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Interactive comment on "The GEWEX LandFlux project: evaluation of model evaporation using tower-based and globally-gridded forcing data" *by* M. F. McCabe et al.

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Author Introduction. We appreciate the insightful comments by Dr Fisher, particularly in regard to elaborating the context of the GEWEX Landflux study and its differentiation from prior analysis. We have attempted to address these points in the responses below.

Reviewer Introduction. This is a well-written study intercomparing 4 ET algorithms against FLUXNET ET measurements. Like the rest of the group of papers coming out of this team (GEWEX/LandFlux, WACMOS), the strengths are in the selection of algorithms, the common forcings, and the rigorous analyses. Similarly, the weaknesses include the fact that the results are scattered among different papers with somewhat

different details of analyses, so it is very difficult to understand the cohesive picture, and that the papers do little to go beyond statistical intercomparison and into the realm of science understanding.

Comment 1. Nomenclature consistency: Mu et al., 2011 abbreviation is referred to inconsistently across projects, i.e., PM-Mu, PM-MOD, PM-MOD16, etc. Same goes with GLEAM (colon/no-colon; Methodology vs. Model).

Author Response. The reviewer raises an important point. It is worth noting that there are a number of versions of the Mu et al. 2011 that have been published in the literature over the last few years. Here we employ the most recent iteration, which has also appeared in a number of earlier papers from our group (where it is referred to as PM-Mu). In order to be consistent with these previous efforts (and past work including the Vinukollu et al. papers), we have retained the current usage. We now make a note in Section 2.2.3 that although the abbreviations are distinct, the models are consistent across both the Landflux and WACMOS-ET projects. We defer to the Miralles et al. (2015) paper and adjust the use of GLEAM to be consistent with that contribution.

Author Change. The following note is included at the start of Section 2.2.3 to highlight the commonality of models across projects, even though the abbreviation is different: "(n.b. the PM-Mu nomenclature used herein reflects an identical model used in Michel et al. (2015) and Miralles et al. (2015), where it is referred to as PM-MOD)".

Reference to GLEAM follows Miralles et al. (2015) as the Global Land Evaporation Amsterdam Model and has been adjusted where relevant throughout the manuscript.

Comment 2. It should be made clear how this study advances past Vinukollu et al 2011.

Author Response.The Vinukollu et al. (2011) paper presented an excellent multi-model evaluation of global flux products. However, there are some key differences and advances between this and our current contribution. Firstly, the scale and scope of the

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analysis: in their paper, Vinukollu studied the period 2003-2006 and compared global scale simulations against 12 flux towers in the US. We examine data from 45 globally distributed (three-quarters outside of the US) and consistent towers (i.e. all towers are used across all models), spanning a period of approximately 10 years (with an average tower record length of more than 4 years). Most importantly, in the Vinukollu study, no analysis of the models was performed at the tower-scale: a key feature of the present work. That is, in examining model response, both large-scale gridded forcing and small scale tower forcing are employed. Additionally, Vinukollu et al. present their analysis at a monthly and annual scale, whereas we examine the finest time resolution of 3-hourly: the first such attempt to do so. Finally, the emphasis in the Vinukollu paper was on developing a satellite driven forcing dataset, whereas we have attempted to assemble a high-quality and consistent forcing product at the grid-scale, irrespective of a remote sensing focus.

Vinukollu RK, Wood EF, Ferguson C and Fisher JB (2011) "Global estimates of evapotranspiration for climate studies using multi-sensor remote sensing data: evaluation of three process-based approaches", Remote Sensing of Environment, 115, 801-823

Comment 3. Also, please make clear how this is *scientifically* different than the Michel paper (in prep at the time of this review writing, but soon to be in Discussions). At first, when reading the Michel paper, I thought the main difference was the 3-hourly analysis, but then I've seen the McCabe paper also includes 3-hourly. . .

Author Response. It is important to highlight that WACMOS-ET is a direct contribution to the GEWEX Landflux efforts, and by no means are these projects competing efforts. As a consequence, there is involvement by key investigators driving these efforts in both projects and deliberate commonalities between the projects. But there are also clear distinctions. The most obvious of these is the motivation behind them. Landflux is focused on the development of long-term (20+ year), climate scale data records, while WACMOS-ET examines a short-term (2005-2007) period focused on demonstrating evaporation capability using predominantly European Earth-observing

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assets. As such, there are clear distinctions in the forcing data used to drive the models. Apart from the more compressed period of analysis in the WACMOS-ET study, the compilation of distinct elements in the forcing data-set allows for an examination of model response to different forcings: work that remains ongoing to tease out these influences. Encouragingly, the outcomes of these two projects seem largely consistent in terms of simulation behavior, even though the assessment period was considerably longer in the McCabe et al. analysis [and also used a greater number of towers: 45 versus 24]. Michel et al. expand the Landflux focus on 3-hourly analysis to the daily scale, while also investigating variation during night and day conditions. Both projects represent significant contributions towards the goal of developing robust global flux products.

Author Changes. Now that the WACMOS-ET papers are in HESS Discussion, we make explicit reference to these works when discussing the different scientific rationales behind the efforts in the Introduction.

Michel D, Jiménez C, Miralles DG, Jung M, Hirschi M, Ershadi A, Martens B, McCabe MF, Fisher JB, Mu Q, Seneviratne SI, Wood EF and Fernández-Prieto D (2015). "The WACMOS-ET project – Part 1: Tower-scale evaluation of four remote sensing-based evapotranspiration algorithms." Hydrol. Earth Syst. Sci. Discuss. 12(10): 10739-10787.

Miralles, DG, Jiménez C, Jung M, Michel D, Ershadi A, McCabe MF, Hirschi M, Martens B, Dolman AJ, Fisher JB, Mu Q, Seneviratne SI, Wood EF and Fernaìndez-Prieto D (2015). "The WACMOS-ET project – Part 2: Evaluation of global terrestrial evaporation data sets." Hydrol. Earth Syst. Sci. Discuss. 12(10): 10651-10700.

Comment 4. Speaking of which, given the whirlwind of papers coming out of this GEWEX/LandFlux & WACMOS group (e.g., Michel, Miralles, McCabe, Ershadi,...), I strongly urge McCabe in particular to write a meta-analysis/review paper of these papers to distill everything down into 1 place (include the Vinukollu, Jimenez, Mueller,

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etc. papers too). Aim high (e.g., one of the Natures, etc., or perhaps WRR).

Author Response. This is an excellent suggestion that is indeed on the radar of the respective investigators of these efforts. A distillation of past work, progress and the way forward would be a valuable contribution to the literature. We hope to rely on other participants in the evaporation community to assist with this effort!

Comment 5. A semantic nuance that would improve the interpretation of the results further would be to rephrase/reframe model performance not so much in that X model overestimates/underestimates, but that it's actually the model in conjunction with the selected forcings. E.g., it may not be inherent to the model itself that it is biased high or low, but rather due to the forcings. This would primarily be for bias, not as much for the other statistics, though the other statistics would not necessarily be completely immune either.

Author Response. We agree with the reviewer that discriminating the role of model response separate to uncertainties in forcing is a needed task. We have attempted to restate that it is the combined influence of forcing and model response that is being examined - and to which further work is required to disentangle. Indeed, the title of Section 3.1 highlights that we are undertaking a "relative performance" of the models when comparing tower and gridded data. The paragraph at the bottom of page 6826 further reinforces this concern:

"Overall, these results confirm that all models display a relatively high sensitivity to changes in the type and quality of input forcing data. While gridded forcing data are expected to have a mismatch with the tower-based forcing due to their larger pixel (and footprint) sizes, this spatial mismatch will impact all of the applied models, albeit to a lesser or greater extent, depending on forcing data requirements. While spatial scale no doubt plays a major role in decreasing model efficiencies at grid-scales, the most likely reason for the differences in tower- versus grid-based results relates to internal inconsistencies within the gridded forcing data. . ..Not surprisingly, results also indicate

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that those models that use fewer inputs show lower sensitivity to changes in the forcing. As such, any inconsistency between the tower and gridded data is likely to have less influence on the PT-JPL, GLEAM and PM-Mu models than it will on SEBS, which in addition to vegetation height, requires both land surface temperature and wind speed data: two variables with considerable spatial variability"

The Landflux focus is to develop (as much as possible) consistent forcing across models, presenting one means to address this complicated task. But we also need to recognise that forcing uncertainties are unavoidable and will always influence simulation results. Characterizing this response requires further attention.

Author Changes. We have added the following sentence to the above paragraph to reflect the combined nature of model and data uncertainty: "Disentangling the varying influence of model structural and forcing data uncertainty requires focused attention and is examined further in the Discussion section".

Comment 6. How can error be reduced in the models further? What causes the error? I think a lot of the error that the authors attribute, as calculated, to the models is in fact error in the data. It remains an outstanding question in this analysis why a model would do well at some sites, but not well at other very similar sites. Or, even inconsistently throughout time within a single site.

Author Response. The Landflux and WACMOS-ET efforts are initial attempts at addressing these types of questions (with the realization that undertaking such works seem to uncover more questions than answers). The challenge of separating the role of process descriptions, model sensitivity to forcing and forcing data uncertainty is an outstanding one that requires sustained community effort to resolve. These questions of attribution are critically important and require continued examination. However, they cannot be done in isolation. Studies such as the present analysis illustrate the inherent variability in performance and multi-model response and provide solid first steps towards addressing such questions. In the related WACMOS-ET contribution, Miralles et

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al. (2015) offer some initial guidance on model behaviour that developers may be able to address. For instance, the underestimation in PM-Mu/MOD is due to an overestimation of evaporative stress, that PT-JPL and GLEAM underestimate in high-latitudes and times of low radiation, and that the role of interception (and partitioning of evaporation between its different components) remains a major source of uncertainty.

Miralles et al. (2015) “The WACMOS-ET project – Part 2: Evaluation of global terrestrial evaporation data sets”, Hydrol. Earth Syst. Sci. Discuss., 12, 10651–10700, doi:10.5194/hessd-12-10651-2015

Interactive comment on Geosci. Model Dev. Discuss., 8, 6809, 2015.