

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

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### Summary

This paper presents a multi-objective calibration study for a large set of river basins in the US. Calibration data include traditional discharge measurements, actual ET from both atmospheric water balance and multi-spectral satellite imagery as well as total water storage change from GRACE. The study contains a rigorous comparison of the value of different data types in terms of improving streamflow prediction. It also facilitates the comparison of model performance across a large set of river basins spanning a wide range of hydroclimatic conditions. The paper should be published after some minor to moderate revisions.

## Review Comments

1. The paper contains insufficient information on the calibration approach. Calibration is performed for both large and small basins. It is unclear if the resolution of ULM is the same in both applications. If it is, the number of calibration parameters will be much larger for the big basins than for the small basins. Which parameters were actually calibrated (all parameters listed in Table 2)? Were regularization constraints applied in the calibration for the large basins? Is the calibration result unique? Are the calibration parameters correlated? Please provide more details on these issues.

2. It is not clear how the TWSC estimates from GRACE were used in this study. Was TWSC inverted for the basin shapes or was a standard GRACE product taken and averaged over the basin shapes?

3. It is not clear from the text how the ETsat product was compared with model outputs. Was the comparison made pixel-by-pixel or was the average actual ET over the basin area compared to the average simulated actual ET? If ETsat was spatially averaged, any information contained in the spatial variations of ETsat would be lost, which may be a disadvantage, particularly for the large basins.

4. The paper emphasizes that the goal of the multi-objective calibration approach is improving the skill of the model in terms of predicting water balance components under various scenarios. However, skill should be evaluated not only in terms of how close the model results are to reality but also in terms of model uncertainty (reliability, sharpness etc.). The paper would benefit if model uncertainty could be added to all model outputs, as done in Figure 8 for simulated TWSC.

## Details

1. Lines 5-10: I think this review should also include SAR and scatterometer soil moisture, which is increasingly used for calibration of models. Milzow et al., 2011 uses this besides TWSC and there are other suitable references, e.g. Brocca et al., DOI:

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10.5194/hess-14-1881-2010.

2. Fig 4: Explain basin abbreviations in the caption or indicate in Fig 1.
3. Fig 11 is hard to read. My suggestion would be to plot 2D cross sections through the objective space so that the Pareto fronts can be clearly seen.
4. Figs 4, 7, 8: Figure 8 is the only place where error bars for ULM model output are given, while Figs 4 and 7 do not include error bars. It is not clear from the paper how the model errors were calculated for Figure 8. It would make the paper stronger if model errors were also added to figures 4 and 7.

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