

## ***Interactive comment on “Multi-criteria parameter estimation for the unified land model” by B. Livneh and D. P. Lettenmaier***

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We thank Referee 1, Dr. P. Bauer-Gottwein, for the positive, constructive review and we agree with most of the recommendations made. Below we respond to them in the order they were raised. Review Comments 1. We have expanded the description of the calibration approach to include the model spatial resolution (1/2 degree for large-scale, 1/16 degree for small scale), clarify which parameters were actually calibrated (Table 2), identify constraints on parameter ranges, and uniqueness of the results. 2. We have added additional explanation of the TWSC data, which came from 3 processing centers that were ultimately averaged over the basin shapes. 3. We have expanded our discussion of the process for comparing the ET products to explain better what was

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done. Due to the fact that we were comparing ETsat (from satellite) to a product that is, by construct, a spatial average (i.e. ETawb – from an atmospheric water balance), we elected to consider a spatial average for ETsat for consistency, to facilitate a one-to-one comparison between ET products. We now point this out in the text. 4. We agree that characterizing model uncertainty would provide further insight into some of the issues presented in the manuscript. We don't think, though, that explicit accounting for model parameter uncertainty is within the scope of the current manuscript (i.e. to repeat the calibrations within, say a Bayesian framework). We think that the referee may have confused the content of Figure 8 with such an uncertainty analysis. Figure 8 shows the difference between observational estimates of TWSC (from JPL, GFZ, CSR), where the range of observed means are shaded darker than observed standard deviation ranges. The idea was to facilitate comparisons with the modeled values, for which reason we showed the interannual variability as the whisker bars. We considered including similar plots for the other two water budget components, Q, ET, however, since they do not draw from 3 streams of data, practical issues arise with showing their inherent uncertainties. For Q (Figure 4), there is no straightforward way to show observational uncertainty across gauges, as some data come from a naturalization procedure. For ET (Figure 7), where there are two observational products, we decided that it was not entirely justified to shade the difference between these, since they represent "independent" estimates of ET (versus Figure 8, TWSC, which are simply different assumptions applied to the same data). Including 5 time series on Figure 7 with whiskers would make it essentially unreadable and difficult to interpret. In consideration of all of this, we've decided that it's best to retain the current presentation. We have included additional text describing the importance and implications of uncertainty in interpreting the figures. Details: 1. We agree. SAR and scatterometer soil moisture have been added to the review, as well as the corresponding citations for Milzow et al., 2011, and Brocca et al., 2012. 2. Agreed. We have added a statement in the caption referring the reader to Table 1, where the abbreviations are explained. 3. We appreciate the suggestion of the referee. However, what is shown is \*not\* a Pareto front, strictly speaking. These

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are the results from individual calibrations, which each produced unique Pareto fronts, from which a single-best calibration was selected and plotted on Figure 11. We have added a more detailed description of this procedure in section 3.4, so as to clarify what is shown in Figure 11, which is in fact the tradeoffs in multi-criteria performance when calibrating to single or multiple criteria, each within their own multi-objective framework. 4. We have added what we hope is a clearer explanation of how the whisker bars were computed. We disagree that the paper would be stronger by including whisker bars on Figures 4 and 7 (see response 4 to major comments above), however, we have addressed the referee's concern by first clarifying the confusion on how the whisker bars were computed, and second by an additional statement describing the importance and implications of uncertainty in interpreting these figures.

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