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Interactive comment on "Mapping evapotranspiration with high resolution aircraft imagery over vineyards using one and two source modeling schemes" *by* T. Xia et al.

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Response to Anonymous Referee (Referee #2)

This paper evaluates two energy balance models forced by very high resolution airborne thermal data over 2 vine fields. The simpler model (DATTUTDUT, or "rectangular" approach) only requires temperature data, while TSEB uses full climate forcing.

Main comments: The originality of the paper lies in the use of very high resolution data obtained during 5 airborned overpasses, but this is not properly put forward in the paper: for TSEB, meter resolution data are used only to evaluate the component

temperature retrieval, and for the rectangular approach running the model at both resolutions is only carried out in a sensitivity test. Model performances obtained when the rectangular approach is applied at the highest resolution could be brought forward or at least added to Table 4. Therefore, it's hard to grasp the added value of this inter-comparison with respect to, say, Timmermans et al. 2015.

Reply: Results from DATTUTDUT using high resolution thermal data are now included in the revised manuscript (see the revised Tables 2-3 and Figures 6, 7, and 9). There is also discussion in the text on page 17 line 6-11: "At both instantaneous and daytime time scales, application of DATTUTDUT with the native (finer) pixel resolution thermal imagery yielded comparable (at Site 1) or significantly greater (at Site 2) discrepancies with the tower measurements than using the 5 m pixel resolution data (see Tables 2 and 3). Changes in the agreement with the tower measurements are mainly attributable to the new hot and cold temperature pixels selected by the DATTUTDUT procedure with the finer resolution TR data." The model inter-comparison is not the only motivation of this paper. Based on the performance of these two thermal-based ET models, one a simple contextual-based single-source approach versus a more physically-based two-source scheme using absolute surface-air temperature differences, we want to investigate their utility and ultimately look at ways of leveraging the strengths of both approaches in order to develop a hybrid modeling system that is more robust. We point out that the DATTUTDUT model is simple, readily operational with high resolution imagery and less sensitive to errors in absolute TR, while TSEB is more physically-based and robust with greater accuracy in flux estimation under different environmental conditions, but it is more sensitive to uncertainty in absolute TR. The paper then focuses on what attributes from these two modeling schemes are robust and would be important to incorporate in an operational ET modeling system applicable to high resolution imagery. This motivation is now emphasized in the Introduction section in the revised paper on page 6 line 8-13: "However, more detailed comparisons between simple one-source contextual-based schemes versus more complex two-source models using high resolution imagery over different surfaces are still needed to fully understand the strengths and weaknesses of both modeling schemes. Such intercomparisons can facilitate development of hybrid schemes that leverage the strengths of different methodologies (e.g., Cammalleri et al., 2012), while incorporating simplications for routine application with airborne imagery."

Also, the interest of either approaches in the context of precision agriculture should be further commented: why testing for precision agriculture a model that requires only temperature data? The cost of a met station is much smaller than that of acquiring airborne data, therefore I doubt that the low data requirement of the rectangular approach is a strong advantage for an application at local scale. Moreover, the rectangular approach provides total ET while TSEB targets E and T separately, which brings some added value in terms of water management and precision farming. Can't you evaluate E and T with the rectangular approach using two rectangles instead of one? (i.e. min/max values for soil and vegetated pixel groups separately ?)

Reply: We agree with the reviewer that the low data requirement of the DATTUTDUT model is indeed a strong advantage for local application, especially for near real time ET monitoring of agricultural fields without user expertise being required for specifying any model input variables. That is why we choose to test DATTUTDUT model in this paper. It is a very novel approach being recommended to model E and T with two separate rectangles (one for vegetation and the other for bare soil/cover crop), so that a simple rectangular approach can also obtain E and T more simply than TSEB. However, this requires having pure vegetation and soil temperature pixels, which there are very few such pure pixels with the current thermal imagery even at the finer pixel resolutions. While it may be possible to estimate Ts and Tc using the visible bands which are at $\sim$0.1 m resolution by sharpening the thermal images just like what is done in this study to compare with modeled Ts and Tc from TSEB in Section 4.1. These estimates only exist for some areas within the vineyards that are higher factional cover (greater LAI) where pure vegetated and bare soil/cover crop temperature pixels can be reliably extracted. Thus only a fraction of the north and south fields will have ET or E

and T estimates using the rectangular approach.

The choice of the contextual model used in the study should be better commented: contextual models take advantage of the various land surface elements within a given landscape. Contextual models are meant to be applied for heterogeneous sites, here the area of interest is small, it is thus expected that contextual models won't perform very well (cf. your comment p11911L20). Here, there are essentially 2 fields, the full triangle or trapezoid method is therefore not necessary, and the rectangular model is preferred, with extreme values being mostly related to the irrigated vegetation and the dry inter-row bare soil. This could be expanded in the introduction to legitimate the methodology. One wonders what causes water status heterogeneity within the vineyards. Some indications about the irrigation system and scheduling are missing here.

Reply: The climate in the study area is arid during much of the vine growing season, and the vine vegetation relies on the drip irrigation to provide water to the root zone to meet atmospheric demand. In the vineyard, the amount of irrigated water infiltrates into the root zone varies as a function of the application rate and soil water holding capacity. In some areas in the vineyard excess irrigated water is transported laterally into the inter-row which results in re-growth of the cover crop. However, generally for most of the growing season the inter-row area is very dry consisting of bare soil and dry senescent cover crop stubble (usually mowed in mid to late Spring). Thus there is often a well irrigated vine crop alongside a very dry non-irrigated inter-row which permits the existence of a wet and dry end-member within the small area.

The sensitivity tests are interesting and should be better presented (at least explicitly) in the text and not only in Table 4.

Reply: The details about the sensitivity tests were presented in Section 4.3. In this Section, the first paragraph introduced the setting of the sensitivity tests, i.e., varying TR for both two models, and varying the end member, study domain and resolution for

DATTUTDUT. The second paragraph explicitly discusses the results from the sensitivity study based on the inputs and statistics reported in Table 6 and illustrated in Figure 10. Finally the last paragraph relates the results in this paper to previous findings in the literature.

Minor comments: - P11907L28: the “rectangular” model (DATTUTDUT) is only insensitive to systematic errors, please correct.

Reply: In the revised paper, “systematic errors” is emphasized on page 2 line 17, thank you for the correction.

- P11910L18: it seems that the applicability of contextual methods for submeter data is more related to the size of the images analyses (I.e. where the extrememe pixels are identified) rather than the resolution itself. Please precise.

Reply: The size of the images had been stressed as the main reason in the revised version on page 4 line 22-25: “With UAV imagery, the pixel resolution can be very fine (i.e., 100 cm – 100 m) in order to map the variability in crop condition within a field. This typically restricts the size of the area or field being monitored and hence reduces the likelihood of sampling the extremes in ET rates (i.e., ET $\sim$0 and ET at potential).”

- P11916L24: why didn’t you use solar radiation as the main scaling factor?

Reply: Discussion referring to the method used to extrapolate instantaneous to daily ET is now included on page 10, line 19-22: “In this study, the observed available energy from the two flux towers during the daytime period for all five days was used to extrapolate instantaneous model estimates to daytime ET totals. However, in practice tower measurements of A would not be available, so results using solar radiation to extrapolate to daytime ET will also be evaluated.” We computed daytime ET using solar radiation with the EF expressed as follows: EF = LE_ins/Rsolar_ins = LE_daytime/Rsolar_daytime (R1) and the comparison between two methods were included in the revised manuscript (see Table 4). In Table 4, the MAE values for daytime

ET using A versus Sd methods were similar for TSEB, but were larger for DATTUTDUT particularly at site 1 the north vineyard. A discussion of the results in Table 4 is on page 17 line 12-19: “In practice, we will not have observations of available energy, A, from a flux tower for extrapolating the instantaneous ET from a single airborne observation to daytime ET, but instead are more likely to have weather station observations of incoming solar radiation, Sd. Results using Sd for extrapolating model estimates instead of flux tower measurements of A are listed in Table 4. In general, the differences between modeled and measured daytime ET (using RE method) increase, although not significantly for TSEB. On the other hand, discrepancies with the ET measurements for DATTUTDUT at the north vineyard (site 1) increase dramatically due to the large overestimation of instantaneous LE on DOY 162 and 219 (see Fig. 6b).”

- P11923L3: you could mention more recent work by Colaizzi et al.

Reply: In Colaizzi et al. (2012), RMSD values comparing observed versus modeled Tc varied from 0.83-3.1 °C. For Ts, RMSD values were from 2.4 to 5.0 °C. These results are described on page 16 line 2-5: “This accuracy was comparable with similar types of comparisons reported by Li et al. (2005), Kustas and Norman (1999, 2000), and Colaizzi et al. (2012a) which had RMSD values ranging from 2.4-5.0 °C for Ts and 0.83-6.4 °C for Tc when comparing observed to TSEB-derived component temperatures.”

- P11924L13: It’s probable that using the true solar radiation instead of the DATTUTDUT estimate is the prime source of error, please investigate or comment.

Reply: In the revised paper, DATTUTDUT is run using Rn and G from TSEB, and the results are shown in Table 5 with related discussion on page 18 line 21-28: “Using measured Sd from the towers instead of computing from the sun-earth astronomical relationships routinely applied by DATTUTDUT, there is only a minor reduction in the differences with the tower fluxes. An overall improvement in DATTUTDUT estimation of LE is achieved by adopting TSEB estimates of Rn and G (see Table 5). This is particularly true for the north vineyard (site 1). However, even with this better agreement in estimated LE, the discrepancies with observed LE from DATTUTDUT is still larger than with the output of TSEB. This indicates that the errors in available energy using the DATTUTDUT formulations are not the only significant source of error in estimating the LE flux." On average (the average value of Site 1 and 2) MAE and RMSD for LERE are reduced from ∼65 and 84 W m-2 to ∼52 and 68 W m-2, which are still larger than ∼37 and 44 W m-2 from TSEB. Therefore, using Rn and G from TSEB does have some value, however there still other source of error for DATTUTDUT. Future applications will try to improve the Rn-G algorithm in DATTUTDAT.

- Table 4: provide at least one performance meter (e.g. RMSD) for each case.

Reply: RMSD values for the daytime ET is now included in Table 6 (it was in Table 4 in the original manuscript), RMSD is calculated as: RMSD = (((O1-M1)ˆ2+(O2-M2)ˆ2)/2)ˆ0.5 (R2) where O1 and O2 are observed daytime ET at Site 1 and 2, M1 and M2 are modeled daytime ET at Site 1 and 2.

- P11929L10: provide an a priori estimate from the FAO56 method to show the added value of the thermal data compared to a classical crop coefficient method.

Reply: The crop coefficient (Kc) in calculating actual ET from the FAO56 method for vines will vary depending on numerous factors including vine type, growth stage/phenology, fractional vegetation cover, and soil water availability. The nominal Kc values recommended in FAO56 for vines are 0.30, 0.70 and 0.45 for initial, middle and late growing periods, respectively (See page 112 in FAO 56 manual). However, it was decided that given the lack of more detailed information about the Kc values for vineyards, it would be more interesting to evaluate Kc using model and measured ET. Detailed discussion about the calculation of actual ET using FAO 56 are now provided on page 24 line 16-30 and page 25 line 1-13: "Current operational techniques for estimating water use of crops primarily relies on the crop coefficient technique based on the FAO 56 publication (Allen et al., 1998). The actual ET of the crop is estimated by

first computing a reference ET (ET0) which is then multiplied by the crop coefficient (KC). This single crop coefficient is often divided (called the dual crop coefficient) into a basal crop coefficient (KCb), which is associated with the crop transpiration and has been related to remotely sensed vegetation indicies (Neale et al., 1989) and a soil surface evaporation coefficient (Ke). There is also included a Ks coefficient to reduce crop transpiration for a deficit in water availability in the root zone so the expression has the form ET=(KCbKs + Ke)ET0. Determining Ke and Ks requires running a soil water balance model for the surface and root zone. A recent application of this methodology over corn and soybean croplands is given by Gonzalez-Dugo and Mateos (2008) where they find this reflectance-based crop coefficient technique can significantly overestimate ET during a prolonged dry down period. There also appears to be no consistent or universal relationship between crop coefficients and vegetation indices and so this approach is not readily transferable to different crops and climatic conditions (Gonzalez-Dugo et al., 2009). As an example, the spatial distribution of KC was computed using FAO 56 estimated ET0 and the ET map from TSEB from DOY 163 (Fig. 13). There is a significant spatial variation in KC due in part to the know effect of leaf area/fractional cover (Choudhury et al., 1994), which is seen in the correlation between the KC map and LAI map of Fig. 4, but there are other factors including the vine variety and possibility of some level of stress in areas of the vineyard that cannot be reliably detected by this approach. Using the ET measurements from the flux towers and FAO 56 estimated ET0, for the north vineyard site 1, the value of KC ranged from 0.55 for DOY 100 to 0.76-0.82 for the other days. For the south vineyard (site 2), KC values ranged from 0.59 for DOY 100 to 0.62-0.65 for the other days, indicating little variation in KC with vine phenology. In contrast, the FAO 56 manual recommends KC values for vineyards at early, peak and end of the growing season of 0.3, 0.7 and 0.45. Clearly, a calibration with this approach is required, which is not only dependent on vine variety but also on vine management (i.e., row orientation and spacing, pruning, irrigation scheduling, etc.)"

- P11932-33: many typos errors, please review carefully.

Reply: We have checked the revised manuscript carefully before submitting it to HESS editorial system this time.

- P11932L26: in the rectangular approach, the max. LE corresponds to H=0 or LE=Rn-G so LE is different from a potential rate classically computed with a Penman-Monteith equation.

Reply: By "potential rate" in this paper, we actually mean maximum possible LE based on the surface energy balance LE=Rn-G, but not potential ET from the P-M equation. The "potential" was replaced by "maximum" ET in the sentence on page 26 line 16-21: "The performance of DATTUTDUT model in computing reliable ET and generating distributions and patterns over the vineyards was similar to TSEB on some of the overpass dates, but for other times the DATTUTDUT model performance was less than satisfactory largely depending on whether there actually existed pixels in the scene that were representative of the extreme ET conditions, namely "maximum" ET (LE=Rn-G) and no ET (LE= 0)."

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C6531/2016/hessd-12-C6531-2016-supplement.pdf

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 11905, 2015.