Response list to the reviewers' comments

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Title: **Soil moisture control on sap-flow response to biophysical factors in a desert-shrub species, Artemisia ordosica**

Authors: TianShan Zha, Duo Qian, Xin Jia, Yujie Bai, Yun Tian , Charles P.-A. Bourque, Jingyong Ma, Wei Feng, Bin Wu, Heli Peltola

Dear Editor,

Thank you very much for your helpful comments and suggestions for improvement of our manuscript. We have been carefully looking at your comments and revising the manuscript accordingly. The following below are our responses showing how we have been revising the manuscript.

We are looking forward to your further comments and a possible publication in the BG special issue (Ecosystem processes and functioning across current and future dryness gradients in arid and semi-arid lands)**.**

Kind regards,

Tianshan Zha

Anonymous Referee #1

General comments

*As the paper is about the soil moisture control on sap-flow and its response to meteorological variables, a physical basis for the definition for drought condition and its severity should be included. Instead, the authors keep on changing their definition of dry conditions for each year and in various figures. What is the reason for using 0.08 m3 m-3, as the threshold to identify drought periods? Is it for severe, moderate or mild drought? The analysis lacks consistency (Example figures 2 6). In section 2.4, they used 0.08 m3 m-3 as the threshold to identify drought conditions. In Figure 2, it is 0.11 m^3 m^{-3} for the drought year 2013 and 0.09 for the wet 2014. Why don't they use 0.08 m^3 m^{-3} in both years? They change threshold, definition of dry condition and VWC values in figure 6. I strongly suggest being consistent in their definition of drought conditions and use the same threshold in all figures. *The root zone depth for this species is around 60 cm (Line 291). The water deep in the root zone can maintain transpiration rates even at low VWC. I think a better way is to define threshold based on root zone soil water content in this paper. Is there any field capacity or wilting point measurements available at the site? If so mention that in the paper and use relative available water content in the root zone. If not, use relative water content (based on maximum and minimum VWC values at the site) in the 30 cm soil layer to identify the drought conditions. The value of VWC shown in Figure 1 indicate that soil drying occurred mainly in shallow layer, not in the deep layer (30 cm), especially during pre and post growing periods.

RE: We agree with reviewer's suggestion of a consistent threshold of soil water content among years. We will be defining the soil drought conditions based on relative extractable soil water (REW) at 30cm depth during measuring period (2013-2014) in the revised manuscript. The consistent soil water threshold for sapflow will be taken over years in the revised manuscript. From our preliminary analysis, the plant is in drought condition when VWC at 30 cm depth is 0.10 m^3 m^{-3} which is equivalent to a REW value of 0.4 that was proposed by Granier et al. (1999;

2003).

Literatures that will be added in the revised manuscript:

1. Granier et al.: Evidence for soil water control on carbon and water dynamics in European forests during the extremely dry year: 2003. Agricultural and Forest Meteorology, 143,123-145, 2007.

2. Granier, A., Bre´da, N., Biron, P., Villette, S.: A lumped water balance model to evaluate duration and intensity of drought constraints in forest stands. Ecol. Model. 116, 269–283, 1999.

*Is it possible to include transpiration (mm) values in this paper? That will add more value to understand the acclimation process of plants to the dry conditions.

RE: Yes, we will add estimated transpiration (mm) values in the revised manuscript. The transpiration has been estimated on the basis of leaf area index (LAI) and sapflow per leaf area.

*The methods section reports leaf area measurements, but its values are not mentioned in the paper. Even in conclusion they have mentioned leaf expanded periods, but no data to support it.

RE: The leaf area measurements were used to calculate the sap flow rate per leaf area, which is a comparative unit with other species. We will add the equation for calculating sap flow rate per leaf area in the revised manuscript. Leaf area measurements will be also added to revised manuscript.

We will also add observations of phenological phases in revised manuscript. Phenological phases observation has been briefly described in "2.1 Experimental site", Line 129-130 "Normally, shrub leaf-expansion, leaf-expanded, and leaf-coloration stages begin in April, June, and September, respectively."

*Statistical significance should be evaluated for each figure and include p value along with R2 in figures.

RE: We will add statistical significance and R square value to figures in the revised manuscript.

*The 2013-2014 data shown clearly indicate that there is no direct control of VWC on sap flow (Figure 2 first vertical panel). Figure 2 also clearly shows that the relation between Js with Rs , T and VPD are non-linear (check previous comments on p-value). If the relationships are non-linear how can they explain the linear regression slopes shown in Figure 3? Is the linear relationships shown are statistically significant?

RE: We defined a VWC cut-point (Figure 2 first vertical panel) as a starting VWC value of drought. We will redefine VWC threshold of sapflow in revised manuscript using REW value. From our preliminary analysis, the VWC threshold of 0.10 m^3m^{-3} is equivalent to a REW threshold of 0.4 (Granier et al., 1999, 2002; Bernier et al. 2002).

Each slope value in Fig. 3 were from a regression between sap-flow rates at specific time and its corresponding environmental factor over growing season (Jun. 1 to Aug. 31). This regression is more like linear relationship and statistically significant. We will show this regression and p-values in revised manuscript.

References:

1. Granier et al.: Evidence for soil water control on carbon and water dynamics in European forests during the extremely dry year: 2003. Agricultural and Forest Meteorology, 143,123-145, 2007.

2. Granier, A., Bre´da, N., Biron, P., Villette, S.: A lumped water balance model to evaluate duration and intensity of drought constraints in forest stands. Ecol. Model. 116, 269–283, 1999.
3. Bernier, P.Y., Bre´da, N., Granier, A., Raulier, F., Mathieu, F.: Validation of a canopy gas exchange model and derivation of a soil water modifier for transpiration for sugar maple (Acer saccharum Marsh.) using sap flow density measurements. For. Ecol. Manage. 163, 185–196, 2002.

Specific Comments

*Abstract: 0.11 m3 m-3 is only for 2013, not for 2014.

RE：We will use consistent VWC threshold of 0.10 for both years as specified above. This will be revised in the revised manuscript.

*Introduction: The section need to highlight what is the need for sap-flow measurements and how it influence ecosystem water transport and balance. The importance and need for the study is not properly addressed even though the authors explain the effect of environmental variables on sap-flow in this section. In addition to this the section should refer more recent papers on sap-flow measurements.

RE: We will be adding the statements addressing the importance and need for the sap flow study in revised manuscript.

*Line 131: Also include root zone depth, and mean leaf area values. Is it possible to include field capacity and wilting point here?

RE：The root zone depth and leaf area values will be added into revised manuscript.

There was no data for field capacity and wilting point values available. Therefore, we calculated the relative extractable soil water (REW) as suggested by reviewer and literature (Fernández et al., 1997; Zeppel et al., 2008).

$REW=(VWC-VWC_{min})/(VWC_{max}-VWC_{min})$,

where VWC is daily soil water content (m^3 m^{-3}), VWC_{min} and VWC_{max} are the minimum and maximum VWC during the measurement period in each year, respectively.

References:

1. Fernández, J. E., Moreno, F., Girón I. F., and Blázquez, O. M.: Stomatal control of water use in olive tree leaves, Plant Soil, 190, 179–192, 1997.
2. Zeppel, M. J. B., Macinnis-Ng, C. M. O., Yunusa, I. A. M., Whitley, R. J., Eamus, D. Long term trends of stand transpiration in a remnant forest during wet and dry years, J. Hydrol., 349, 200-213, 2008.

*Line 140: ‘after dynamax 2005’, what is that?

RE: This citation ‘after dynamax 2005’ will be revised into ‘Dynamax, 2005’.

*Line 141: What is the frequency of measurements?

RE：The frequency of sapflow measurements is one record per minute. This will be added to the method section in revised manuscript.

*Line 143: What was the mean leaf area? How did it vary with season?

RE: Mean leaf area is mean of estimated leaf areas of five shrubs. The leaf area of each shrub is

the product of branch numbers and leaf area per branch. The seasonal changes in leaf area will be present in revised manuscript.

*Line 151-155: decoupling coefficient re-expresses gs, and can be removed.
RE：We will be removing decoupling coefficient in revised manuscript.

*Line 164-171: Be consistent with label style. It is better to italicize all mathematical variable labels. Only u, gs and Js are italicized.
RE：We will consistently italicize the term label throughout the text in revised manuscript.

*Line 178- What is the reason for selecting VWC=0.08 m3 m-3 as the threshold to determine the drought condition. It is not explained in the paper. The time series of VWC (Figure 1) don't show any severe drought conditions in 30 cm depth. It is useful if the authors can include relative water content within 0-30 cm layer.
RE: The VWC threshold of 0.08 was selected from first vertical panels of figure 2. The VWC threshold indicated the starting point of dry condition (or drought start). We agree with reviewer that this definition of threshold was not robust. We will revise the VWC threshold using relative extractable soil water (REW) and VWC at 30cm during measuring period (2013-2014) in revised manuscript.

*Line 197: 'Lower than...' What is the reduction in percentage?
RE：We will add the statement "Total precipitation and number of rainfall events during the 2013 measurement period (257.2 mm and 46 days) were about 5.6% and 9.8% lower than those during 2014 (272.4 mm and 51 days; Fig, 1d), respectively." into revised manuscript.

*Line 205-210: Can you add time series of gs here?
RE：Yes, we will add time series of gs as suggested by reviewer.

*Line 215: See general comments above. The threshold to define drought conditions should be the same in both years.
RE：Yes, we will revise VWC threshold as responded to general comments above.

*Line 222-228: How can you explain the use of the slope of linear regression relationship if the variation of Js with Rs, T and D are non-linear? Use values only when $p<0.05$.
RE: The each of slope values in Fig. 3 was from a regression between sap-flow rates at specific time and its corresponding environmental factor over growing season (Jun. 1 to Aug. 31). This regression is close to linear relationship and statistically significant. We will show this regression and p-values in revised manuscript.

*Line 233-243: What is the reason for this delay?
RE：The reason for the delay between Js and R_s would be energy force. Specific explanation would be that R_s can force T and VPD to increase, causing a phase difference in time lags among the relations J_s-R_s, J_s-T, and J_s-VPD. Stomatal conductance gs peak earlier than Rs. These delay reflect an acclimation of plant to dry and hot environment. We will add detailed explanation in the

revised manuscript.

*Line 246-252: Figure 6 shows data from three days. What are those days in day number? A meaning full explanation should be given for the use of VWC limits. The first panel shows VWC variation within 0.001 m3 m-3! Is it meaning full considering the errors in VWC measurements? Also use only significant digits while using VWC values. The data is only three days. Is it possible to add more data in this figure, also from both years? Using only three days for this analysis is not conclusive.

RE：We will add the DOY in Fig.6 caption. This figure compared the degree of soil water control on the hysteresis between J_s and R_s. Therefore, we took three contrastive drought degrees (severe, moderate, light) to see corresponding changes in the hysteresis in response to the drought degrees. We will specify these and give more days for this analysis to make this result more conclusive in the revised manuscript.

*Line 252: Figure 8 should be included in the results section.

RE：We will include Fig.8 in the results section.

*Line 263-265: This is already known. Provide some references here.

RE: We will add references listed below to explain this result. Similar result was reported previously (Qian et al., 2015; Zha et al., 2013).

References that will be added:

1. Qian, D., Zha, T., Jia, X., Wu, B., Zhang, Y., Bourque C. P. A., Qin, S., and Peltola, H.: Adaptive, water-conserving strategies in Hedysarum mongolicum endemic to a desert shrubland ecosystem, Environ. Earth. Sci., 74, 6039–6046, 2015.

2. Zha, T., Li, C., Kellomäki, S., Peltola, H., Wang, K.-Y., and Zhang, Y.: Controls of Evapotranspiration and CO2 Fluxes from Scots Pine by Surface Conductance and Abiotic Factors, Plos One, 8, e69027, 2013.

*Line 271: Rewrite this sentence. VWC don’t show any direct effect on Js in the figure shown

RE：We will revise this sentence as “VWC is the most important factor modifying the response of sap flow to other environmental factors.”

*Line 291: Provide information on root zone depth in the methods section.

RE：We will add information on root zone depth in the methods section of revised manuscript. Over 60% of the total roots distributed in the 0-60cm depth (Zhao et al. 2010). Our measurements showed over 80% roots distributed in the 0-60cm depth (Jia et al., 2016).

References that will be added:

1. Zhao, W., Liu, B., Chang, X., Yang, Q., Yang, Y., Liu Z., Cleverly, J., Eamus, Derek.: Evapotranspiration partitioning, stomatal conductance, and components of the water balance: A special case of a desert ecosystem in China. J. Hydrol., 538, 374-386, 2016.

2. Xin Jia, Tianshan Zha, Jinnan Gong, Ben Wang, et al.: Carbon and water exchange over a temperate semi-arid shrublandduring three years of contrasting precipitation and soil moisturepatterns. Agricultural and Forest Meteorology, 228, 120-129, 2016.

*Figure 1: Dotted line is not explained in the figure caption.

RE：We will add the explanation of dotted line in the Fig.1 caption as " Dotted line represents VWC threshold of 0.10 m^3 m^{-3} in the revised manuscript".

*Figure 2: Use the same definition for dry periods in 2013 and 2014 as mentioned above.

RE：We will revise VWC threshold and use the same definition for dry periods in 2013 and 2014 in the revised manuscript.

*Figure 8: This figure is not mentioned in results sections. Look like p value is low (both N and R2 low) and not statistically significant. If it is below 95.

RE: Fig.8 was simply used to explain the hysteresis between sapflow and environmental factors. We will add some results from figure 8 in the result section in the revised manuscript. The statistical significance has been checked. Only regression line with p value < 0.05 will be showed in this figure in the revised manuscript.

Anonymous Referee #2

*General comments

I have some minor comments which should be addressed about the drought classification, soil and vegetation characteristics. Also at the end, I have some minor points about writing. Based on Li et al., 2014 (L108), shrub is shallow rooted. If available/known, it may be good to include root distribution of Artemisia ordosica such as XX% of shrub roots are located within the top 30 cm, and tap root can reach up to 60 cm (Zhao et al., 2010 from L291). This also supports your soil moisture content measurements in the top 10 cm and 30 cm.

RE：

1) We will define the soil drought conditions based on relative extractable soil water (REW) at 30cm depth during measuring period (2013-2014) in the revised manuscript. The consistent soil water threshold for sapflow will be taken in the revised manuscript. From our preliminary analysis, the plant is in drought condition when soil water content (VWC) at 30 cm depth is 0.10 m^3 m^{-3} which is equivalent to a REW value of 0.4 as reported by Grannier et al. (Granier et al., 1999, 2003). The drought severity will be classified by REW and VWC magnitude (Granier et al., 1999, 2002; Bernier et al. 2002) in the revised manusript.

References that will be added in the revised manuscript:

- Granier et al.: Evidence for soil water control on carbon and water dynamics in European forests during the extremely dry year: 2003. Agricultural and Forest Meteorology, 143,123-145, 2007.
- Granier, A., Bre´da, N., Biron, P., Villette, S.: A lumped water balance model to evaluate duration and intensity of drought constraints in forest stands. Ecol. Model. 116, 269–283, 1999.
- Bernier, P.Y., Bre´da, N., Granier, A., Raulier, F., Mathieu, F.: Validation of a canopy gas exchange model and derivation of a soil water modifier for transpiration for sugar maple (Acer saccharum Marsh.) using sap flow density measurements. For. Ecol. Manage. 163, 185–196, 2002.

2) Information on root zone depth will be added in the methods section of revised manuscript.

Overall, more than 60% of the total roots distributed in the 0-60cm depth (Zhao et al. 2010). Our measurements showed over 80% roots distributed in the 0-60cm depth (Jia et al., 2016).
References that will be added in the revised manuscript:

- Zhao, W., Liu, B., Chang, X., Yang, Q., Yang, Y., Liu Z., Cleverly, J., Eamus, Derek.: Evapotranspiration partitioning, stomatal conductance, and components of the water balance: A special case of a desert ecosystem in China. J. Hydrol., 538, 374-386, 2016.
- Xin Jia, Tianshan Zha, Jinnan Gong, Ben Wang, et al.: Carbon and water exchange over a temperate semi-arid shrublandduring three years of contrasting precipitation and soil moisturepatterns. Agricultural and Forest Meteorology, 228, 120-129, 2016.

*If available, it will be good to include stomata closure point, wilting point, and hygroscopic point levels. Hence, the reader can judge the severity of drought. So, there will be some justification based on your drought classification. You used 0.08 (L178), 0.09 (Figure 2), and 0.11 (Figure 2). Is it 0.08 or 0.09?
RE: There are no values of stomata closure point, wilting point and hygroscopic point available at moment. We will add stomatal conductance measurements to figure 1 in the revised manuscript.
The soil drought conditions will be defined based on relative extractable soil water (REW) and VWC at 30cm depth during measuring period (2013-2014) in the revised manuscript. The drought severity will be classified by REW and VWC magnitude (Granier et al., 1999, 2002; Bernier et al. 2002). We are going to take consistent VWC threshold for both years in the revised manuscript.

*Also knowing wilting point and hygroscopic point helps us appreciating the Figure 6. You stratified soil water content based on three limits. How much severe the lowest value. My back of envelope calculation by using Campbell (1974) for sandy soil where porosity is ~0.42 (1-1.54/2.65), the wilting point (15000cm) is ~0.07. It seems your wilting point is much lower. Definitely, to appreciate the Figure 6 and drought severity, giving values are beneficial.
RE：From our preliminary analysis of REW and VWC, the plant is in drought condition when VWC at 30 cm depth is 0.10 m^3 m^{-3} which is equivalent to a drought REW value of 0.4 reported by Granier et al. (1999, 2003). We will give the values of drought severity in the revised manuscript.

*A little more detail about vegetation setting is beneficial. LAI and plant canopy cover of shrub are beneficial. As far as I know, in Mu Us Desert dunes are migrating or semi-migrating depending on canopy cover. So, it will be beneficial for readers.
RE: We will add LAI measurements and descriptions of vegetation characteristics in the revised manuscript.

*L272-274. In your DISCUSSION, it will be good to include climate for these plant species. Because your ecosystem which is water-limited, most probably different than their study sites! For example, Huang et al. (2009) study site (L275) is in Guangxi, where annual precipitation is 1900 mm, and mean annual temperature is 19.3 °C. Most probably some/most part of the year, the ecosystem is energy-limited. So, it is not so surprising to see solar radiation control on sap flow. I could not find electronic copy of Zhang et al. (2003) work. Please include prevailing climate in their study area too.

RE: We will add prevailing climate of these species in the revised manuscript. Generally, the present result is in contrast to other shrub species. For example, it has been found that sap flow in *Haloxylon ammodendron* in northwest China, where annual precipitation is 37.9 mm, and mean annual temperature is 8.2 °C, was mainly controlled by temperature (Zhang et al., 2003), while sap flow in *Cyclobalanopsis glauca* in south China, where annual precipitation is 1900 mm and mean annual temperature is 19.3 °C, was controlled by both radiation and temperature with VWC not limiting (Huang et al. 2009).”

*L276-L278. To emphasize the importance of small events on ecological processes, I want to draw authors attention another study by Sala and Lauenroth (1982).
Sala and Lauenroth (1982) showed the ecological importance of small events (<5mm) in semiarid site where dominated by C4 grass. I will be worth to check!
Sala O.E. and W.K. Lauenroth (1982). Small rainfall events: an ecological role in semi-arid regions. Oecologia, 53 (3), 301-304.
RE: We appreciate the recommendation of this literature. We have read the paper and will add the findings in this literature as a support and generalizaion of our finding in our revised manuscript.

*Minor Points:
L69. VERB. ....low soil water availability limitS .....,
RE: We will correct word ‘limit’ into ‘limits’ in the revised manuscript.

L70. VERB. .....limitS vegetation productivity
RE: We will correct word ‘limit’ into ‘limits’ in the revised manuscript.

L73. I recommend citation for: grass replacement by shrubs.
RE: We will add the citation in the sentence “…semi-arid areas of northwestern China (Yu et al., 2004).” in the revised manuscript.

L103. Capitalization. ...the Mu Us Desert.....
RE: The name ‘Mu Us desert’ will be corrected into ‘Mu Us Desert’ in the revised manuscript.

L125. Capitalization. ...the Mu Us Desert....
RE: The name ‘Mu Us desert’ will be corrected into ‘Mu Us Desert’ in the revised manuscript.

L137. VERB. Mean height and sapwood area of sampled shrubs WERE .....
RE: We will correct it as suggested.

L156. Replace UPSILON in the equation with lower-case gamma, γ for psychrometric constant.
RE: We will be revising it as suggested.

L161. Insert a comma after “ground”. ....the ground, and....
RE: We have inserted a comma in this sentence.

L180. VERB. Linear and nonlinear regression WERE .....

RE: We have revised the verb in this sentence.

L197. VERB. Total precipitation and number of rainfall events.... WERE lower than THOSE....
RE: We have revised the verb in this sentence.

L266. VERB. Synergistic interactions ..... ARE....
RE: We have revised the verb in this sentence.

L355-461. Please go through the references. Make sure the unity within the references. Journal names abbreviated some of them (L361, L367, L370 etc.), but not others (L 358, L383, L386 etc.). Choose one of them and stick with it. L424. Typo. Systems... L430. Typo. EcologY... L449. Typo. PLoS ONE. Compare with (L461 and L373). Use lower case for article names. Check (L456, L461, L416 etc.).
RE: We have carefully checked and will be revising citations and references throughout manuscript as suggested.

L541. Figure 4. I recommend following some color scheme (pattern) to represent different months such as jet etc. This change will help the readers to follow the figure easier than the current form.
RE: We have replot figure 4 using color scheme as suggested.
L553. Insert a comma after (dimensionless). .... (dimensionless), and ....
RE: We will revise it as suggested.

L554. To distinguish from straight arrows, I recommend using 'curved arrows' such as: The CURVED arrowS indicate the clockwise....
RE: We will be revising it as suggested.

L558. I recommend using 'three' instead of '3' days.
RE: The number "3" is corrected into 'three' in Fig.6 caption in the revised manuscript.