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Interactive comment on "Spatial variability of mean daily estimates of actual evaporation from remotely sensed imagery and surface reference data" *by* Robert N. Armstrong et al.

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We are grateful for the comments from RC1. The following responses are intended to discuss key edits which have been made to the manuscript based on the range of comments given by the reviewer regarding: restructuring of the manuscript, discussion on potential implications and limitations, energy flux and EC data and modelling uncertainty.

Regarding comments related to the EC data:

More information has been given regarding the EC measurements in the field obser-

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vation section 3.2. For example, fluxes reported as 15 min averages, data filtering was used but there was no bad data or spikes observed on the day. All flux samples were accounted for and no gap filling was required. Use of the planar-fit axis rotation method to correct the latent heat flux (and sensible heat flux) measurements was also previously referred to in section 3.2. Given the corrections applied and no missing data or spikes were observed, the fluxes were considered to be of good quality for the case study. Unfortunately, post-processing of the raw data is not possible at this stage to generate quality flags according to the methods of Mauder and Foken 2004.

Partitioning of the energy fluxes is now discussed in section 4.6 where a comparison is made between the estimated evaporation rate from a linear transect upwind of the EC station and the measured EC flux. The linear transect has been overlayed on the map in Figure 9. The text referring to the flux contributions from the upwind fetch has been clarified. Specifically it has been noted that 80% of the upwind contribution is expected to come from within 100 m of the EC station, based on a cumulative flux calculation with the model of Scheupp et al, 1990. This is along a similar linear transect used for averaging the G-D model estimates upwind of the EC station which has now been clarified in the text.

In terms of the flux components and ratio of energy balance closure, the fluxes were specified as mean daily values in W/m2: (LE + HE) / (Q* – Qg) = (63 + 55) / (144 – 2) which gives a closure of 83%. The Bowen Ratio of 0.87 is reasonable in this semi-arid landscape due to drying of the upwind grass surface and reduced photosynthesis of the grasses as anthesis is typically in mid-late June. Uncertainty in over estimating evaporation due to neglect of the ground heat flux and possibly under measured fluxes is now referred to in section 4.6.

Regarding comments related to modelling assumptions and uncertainty:

Uncertainty associated with the modelling assumptions has been partly addressed by moving the surface reference parameter section (now 3.3) into the methods and text modified to provide clarity regarding the assumptions applied. A new section (4.10) was added to further discuss the general uncertainty of the methods applied. This includes discussion related to regions where the model may perform more poorly due to neglect of the ground heat flux or wind speeds may vary due to the changes in the roughness of the surface elements.

The relatively small magnitude of the ground heat fluxes under grass surfaces with good cover at two measurement sites has now been discussed in section 3.3 and is referred to again in section 4.10. A focus of this study was on the potential to scale measured values of driving energy factors across the larger field based on the observable surface properties directly related to the net radiation. Which is not practical in this case for the ground heat flux without further information on the land cover in each pixel and application of a numerical model. Estimates could be produced at every pixel through complex radiative modelling but the uncertainty may be larger than the error of the estimates reported for the net radiation estimates. It is not uncommon to neglect the ground heat flux but implications are discussed in section 4.10.

To the best of our knowledge there were no C4 plants at the study location – all grasses/crops were cool season C3 types. Uncertainty related to prior developments of the vapour transfer function for different surface types (including C3 plants) and possible requirement of new equations for C4 plants is now noted in section 4.10.

Regarding comments related to the wind speed and turbulent energy applicable to the estimating the drying power of the air, EA:

The discussion regarding development of the surface roughness length map in section 3.4.5 has been improved for clarity and to provide evidence of considerations for potential impacts of changes in roughness and wind speed. As was stated in section 3.4.5 representative roughness lengths were selected based on reported values from Brutsaert (1982) for similar types of surfaces elements and heights for vegetation ranging between 3 – 10 m. Regarding restructuring and combining images: The resulting maps of albedo and Ts and the validation discussion (section 4. 1 and 4.2) are introduced earlier in the result and discussion section. Implications of relative variations in albedo and TS for estimating the net radiation and final estimates of E are discussed briefly in each of those sections. A major restructuring was done to combine several images which reduced the number of figures from 17 to 12. The manuscript has been modified in section 4.7 and 4.7.1 and graphics have been combined so as to be more appropriate to discuss variations in the underlying distributions of driving of factors and how they relate to the net radiation and impact final estimates of E. For example the underlying variability in albedo and TS appears to be much larger than the resulting variability of net radiation and E, due to the interaction of the relative evaporation, G term. Previous figures for the frequency distributions for evaporation estimates and relative contributions have been combined in to Fig. 10. Previous figures 12 – 14 have been combined into Fig 11 and previous figures 15 – 17 have been combined into Fig 12.

Previous figures 2 and 3 have been swapped as the discussion for figure 2 related to albedo point sampling and conversion to broad-band was moved into the methods section.

Regarding comments on covariance:

The text has been modified to clarify the impact of the relationship between relative evaporation G and net radiation. G is a non-linear function of the relative drying power D which is a function of the drying power of the air, EA and also the available energy. EA is dependent on the surface roughness, wind speed and humidity deficit. The non-linear inverse relationship between net radiation and G is more clearly shown and discussed via figure 12. The impact of this relationship for this study generally results in higher values of G associated with lower values of net radiation and much lower values of G associated with higher values of net radiation. The resulting interaction produced a very small covariance.

The covariance was found to be even smaller when computed within each roughness class.

Albedo estimates which were based on the DN index showed a correlation of 0.67 with TS, which is reasonably high. However, the computed covariance was only 0.06, suggesting that this may not be an issue.

Regarding technical corrections:

Idrisi software used to segment the surface now referenced, and company referenced for post-processing done with Matlab software.

As indicated above several figures have been combined and discussed more appropriately.

The boxplots have been modified to remove the redundant information and the large number of data points have been overlayed and plotted with jitter.

Removed the coefficient of variation for the aerodynamic component as it appears bimodal.

Vegetation types have been more clearly defined – also figure 1 was replaced with a photo of the study region which provides more context for reference.

Tree rings clarified to narrow rings of trees.

The manuscript has been cleaned up to address typos.

The number of validation sites for net radiation has been clarified to 2 sites.

Description of visual differences in distributions across roughness classes has been removed and the text was modified to state Kolmogorov-Smirnov tests of the individual distributions for the respective variables showed significant differences across the roughness classes (p-value < 0.001).

Representative roughness values were cited from Brutsaert (1982) which indicate 0.4

m for trees up to 10 m tall. In our case we state the narrow rings of tall shrubs and trees varied between 3 m and 10 m. They also have a limited spatial footprint compared to more uniform and extensive cover for which a larger roughness length may apply.

Title for section 3.4, now labelled 3.5 due to reorganisation of the manuscript, has been changed to ‘Exploratory analysis of surface variables and evaporation estimates’.

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