

## ***Interactive comment on “An application of GLEAM to estimating global evaporation” by D. G. Miralles et al.***

**D. G. Miralles et al.**

diego.miralles@falw.vu.nl

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We would like to thank Dr. A. J. Teuling for his detailed review of our manuscript. We are also grateful for his scripts to develop bivariate colour maps. His comments are addressed in the following response and the manuscript is being revised to accommodate the changes.

### **Referee #1**

The title suggests that the paper is an application of a method to learn something about a process (i.e., global evaporation), but it remains unclear from the abstract what has been learned exactly. Obviously, the manuscript can make the biggest contribution by

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focusing more on the different components of evaporation and how they relate, since this is where the manuscript differs most from similar papers. While some analyses have been performed in this direction, many obvious questions remain unanswered.

### **Reply**

We acknowledge that at some points the paper seems to lack a clear message. Our intention is to extend the knowledge about the global distribution of land evaporation by benefiting from the ability of GLEAM to separate the different constituents of the evaporative flux.

The corrected paper will give more emphasis to the decomposition of evaporation. We have prepared new figures that explore the relative importance of the different components over the Earth's ecosystems (see below). Moreover, Abstract and Conclusions will be revised to put more focus on the ability of GLEAM to calculate these different components of the evaporative flux separately.

### **Referee #1**

What is the global evaporation for the period 2003–2006 and its possible interannual variability? (presented in different units, so volume and depth, and with uncertainty estimates, see comment below, so that the numbers can be easily used by others).

### **Reply**

The global evaporation for the period 2003–2007 is presented in Tables 2 and 3, both in volume and depth. The text of the corrected manuscript will also reflect the percentage of this total evaporation that corresponds to each component of the flux.

### **Referee #1**

How does this estimate compare to numbers in other studies? (surely there are more

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numbers in the literature than the two others mentioned on Page 11).

#### **Reply**

The paper by Oki and Kanae (2006) will be also mentioned in the manuscript. Therefore, we will report the numbers from four previous studies. It is important to note that the majority of the existing methodologies have not published their results in units of volume but in units of depth (with no information about the area of the grid-cell or the spatial domain of the product there is no conversion possible).

Regardless, an independent detailed inter-comparison study that includes GLEAM is currently being performed (by Dr. C. Jimenez) within the frame of the LandFlux initiative.

#### **Referee #1**

How much do certain ecosystem types, continents and processes contribute to the total global evaporation? (presented also as % of  $E$ , possibly in a graph or map).

#### **Reply**

A new figure will be added to the text in the form of a bar diagram to Sect. 4.2. It will illustrate the percentage of global land evaporation that is supplied by each continent and by each biome. This figure will also show what fraction of that percentage corresponds to each of the components of the evaporative flux.

#### **Referee #1**

What is the dominant contribution to total  $E$  in a given region? (i.e., bare soil, transpiration, sublimation, this can be presented in the form of a map)

#### **Reply**

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The old Fig. 4 that showed the map of the components of land evaporation will be modified to include a latitudinal profile for each of the components. We believe that this updated figure - together with the new bar diagram mentioned above - will make clear the dominant contribution to total  $E$  at any given region in the globe.

#### **Referee**

What is the average soil moisture stress in each pixel? The authors correctly state that the stress parameterization is of key importance, but without it being presented explicitly there is no way of knowing its regional importance (note that the correlations in Figure 6 only reflect part of this information).

#### **Reply**

A new figure will be added showing the global average distribution of the daily stress factor for the months of JJA and DJF. This figure will be included within the drivers section (Sect. 4.3) to point out the areas in which land water availability is insufficient to meet the atmospheric demand according to the model.

#### **Referee**

A general comment related to my previous one deals with the lack of uncertainty estimates for the GLEAM product. Many different gridded ET products exist nowadays, and these products typically differ significantly (Müller et al., 2011). Information on uncertainty is almost indispensable in present-day science in general, and in application and comparison of gridded datasets in particular. Such information can for instance (in the case of GLEAM) be derived from statistics of the data assimilation increments (i.e., the imbalance between the Priestley-Taylor evaporation and the calculated soil water budget), or by creating a GLEAM ensemble with perturbed parameters.

#### **Reply**

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Several sensitivity analyses based on Monte Carlo simulations have been carried during the development of the model. The results of these studies gave practical information about the parameters that evaporation estimates are more sensitive to. However, the lack of information about the real uncertainty of some of the inputs precluded these analyses from being published. Moreover these analyses do not give any information about the intrinsic errors of the model.

Recent efforts towards a better characterisation of the error structure of GLEAM have been focused on the applicability of the Triple Collocation (TC) technique for our purposes. TC could be used to retrieve the RMSE of GLEAM at every pixel by inter-comparing it with two independent evaporation products through a long enough period. TC however requires de-trending of the seasonality and scaling of the products, and therefore could not be used to characterised the bias but only the error in short-time dynamics of evaporation (e.g. how well the model estimates the change in evaporation after a rainfall event) – see for instance Miralles et al., 2010.

This TC analysis – which was initially planned for the long term dataset – will be considered for this paper. Other possibilities (like the application of the method of moments) are also being explored.

Nevertheless, the corrected manuscript will include a short section dealing with the uncertainty in the final GLEAM estimates of evaporation.

#### **Referee #1**

A third general comment concerns the usage of the term “physics-based”, also commented on by Fischer, in both the manuscript and the response to Fischer. The authors claim that “physics-based” methods are “data-driven”, whereas “model-driven” methods are empirically-based. In my view, it is exactly the opposite. Physics-based methods are based primarily on fundamental laws of physics that don’t (or to a very limited degree) depend on parameterization. Data-driven methods are by definition em-

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pirical, but they are indispensable in earth system sciences since the world cannot be modeled by fundamental physics alone. Since GLEAM violates the most fundamental physics law for hydrologists, namely the conservation of mass, and uses several empirical relationships, it cannot be called “physics-based”. Note that this is not necessarily a bad thing, since the final product can still be optimal in a statistical sense. My suggestion would be to just describe the method as it is, and avoid any discussion about “physics-based” versus “model-driven”.

#### **Reply**

It appears that this is a very sensitive topic. We will avoid using these labels in the corrected version of the manuscript. However, I would like first to clarify once more what we meant: we claimed it is “physics-based” as opposed to “empirically-based” because is based on the parameterisation of physical processes (i.e. it is not a black box). We also claim it is not “model-driven” but “data-driven” because the methodology has been tailored based on the data that were available (trying to find the equations that could make the best use of the existing data, as opposed to finding the data that fit an existing equation).

None of these terms will be mentioned in the manuscript.

#### **Referee #1**

Page 2, Line 16: “This study gives new insights into the relative importance of precipitation and net radiation in driving evaporation”. Can such new insights be obtained by studying signals that are not independent? The fact that precipitation, soil moisture, as well as radiation are at the heart of the GLEAM model, and not independent observations (as was the case in the analysis of Teuling et al., 2009) should be acknowledged.

#### **Reply**

Precipitation, soil moisture and net radiation are not independent observations and

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this should indeed be acknowledged in the text. Eventually we tried to use independent global estimates of these variables in our analysis. This however made it hard to interpret the figures, as those independent variables also had new independent uncertainties. Previous studies like the one by Teuling et al. (2009) do not reveal the impact of the rainfall interception as rain-days are excluded from the analysis – probably because of the problems of FLUXNET stations when it comes to measuring wet evaporation – and therefore analyse only the drivers of transpiration and soil evaporation. In that sense, the inclusion of interception in GLEAM has a significant impact on the study and allows a better understanding of the processes limiting evaporation.

It is our intention to get a better understanding of how the methodology captures real land-atmosphere processes. Therefore we do not pretend to identify new interactions but to get an insight into the relative importance of the parameters controlling evaporation in different regions in the world (taking advantage of the daily frequency and separate estimation of the different components of evaporation within GLEAM).

In that sense, even though the analysis we present is highly affected by the level of sensitivity of the estimates of evaporation to each of the inputs, we still believe that it gives further information about the different response of evaporation to changes in precipitation and net radiation over different regions. We understand however that these results must be discussed with more care due to the above-mentioned dependency (inter-dependency in the case of soil moisture). The manuscript will be revised to avoid the misinterpretation of the results of our analysis; the difference from the study by Teuling et al. (2009) will be mentioned.

#### **Referee #1**

Page 3, Line 25: “calibration or tuning of new parameters is thus unnecessary”. This is a very strong and somewhat strange statement. Surely, the parameters used might result in reasonable estimates of evaporation, but all of the parameters in the model will

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turn out to vary both in space and time when studied in detail. Even the PT-“constant” is known to vary from 1.08 to 1.75 depending on, unfortunately, evaporation itself.

#### **Reply**

This seems to be a sensitive topic as well. We will avoid mentioning this issue in the corrected manuscript.

#### **Referee #1**

Page 3, Line 26: “explicit coupling between evaporation and soil moisture conditions”. This coupling is not explicit since the soil moisture balance is controlled by data assimilation.

#### **Reply**

Indeed. Yesterday’s evaporation will not affect explicitly today’s soil moisture because of today’s data assimilation. That is correct. However, today’s soil moisture – as it is already after the data assimilation – will affect (in a more explicit way) today’s evaporation through the computation of the stress factor ( $S$ ). We should also notice that in the computation of  $S$ , the vegetation optical depth plays a role over short vegetated ecosystems; therefore  $S$  does not depend exclusively on the soil moisture conditions.

We acknowledge there is not such a straightforward relation between soil moisture and evaporation in the model so we will avoid using the term ‘explicit’.

#### **Referee #1**

Figure 3/4: Figure 3 contains interesting information, but why isn’t bare soil evaporation included? Alternatively, Figure 4 could be extended with small panels on the sides of the maps that show the latitudinal distribution of all components.

#### **Reply**

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Correct. Figure 4 (as mentioned above) will be modified to include panels on the sides of the maps with the latitudinal distribution of all components.

#### **Referee #1**

Figure 6: This data is indeed suitable for plotting with a bivariate color scheme. Such schemes, however, are notoriously difficult to read, and care should be taken that the use of information in color is maximized. In the current color scheme, only a limited subset of all possible colors is used (i.e., the green component seems not to be used), effectively compromising the interpretation. A wider spectrum of colors is used in Figures 4 and 5, whereas they only use 1D color schemes. A method that makes more effective use of the degrees of freedom offered by the different color components is described in Teuling et al. (2011). A code is available upon request.

#### **Reply**

We thank the reviewer for his suggestion. The new figure will be developed using the technique presented in Teuling et al. (2011). We do believe this will ease the interpretation of the figure.

#### **Referee #1**

In addition, the authors should be aware of and account for possible negative correlations between soil moisture and evaporation in humid regions. These are not artifacts or noise, but an inherent consequence of the non-linear relationship between soil moisture and evaporation.

#### **Reply**

Negative correlations will be considered in the new figure and discussed in the corrected manuscript.

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#### **Referee #1**

Table 2/3: I assume these values are yearly sums, and not the total sum over the period 2003–2007?

#### **Reply**

This is indeed an error. 'Annual evaporation' will be substituted for 'Total evaporation'.

#### **References**

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