Authors' Response to Referee Comment by S. P. Good

General Comments:

The manuscript submitted by Zhang et al. is a comparison of upscaling techniques to estimate landscape level transpiration fluxes. The authors present results based on leaf-level, sap flow, and eddy covariance observations. Each of these methods have different strengths and weakness, yet are based on measurements of fluxes a vastly different scales. The inter-comparison of these methods is a difficult challenge facing the hydrology and earth systems science community, and therefore an excellent topic for this journal.

Response:

Thank the Referee very much. To the authors' best understanding, the following 3 major concerns are extracted from the specific comments by S. P. Good, which are listed and responded separately below.

Comment #1:

Overall, I find this paper very well written and sufficiently detailed. Both the figures and tables are helpful in conveying the subject matter.

Response:

Thanks for the positive comments.

Comment #2:

The main concern with this paper is the propagation of errors in the assessment of flux uncertainties. Errors in the soil flux are examined in detail, but should also be addressed and discussed for the other upscaling methods (1-6) in a consistent manner. Section 3.3.6 should be reworked into a separate subsection (3.4) detailing the uncertainties of each upscaling method.

Response:

We agree with the referee that it is an important issue to discuss the propagation of errors in the assessment of flux uncertainties. By following the Referee's suggestion, the error analysis of upscaling approaches (1 to 6) have been done in the revised manuscript, and the results have been shown in a separate section (Section 3.4). $\frac{\sigma_{M_P}}{M_P}$ *or* $\frac{\sigma_{E_{SF}}}{E_{SF}}$ *for upscaling approaches (1 to 6) have also been presented in Table 5 for comparison. Thanks.*

Comment #3:

How does the propagation of the uncertainties affect confidence in each of the final flux approaches? What are the drivers of uncertainties at each scale of measurements, and what approaches then produce the most reliable result?

Response:

Thanks for the interesting questions. We add a new section (3.4) to discuss the propagation of errors, and in the following we try to make some explanation on the drivers for different approaches associated with different scales.

At the plant scale (Approach 1 and 2), the variability of representative leaf transpiration rate and leaf area both affect the precision of upscaling results. Since the canopy structure has been considered in Approach 2, the $\frac{\sigma_M}{M}$ *obviously decreases and is less than that in Approach 1. Meanwhile,* $[\frac{M_{P1}{}^2 + M_{P2}{}^2 + M_{P3}{}^2}{M_P{}^2}]$ *is always less than 1, suggesting* $\frac{\sigma_{M_P}}{M_P}$ *would be less in Approach 2. It is worth noted that if we take the transpiration difference of sun leaf and shaded leaf into account, the* $\frac{\sigma_{M_P}}{M_P}$ *should even be larger in Approach 1. Therefore, compared with Approach 1, Approach 2 provides us more reliable upscaled transpiration at the plant scale.*

At the field scale (Approach 3 to 6), the precision of upscaling results are affected by the measurements of sap flow, plant density and the representative stem diameter or leaf area. The results suggest that although Approach 6 introduces more parameters into the estimate of field transpiration, the flux uncertainty decreases in this approach. That is because the variability of sap flow rates has been reduced when the rates are expressed on unit leaf area, meanwhile, the variability of leaf area estimate has been reduced by the application of dynamic relationship between leaf area and stem diameter. That is to say, from the statistic perspective, Approach 6 provides us the most reliable upscaled transpiration at the field scale in this study.

However, since the true values of evapotranspiration cannot be obtained, the error analysis above is only based on the standard error, representing the variation relative to the mean, but not an indication of measurement accuracy.

Authors' Response to comments by Referee #2

General Comments:

It's a good paper that the authors have done lots of excellent work. In general, it's difficult for us to compare the results of different measurements of different scales. However, in this paper photosynthesis system, sap flow and eddy covariance at different scales for measuring evapotranspiration were carried out carefully in field. And some reasonable upscaling approaches, which would be the good references for other researchers, were presented. In addition, the authors applied the upscaling results and gave a fraction of transpiration to evapotranspiration at flower and bolling stages, i.e. mulched drip irrigation is obvious beneficial for saving water.

Response:

Thanks for the positive comments.

Specific Comments:

Since lots of complex work was done in the research, I have a few questions or suggestions about the analysis process: 1. For sap flow gauges, the representative plants with averaged height and leaf area index were selected. So, are there any differences of the plants between wide-row and narrow row that may have different soil water content, and the differences of the plants growing under various salinities in field?

Response:

We agree with the Referee that soil moisture and salinity may affect plant transpiration rate. Owing to the distance from drip pipe located in the middle of four cotton rows, the wide-row cotton possessed higher soil water content than narrow-row cotton. On July 9th, 2012, cumulative sap flow rate of wide-row plants (plant 2 and 3) was 0.299 and 0.284 g cm^{-2} per day, which were higher than that of narrow-row plants (plant 1 and 4) with the value of 0.275 and 0.280 g cm^{-2} per day. Therefore, we always considered the difference of transpiration *rates between wide-row and narrow-row cotton plants when we carried out the experiments. Two wide-row plants and two narrow-row plants were selected to install the four sap flow sensors for all the periods, and the averaged value was used to represent the individual plant transpiration rate. We have revised the manuscript to clarify the representation of sap flow measurements.*

Since the effect of soil salinity on transpiration is complex and still not clear, we didn't consider it in this study. In further researches, more studies should be performed to obtain reliable relation between salinity and transpiration. Using this relation, we can get salinity-corrected field transpiration based on the spatial distribution of salinity, and the upscaling results might be improved accordingly. Thanks.

2. For upscaling approach 6, you considered the leaf area and stem diameter in the function. However, why the plant height is not involved? If plants have the same leaf area, stem diameters but different plant heights, they may have different canopy structures which have effects on transpiration.

Response:

We agree that the plant height may impact the canopy structure. In previous studies, since the canopy structure was not taken into account, the plant height was rarely used for upscaling. In this study, we took the canopy structure into account to obtain more reliable transpiration at plant scale. However, since the relation between canopy structure and plant height is still not well defined in the literature, we cannot use dynamics canopy structure corresponding to different plant height to get the transpiration at field scale. More studies can be performed to clarify the relation between plant height and canopy structure in future. Thanks.

3. It's interesting that the fraction of transpiration to evapotranspiration was quantitative defined at flower and bolling stages in this paper. I think the plastic film may have more meaning for the young plant with small leaf area and the

comparison between mulch drip irrigation and food irrigation would be more significant.

Response:

There are several different methods which can be used to partition evapotranspiration components, and each method has its limitation. Since the sap flow sensor can't be installed on tiny stem, the method presented in this study is not suitable for the seedling stage when the cotton is young. During seedling stage we can use some other methods, such as micro-lysimeter to partition ET components.

However, during flower and bolling stages, the partitioning method using sap flow is more advanced and reliable. That is because micro-lysimeter may not provide reliable ET value when the irrigation is implemented. The lateral flow and leakage of soil water induced by irrigation are always cut off by the wall of lysimeter, resulting in the misrepresentative of soil water content in the lysimeter. Therefore, it is difficult to obtain sound ET rates by lysimeter method during irrigation period. Our study provides a useful approach to evaluate ET components under irrigation condition. Thanks.

4. I also have a little confusion about the title. The results of upscaling approaches were used to obtain the fraction of transpiration to evapotranspiration. However, these contents were not reflected in the title.

Response:

Thank you for the suggestion. As in your comment #3, it is important to quantify evapotranspiration components in the whole growth period. However, in this study, we just quantified the ET components in the flower and bolling stages. What's more, we mainly focused on the upscaling approaches and comparison between different methods in this paper. Evapotranspiration partition is just a case of application. Therefore, the title <A comparison of methods for determining field evapotranspiration: Photosynthesis system, sap flow, and eddy covariance> is used here.

The list of all relevant changes made in the manuscript

1. The error analysis of upscaling approaches (1 to 6) have been done in the revised manuscript, and the results have been shown in a separate section (Section 3.4). The propagation of errors and drivers of uncertainties at different scales *have also been discussed in Section 3.4.*

2. We have revised Section 2.3.1 to clarify the representation of sap flow measurements.

3. The effects of spatial heterogeneity on upscaling process have been discussed in Section 4.

4. One more paper (Loranty et al., 2008) has been added into the Reference list.

5. The Fig. 2 has been revised to clarify the wide-row and narrow-row cottons.

6. $\frac{\sigma_{M_P}}{M_P}$ *or* $\frac{\sigma_{E_{SF}}}{E_{SF}}$ *for upscaling approaches (Approach 1 to 6) have been presented in Table 5 for comparison.*