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Hydrology and Earth System Sciences Discussions

Interactive comment on "Uncertainties in using remote sensing for water use determination: a case study in a heterogeneous study area in South Africa" *by* L. A. Gibson et al.

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We would like to thank the reviewer for the helpful comments and suggestions. We plan to improve this paper by expanding our introduction in order to state our objectives more clearly and to better place our work within the frame of the literature. We also plan to expand the section on heterogeneity in the revised paper.

Reviewer 3 Comment:

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Interactive Discussion

Discussion Paper

(1) In the introduction section (p.6583, L.3-7 and p.6584, L.10-14), the author indirectly concludes a high error/uncertainty in ET calculation by SEBS referring to a project finding (Gibson et al., 2010) which revealed the total annual ET calculated by SEBS exceeded the total rainfall for the study area. Although the uncertainties can be still there in a complex model like SEBS, the higher total annual ET than precipitation doesn't necessarily need to be an overestimation of ET, if there is water use from the groundwater storage for irrigation. And from the details of the paper, it is understood there are also irrigated agriculture activities in the basin. Therefore, it would be better to define the conditions briefly (or validation) why it is considered unrealistically high the calculation of ET by SEBS rather than providing such a generic statement (also considering the project report by Gibson et al. (2010) was not accessible through web by the date of 15th Oct., 2010).

We reply:

We address this by expanding the introduction section of the revised paper. The report should be available soon on the Water Research Commission website: www.wrc.org.za. However, the required details will be added to the revised paper.

Reviewer 3 Comment:

(2) As it can be seen in Eq.23 in Su (2002), sensible heat flux (H) is directly related with temperature gradient between land surface and near surface air (T0-Ta), while it is inversely related with aerodynamic resistance term in the denominator. As the author mentions, Su (2002) indicates the sensitivity of H as ΔH = 10 Δ(T0-Ta), which is similar by the finding of the author for wheat land cover. In theory (according to Eq 23 in Su, 2002), higher the temperature gradient, higher H gets. And, since SEBS calculates LE as the residual of the surface energy balance, higher the H gets lower the LE becomes for the same available energy. This is also confirmed by the decreasing trend of daily ET with increasing (T0-Ta) in Fig2 (p.6605) for wheat land cover. However, there is a completely different correlation between daily ET and (T0-Ta) for the case of apple

orchard as shown in Fig. 2, and stated in p.6590 between L5-10. It would be good to discuss in more detail why daily ET start to decrease with decreasing (T0-Ta), when (T0-Ta) gets smaller than 8, assuming other parameters are the same? For example, in p.6588, L16-19, it is mentioned the role of T0 in the calculation of aerodynamic resistance? Could it be explained more explicitly how?

We reply:

On p.6588, L16-19 has been poorly formulated. We would like to change this to: "its main contribution (together with the aerodynamic resistance) is in the calculation of the sensible heat flux."

SEBS limits evapotranspiration by setting a wet and a dry limit. In the apple orchard at T0-Ta < 7.4, the sensible heat flux is at the wet limit. At the wet limit, the equation used to calculate the sensible heat flux is given in Su (2002) Eqn 16 which differs from the sensible heat flux equations which are used when the wet limit has not been reached (Su, 2002; Eqns 4-6). In Equation 16, with decreasing T0-Ta, the denominator is decreased by a decrease in the Δ (the rate of change of saturation vapour pressure with temperature) and therefore the sensible heat flux at the wet limit increases, resulting in a decrease in the latent heat flux, a decrease in the evaporative fraction and a decrease in the daily evapotranspiration. It is believed that this is the reason for the decrease in daily actual evapotranspiration with T0-Ta once the wet limit has been reached.

Where the wet limit has not been reached, Eqn 5 (Su, 2002) is used in the determination of the sensible heat flux. In Eqn 5, with decreasing T0-Ta, there will be decreasing sensible heat flux estimation, resulting in increasing latent heat flux and therefore increasing daily actual evapotranspiration. This explains why the daily actual evapotranspiration increases with decreasing T0-Ta until the wet limit is reached. At the wet limit a different equation is used (Eqn 16) and the daily evapotranspiration decreases with decreasing T0-Ta due to decreasing saturation vapour pressure.

In SEBS, the wet limit equations are used when the sensible heat flux calculated using

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Eqns 4-6 in Su (2002) is less than or equal to the sensible heat flux at the wet limit calculated using Eqn 16. In the case of the wheat growing area, the wet limit was not reached when using similar T0-Ta values as was used for the apple orchard scenario. This is possibly due to the calculated lower roughness lengths of the wheat fields (in combination with different atmospheric conditions) when compared with the apple orchard, resulting in a higher sensible heat flux for the same T0-Ta as observed in the apple orchard (Eqn 5). For this reason in the selected T0-Ta range used in this paper, the sensible heat flux was not calculated to be low enough using Eqns 4-6 to force it to the wet limit and this is why the decrease in evapotranspiration with decrease in T0-Ta is not observed as it was in the apple orchard. In the revised paper we will extend the range shown for the wheat growing area on Figure 2 to show the wet limit drop off in evapotranspiration which occurs at T0-Ta $\sim$3 in this particular instance.

See Revised Figure 2

Reviewer 3 Comment:

(3) Fractional vegetation coverage (Fc) is one of the key (intermediate) parameters of SEBS, which is not only used in the parameterization of H (through the calculation of T0, and also aerodynamic resistance), but also G. The author takes attention to the choice of Fc formula through testing the sensitivity of SEBS to the selection. However, one must be careful checking how Fc is utilized differently in different modules of SEBS: although physically they are supposed to be the same, sometimes different formulations of Fc are used in different modules of SEBS intentionally, since they are meant to fit particular parameterizations: For instance, NDVI based Fc equation proposed by Sobrino and El Kharraz (2003) is meant for calculating emissivity and then the land surface temperature as the title of their article implies "Surface temperature and water vapour retrievals from MODIS data". Indeed, also in SEBS model, the algorithm by Sobrino is used in calculating land surface temperature (T0). As the author highlight, this particular equation uses constant min. and max. values of NDVI (0.2 and 0.5) for defining bare, mixed and full vegetation conditions. So, in the case of

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Fc formula for T0 parameterization, what is more important is the calibration of these boundary values to the particular study area rather than the selection of the formula.

The author already presents several examples of calibration (e.g. NDVI time series), and in deed adapts the NDVImax to 0.65 using field data of G in the case of the study area in South Africa.

However, as mentioned in previous paragraph, Fc is not only used in T0 calculation but also in the parameterization of surface resistance (in the calculation of dimensionless kB-1 parameter, which relate roughness length for heat (z0h) with momentum (z0m)) and in the parameterization of G0. In SEBS, if an input map of LAI is provided, which is generally advised, SEBS uses another Fc formula based on LAI (Fc=1-exp(-0.5*LAI)) for specifically the calculation of kB-1 (in relation with roughness lengths, and H calculation) and G0. Therefore, while it is good to take attention how sensitive is SEBS to the selection of Fc formula (Fig. 4), it should be bear in mind that some specific formulation of Fc is meant to fit to a specific purpose (as in the case of Sobrino and El Kharraz, 2003) and it can be better to put the attention to the calibration of it rather than selecting which formula. In fact, it is interesting to observe in Fig.4 that, when the max NDVI is changed from 0.5 to 0.65 (eq. 3c in Fig.4), they produce the same daily ET with LAI based formula (eq.2 in Fig.4).

We reply:

In the revised paper we will indicate where SEBS uses fc. This will include, as the reviewer points out, LST, the soil heat flux, and the sensible heat flux.

Reviewer 3 Comment:

(4) In Fractional vegetation coverage section (4.2, P.6592, L.17-19), it is mentioned "where fc=1, sensible heat flux is at a minimum and actual ET equals potential ET. This is the case where NDVImax=0.5. However actual ET is not equal to potential ET where NDVImax equals to 0.65." When fc=1.0 (full vegetation coverage), actual ET

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does not necessarily need to be equal to potential ET. While the vegetation coverage can be full, there can be still water stress (which affect in turn the surface resistance, H, and LE finally) due to less soil moisture availability (in surface energy balance models, the effect of soil moisture is supposed to be indirectly reflected through land surface temperature, T0). Therefore, the same type of landcover with same full vegetation coverage can depart from potential ET depending on T0 data.

We reply:

We agree that we looked at this too simplistically. We see that you are correct in pointing out that maximum fc does not necessarily equate to potential ET and other factors such as soil moisture do need to be considered. In this particular case, at fc > 0.7, the sensible heat flux is at the wet limit; however, it would be wrong to draw general conclusions from this. We will revise the text accordingly.

Reviewer 3 Comment:

(5) The section 4.4 and the related Figs. (Fig. 6, 7, 8) are expected to address (according to the objectives of the paper given in introduction) how the heterogeneity of study area and the sub-pixel heterogeneity of MODIS pixel can affect the uncertainty in daily ET calculation. However, while all the relevant figures are indicating how much the study is heterogeneous in different ways, they are not providing any significant insight (in quantified manner) how the daily ET calculated by SEBS is sensitive to and affected by such a heterogeneity. Alternatively, a comparison of daily ET results from a high resolution image (e.g. Landsat) with a moderate resolution (MODIS) could provide better insights to analyze the effect of sub-pixel heterogeneity as an uncertainty in daily ET calculation. It would be good to modify this section in a manner to address the stated objective. In fact, in the case of a heterogeneous landscape and if the target is to quantify water use at farm level (p.6584, L.1-4), obviously the moderate spatial resolution provided by MODIS (1km) won't be good enough to satisfy such an objective.

We reply:

In the revised paper we will include the results from a single date ASTER image compared with the results of the same date MODIS image to illustrate the effect of heterogeneity.

Reviewer 3 Comment:

Some further remarks: P.6588, L.15-19: (T0-Ta) is stated as the most sensitive parameter of SEBS, and its role in affecting Rn, G0, and H are mentioned. It's stated that "it affect most the sensible heat flux (H) through calculation of aerodynamic resistance". According to the definition of H; H= Cp (T0-Ta)/ra where Cp is the heat capacity of air, is density of air and ra is the aerodynamic resistance. Obviously, (T0-Ta) is the main forcing magnitude and directly affects the H, independent from the calculation of aerodynamic resistance.

We reply:

We have addressed this sentence construction in a previous comment (your comment 2).

Reviewer 3 Comment:

P.6589, L.3-6: it is stated "Additionally, the heterogeneity of the study area implies that an accurate interpolation of air temperature across the study area is needed in the absence of distributed field-based air temperature measurements." This statement is logically not correct. In the absence of distributed field measurements, and presence of topographically heterogeneous landscape, an accurate interpolation is not possible (by the definition and functionality of interpolation). Global climate data products (e.g. ECMWF) could be an alternative source for distributed air temperature.

We reply:

We would like to change this to "Additionally, the heterogeneity of the study area implies that spatially distributed air temperature across the study area is needed. Potentially global climate data products could be considered for catchment scale observations;

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however, this may not be suitable for field-level studies."

P.6591, L.6: It is stated ": : : pixels with values of 0.2 or lower are considered to be sparsely vegetated or to contain bare soil". According to Eq (2), and when NDVImin = 0.2, NDVImax=0.5, Fc becomes "0" for NDVI value of 0.2, which indicate complete bare soil conditions but not sparsely vegetated or partially containing bare soil. Therefore, SEBS assign "0" values of Fc according to Eq (2) for the NDVI values of 0.2 or lower. The values between the min and max represent the mixed vegetation cover with different degree of sparse vegetation.

We reply:

Noted, we will make the suggested change.

Reviewer 3 Comment:

P.6592, L18-19: Grammatically it is better to say "However actual ET is not equal to potential ET where NDVImax equals to 0.65" instead of putting mathematical signs in the sentences.

We reply:

Noted, we will make the suggested change.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 6581, 2010.

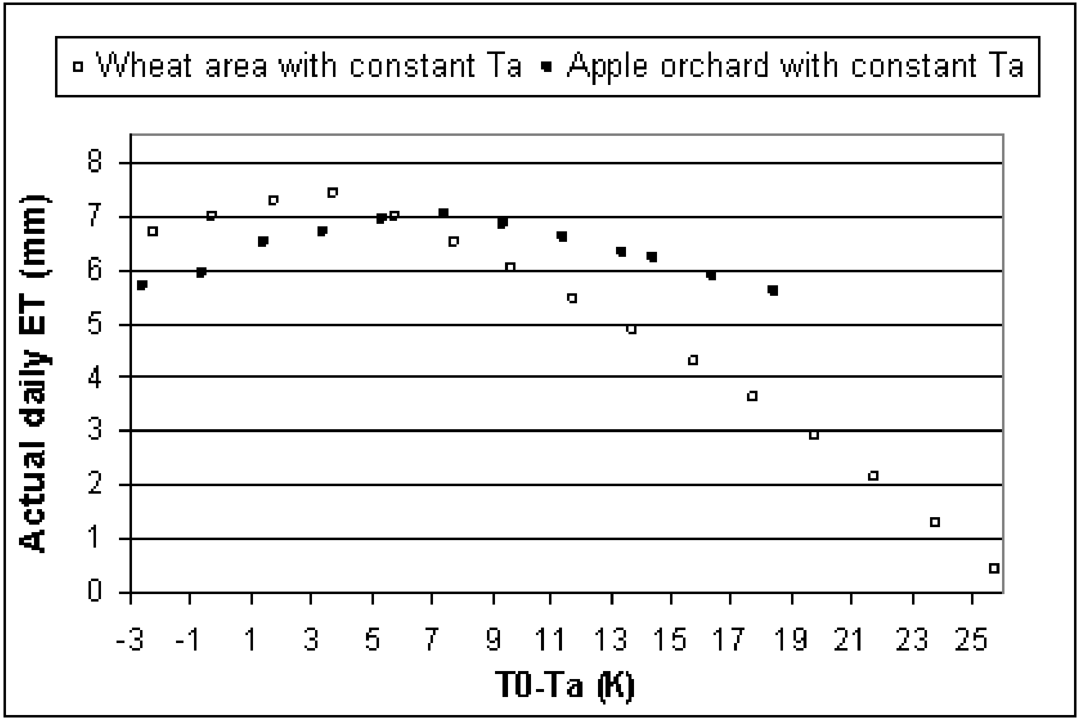

Fig. 1. Revised Figure 2