if creosotebush VOC emissions are important at the local and regional scales. In the future, we hope to conduct ecosystem scale flux studies coupled with ozone/NOx over a full annual cycle to answer this question.

Comment 8 p. 17117: here we are lacking a statement of the research objectives/hypothesis; note that the hypothesis formulated in l. 20-22 cannot be tested with the present data but would need additional measurements during the dry season

Response 8 We now include a statement of the objectives of this study in the introduction.

Comment 9 p. 17118, l. 7: use SI units throughout the paper and in the supplementary material

Response 9 SI units are now used throughout paper and supplementary material except when describing the GC oven temperature programs where minutes are used to be consistent with the GC literature.

Comment 10 p. 17119, l. 10: in my experience detaching branches and twigs may easily lead to artifacts in terms of the magnitude and composition of emitted VOCs – have the authors checked their data for such effects?

Response 10 In this study, VOC identities were determined by GC-MS and GC-PTR-MS from samples collected from intact branches in the field as well as by GC-MS from a detached branch brought to the Biosphere 2 trace gas laboratory. All quantitative work was done with PTR-MS in the field. We acknowledge that detaching branches can create artifacts with respect to the composition of VOC emissions. We will include the following in the results section. "All but four compounds (1-hexen-3-one, 1-octen-3-one, limonene oxide, 1-methoxy-2-methyl-benzene) detected from the detached branch were also found to be emitted from intact branches in the field. However, intact branches in the field emitted many additional compounds (>24) not detected from the detached branch under laboratory conditions."

Comment 11 p.17120, l. 22-p. 17121 l. 6: should go into methods section

Response 11 The recommended change has been made.

Comment 12 p. 17121, l. 8-9: are Figs. 5-13 showing all the same days – what about the other days?

Response 12 Figs. 5-13 all show the same days as representative time-series plots of the data. The other days qualitatively show the same diurnal patterns but with different branch emission and ambient concentration magnitudes. In the updated Table 1, we summarize the variability of noontime emission rates and ambient concentrations.

Comment 13 p. 17121, l. 10: what is driving these strong diurnal patterns?

Response 13 We now include photosynthetically active radiation and branch enclosure air temperature data to support the discussions on the environmental drivers of the branch VOC emissions.

Comment 14 p. 17121, l. 15-16: this would imply growth to take place during the night – any data to back up this hypothesis?

Response 14 We do not have any data to back up this hypothesis, but note that the continued production and emission of methanol in plants at night has been previously described (Harley et al., 2007). In the new manuscript, we have inserted the reference by Harley et al.

Comment 15 p. 17121, l. 29: a sonic anemometer measures the speed of sound from which the so-called sonic temperature may be calculated; the latter is very close to virtual temperature; calculating air temperature requires an estimate of air humidity; very often air temperatures calculated with sonic anemometers may exhibit several

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degrees offset (which is not a problem for eddy covariance though were the average is subtracted anyhow).

Response 15 We will acknowledge the potential offset between sonic temperature and the actual air temperature in the discussion. “Although an offset of a few degrees between the sonic temperature and the actual air temperature likely exists due to humidity effects on air density, these values fall into a normal ambient temperature range for low elevations of the southwest region during the summer, and suggest that extreme heating inside the branch enclosure did not occur.”

Comment 16 p. 17122, l. 6: what are the causes for the factor of 10 variation?

Response 16 We now include the following sentence, “The cause of the variation observed in noon time branch VOC emission rates may be due to variations in environmental conditions like light and temperature, natural variability between branches/plants, and variability influenced by physiological processes like flowering during the experiment. During the summer of 2009 monsoon, at least two distinct flowering events occurred.”

Comment 17 p. 17122, l. 21-22: how did you quantify the loss of these compounds?

Response 17 The loss of these compounds in the condensed water was not quantified. Emission rates of these compounds were only reported from the three branch enclosures where condensation did not occur.

Comment 18 p. 17123, l. 13: what is (wet & dry) nitrogen deposition to this site?

Response 18 We did not quantify nitrogen deposition to this site.

Comment 19 p. 17123, l. 14 and 17: you need to convert the leaf area values to ground area for this comparison to make sense.

Response 19 In the new manuscript, we have converted the leaf area values to ground area to facilitate the comparison.

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Comment 20 17129, l. 1-4: in order to really judge whether emissions are substantial we need to know (i) about values on a ground area basis and (ii) integrated over at least one wet and dry cycle, preferably over the course of a year.

Response 20 We agree and have changed the text to the following: “Although desert ecosystems are generally considered small sources of reactive hydrocarbons in the atmosphere, we find substantial branch-scale emissions of a wide variety of compounds from creosotebush which were also detected in the ambient air above the canopy. Additional research to quantify ecosystem-scale VOC fluxes, preferably over a full annual cycle, is needed to understand the impact that these emissions may have on regional air quality and climate.”

Comment 21 p. 17130, l. 15-17: previously you mentioned no obvious signs of stress!

Response 21 We have rephrased this to avoid confusion as follows. “Although the branches were not under any obvious mechanical or herbivory stresses while in the enclosure, other abiotic stresses may have been present such as elevated light and temperature typical of noon time conditions.”

Comment 22 Table 1: for printing in b&w I would suggest to use different graphical means of grouping data.

Response 22 Solid black lines are now used in Table 1 to group the data.

Comment 23 Fig. 1: would profit from using more standardized symbols; e.g. what do the little arrows on VOC standard and zero air represent?

Response 23 We have provided more detail in the Fig. 1 legend with respect to the symbols used.

Comment 24 Supplementary material: essential methodological information should be moved into the main paper.

Response 24 The recommended change has been made.

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References Harley, P., Greenberg, J., Niinemets, U., and Guenther, A.: Environmental controls over methanol emissions from leaves, Biogeosciences Discussions, 4, 2593-2640, 2007.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 17113, 2010.

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