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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Estimating Daily Evapotranspiration Based on a Model of Evapotranspiration Fraction (EF) for Mixed Pixels" *by* Fugen Li et al.

Fugen Li et al.

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General comments: 1) I find it strange that no reference is made to the only widely accepted disaggregation method currently producing high resolution ET: ALEXI/DISAlexi. Response: Thanks for you kind reminder. This manuscript has been modified several times before submission, and this mistake must have been missed by the authors during this process. The references were added into the introduction section as below:

Classical satellite-based models such as the Surface Energy Balance Algorithm for Land (SEBAL) (Bastiaanssen et al., 1998), Surface Energy Balance System (SEBS) (Su, 2002), Atmosphere-Land Exchange Inverse (ALEXI) and an associated flux dis-

aggregation technique (DisALEXI) (Anderson et al., 2011; Anderson et al., 2012),and the temperature-sharpening and flux aggregation scheme (TSFA) (Peng et al., 2016) have been developed to monitor land-atmosphere energy balance flux interactions.

2) The biggest concern I have with your approach is that your approach specifies two hypothesis that are used to upscale. However in this there is (in my opinion) two serious flaw: a. An underlying assumption (that is not specified) is that the evaporative fraction at coarse resolution is correct. Considering that this evaporative fraction was determined over a coarse resolution (without considering subsurface heterogeneity) in the first place. As such oasis effects are not taken into account and can result in serious errors. Response: Thanks you for this question. It was very helpful for the authors to interpret the method more clearly and improving its representation er in the manuscript. In this method, the LE and EF of pure pixels at coarse resolution were regarded as accurate and then used to calculate the EF of mixed pixels through the area fraction of each land cover in the mixed pixel and the corresponding EF of each land cover, which is represented by the EF of the nearest pure pixel with the same land cover. Therefore, the subsurface heterogeneity in the mixed pixels is considered while subsurface heterogeneity in pure pixels is ignored since the pixel is "pure", which is the underlying assumption and starting point of this proposed method. The pure pixel is defined as the pixel with only one land cover type inside the pixel. This underlying assumption is acceptable and sufficient for the purpose of this study since the mixture of different land cover types is the most significant heterogeneity (Blyth and Harding, 1995; Bonan et al., 2002; McCabe and Wood, 2006; Moran et al., 1997; Peng et al., 2016) and should be considered initially. One may argue that a better method is available for defining pure pixels by using both land cover and other surface variables. However, in our opinion, such a method may help to obtain purer pixels but will not help to obtain a better ET estimation since the probability of finding proper pure pixel for each land cover in mixed pixels becomes extremely low and reduces the applicability of the method. The following paragraph was added at the end of section "5 Discussion". (4) The underlying assumption and starting point of this method is the

actual “purity” of the pure pixels; therefore, the EF of pure pixel is representative at least to the mixed pixels nearby. Only land cover information was used to define pure pixel; therefore, subsurface heterogeneity in pure pixel caused by other aspects (such as variation in the surface variables) may have certain influences on the results. Involving more features in the definition of pure pixels may increase the complexity of the model and the difficulties of its application significantly.

b. Secondly, hypothesis 1 (having EFi = EF) only is valid for incoming radiation (optical and thermal). However considering that the outgoing radiation depends on LST, albedo and emissivity (each with greatly varying heterogeneity) this cannot be said for the net radiation consequently on the available energy. While for many agricultural site’s the application might hold true, it cannot be stated as an overarching law. While this is kind of reflected in the text (as you change denotation from LE to LE_), the is not further touched upon at all. Response: As noted, hypothesis 1 (i.e., EFi = EF) is carefully used throughout the manuscript and its possible error were indicated on the first instance of its use ((LE) ÌČ denotes the latent heat flux in mixed pixels based on Hypothesis 1). A section (4.3.1 Error analysis of Hypothesis 1) has been included to discuss this hypothesis and the errors. As shown in the manuscript, the errors are small (less than 7 WÂům-2) and the hypothesis is acceptable.

c. While for hypothesis 2 at least some justification is provided (though one can argue what objectively is specified as ‘near’, no justification/argumentation for the 1st hypothesis is given. Response: A section (4.3.1 Error analysis of Hypothesis 1) has been included to discuss hypothesis 1 and its errors. As shown in the manuscript, the errors are small (less than 7 WÂům-2) and the hypothesis is acceptable. Hypothesis 2 was carried out based on Tobler’s First Law (TFL): everything is related to everything else, but near things are more related than distant things. The term “near” refers to spatial distance in this hypothesis, it was added in the section 2.2 to define the concept of “near” in the method. As below: As for the nearest pure pixel(s), it is defined as follows: if a subpixel in a mixed pixel and a set pure pixels have the same land cover as

a subpixel in the study area, then a circle should be drawn with its centre in the mixed pixel to find the first-closest pure pixel(s) to the subpixel.

d. Finally, at 30m resolution horizontal transport is becoming much more important (as you yourself indicate when considering EC footprints). Response: Advection and its influences are not considered in this study because they are not the main concern of this work, and addressing two types of problems at the same time would be excessively complex. This concerns appears to focus on mismatch in physics if we use field measurements contaminated by horizontal transport (such as oasis effects) to validate results without advection effects. The authors are aware of this risk and have removed the data contaminated by advection (a threshold “H+LE>Rn+G” is used to find advection effects) from the validation dataset. As for considering advection in the model calculation, to my knowledge, such a process remains a huge challenge in the remote sensing of heat fluxes.

Specific comments: 1) These shortcomings are reflected in that for EC4 (your most successful disaggregation site) still an error (2.7MJ) a factor 2 above any of your homogeneous sites (EC2,6,12 and 14) (each with errors below 1.2 MJ). This however is not touched upon in the text. Response: Thank you for this kind reminder. The validation results shown in Table 3 and Figure 7 have confirmed the success of the proposed method in correcting the spatial scale error and estimating accurate daily ET from coarse resolution data. The outcome of EC4 is the most successful example when considering the relative RMSE change (RMSE decreased nearly 50%). However, additional errors are observed for the corrected ET compared with the homogeneous sites, and the possible reasons for these errors have been analyzed in lines 16-22 in page 16. The remaining larger errors in such pixels represent a reminder that such method has limitations in extreme conditions. More complex models should be built for such circumstance and more information other than land cover should be included when considering subsurface heterogeneity in order to obtain results that are as accurate as those for homogeneous sites. This ambitious goal will be the focus of future

studies in spatial scale issue in the remote sensing of LE and ET. These statements have been revised as follows: The correction effect of the EFAF method was most distinct at the EC04 site, and the RMSE at EC04 decreased from 5.36 to 2.72 MJÂům-2 (about decreased by approximately 49.25%); this improvement stemmed from the fact that EC04 had the highest complexity of all sites. Maize-dominated pixels in EC04 included maize, vegetables, buildings and bare soil, at a ratio of 53:26:19:2, respectively. We conclude that maize and vegetables were land cover types with a high EF, while bare soil had a low EF. For buildings, the EF value was 0 in this study. Similarly, the difference of them against the EC measurements had also declined from 4.12 MJÂům-2 to 2.32 MJÂům-2 (decreased by approximately 43.3%). Additionally, there were large discrepancies between the observed and retrieved LE values at EC04. Specifically, there are two points far from the 1:1 line in Fig. 7 (d), with values of 8.36 MJÂům-2 on 27 July and 9.33 MJÂům-2 on 3 August. Even after the EFAF method was applied, these values were 5.20 MJÂům-2 and 4.59 MJÂům-2, respectively, because EC04 was positioned in a maize-dominated pixel and the EC tower was located in a built-up area, thus generating errors associated with temperature retrieval that would create further errors in estimating Rn. For example, on 27 July and 3 August, the Rn observed by AWS for the EC station was 15.95 and 15.35 MJÂům-2, respectively, while the retrieved Rn of the pixels was 18.14 and 18.80 MJÂům-2, respectively. On the other hand, the remaining larger errors in such pixels are a reminder that such method has its limitations under some extreme conditions. More complex models should be built for such circumstances and more information other than land cover should be involved in considering subsurface heterogeneity to obtain results that are as accurate as those obtained for the homogeneous sites.

Technical comments: 1) Specifically figure 4 and 5. Here you want to show the difference between Lumped and EFAF (LE/EF) next to each other. In my view this could be better shown by 1 graph of Lumped LE/EF, and a 2nd showing the difference between Lumped and EFAF (LE/EF). At present the colouring of the maps hide where specific improvements are made. Response: Thanks for your good suggestion. We

have shown the difference between lumped and EFAF (EF/LE) in Figures 4 and 5.

(a) (b) (c)

(d) (e) (f) Figure 4. Maps of (a) lumped EF, (b) EFAF EF, (c) difference between the EFAF and lumped EF (EFAF EF minus the lumped EF), (d) lumped daily LE, (e) EFAF daily LE and (f) difference the between EFAF and lumped LE (EFAF LE minus the lumped LE) on July 8th, 2012

(a) (b) (c)

(d) (e) (f) Figure 5. Maps of (a) lumped EF, (b) EFAF EF, (c) difference between the EFAF and lumped EF (EFAF EF minus the lumped EF), (d) lumped daily LE, (e) EFAF daily LE and (f) difference between the EFAF and lumped LE (EFAF LE minus the lumped LE) on August 22nd, 2012

2) You denote the validation-results in MJ/m2 instead of the customary mm/day. While this is simply a division by the latent heat of vaporization, denoting it in these units prohibits the comparison with other validation researches. Response: Thanks for your careful reading of our manuscript. Accurate latent heat of vaporization is as a function of temperature. If biases occur in the temperature measurement, the latent heat of vaporization and ET values will be affected. In this study, temperature values are external inputs; therefore, we cannot distinguish the errors from the EFAF retrieved or the temperature products. Thus, in our opinion, the validation results in MJ/m^2 would be batter compare with other validation results.

3) Also in the start of the manuscript you refer to results of intercomparison studies as 'biases' (while they should have been called errors/uncertainties), while you specify (in fiture 4.3) errors which cannot be qualified as such (as they do not refer to a comparison between ground measurements and retrieval), but instead are just variances of a single map. Response: Thanks for your careful reading of our manuscript. For section 4.3, we analyzed the approximate errors of two key hypotheses. Section 4.3.1discussed

the approximate errors of Hypothesis 1, which states that the available energy (AE) of each sub-pixel is approximately equal to that of any other sub-pixels in the same mixed pixel within an acceptable margin of bias and is equivalent to the AE of the mixed pixel." Therefore, the pixel values of a lumped 300 m resolution should be compared to the 10 $\times$ 10 set of 30 m pixels that they were drawn from in this study. However, obtaining simultaneous ground measurements of AE in 10 $\times$ 10 set of 30 m samples and a 300 m sample is difficult. Even if one or two datasets are obtained, generating the representativeness of the whole study area is difficult. Therefore, we consider the distributed retrieved values at a 30m resolution as accurate values and compare them with the 30 m resolution sub-pixel values, which have the same values as the lumped AE measured at a 300 m resolution from each mixed pixel. This method is relatively better for analysing the errors of Hypothesis 1 throughout the whole study area. Section 4.3.2 discusses the approximate errors of Hypothesis 2, which states that the EF of each sub-pixel in a mixed pixel is approximately equal to the EF of the nearest pure pixel(s) of the same land cover type. As for ground measurements of EF, the ground measurements of Rn, G and LE are required. The ground measurements of Rn and G are point-based observations, and that of LE is region-based observations because the footprints of EC measurements are considered. Therefore, using the ground measurements of AE (Rn-G) and LE to form a consistent spatial representation is difficult. For Hypothesis 2, the inherent significance is the use of the EF for each pure pixel as the correct value. Therefore, we can determine the approximate error caused by Hypothesis 2 by discussing the difference between the two nearest correct values, i.e., the EF of the two nearest pure pixels. Above all, the errors of the two hypotheses are hard to analyze by comparing retrievals with ground measurements. By analyzing the errors of the whole study area, we can better explain the rationality of the two hypotheses. For the word "bias", we have revised it to the errors or uncertainties in the manuscript

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Anonymous Referee #2

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This document contains the following: (1) comments from Referees, (2) responses from the authors (in blue), and (3) author's changes in the manuscript (in red).

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Fig. 1. Reply-RC2x