Interactive comment on "Evaluating the strength of the land–atmosphere moisture feedback in earth system models using satellite observation" *by* P. A. Levine et al.

P. A. Levine et al.

plevine@uci.edu

Received and published: 16 August 2016

This response is intended to supplement the already-submitted response to the review by Referee #3. As discussed in our main response, the reviewer was concerned that our observational metrics may be compromised by the uncertainty inherent in the satellite data combined with the relatively short time scale ($\sim$13 years). It was suggested that our finding of stronger feedback metrics in models relative to those from the observational data could be the result of observational error degrading the correlations that our metrics are based on.

In order to test the sensitivity of our metrics to this type of error, we used Monte Carlo sampling of the CESM Large Ensemble (LENS) with random noise. At each grid cell,

we added random noise to each data point within the 12–13 year time series. Random noise was generated with numbers sampled from a random Gaussian distribution with a mean of zero and a standard deviation equal to 25% of the standard deviation of the source data. This was repeated 10 times for each of the 38 ensemble members from LENS.

The results of this test are illustrated in the figures below. The perturbed ensemble members did yield weaker correlations, but the difference between the perturbed and original ensemble members was very small relative to the difference between the observed and modeled feedback metrics when averaged across latitudes. This indicates that our metrics are fairly insensitive to this level of random noise, which we believe is a reasonable amount considering the error associated with the remote sensing data sets we use.

We plan to include the figures below as additional supplementary figures to our manuscript. We also plan to mention this test and discuss its implications with some additions and revisions to our text. We plan to add a new sub-section to our methods section, **2.4 Assessment of uncertainty**. We plan to move Page 2, lines 2–7 to this new section, along with the following new text:

> We assessed the sensitivity of our metrics to observational uncertainty using a Monte Carlo sampling approach. For each of the 38 members of LENS, we calculated feedback metrics ten times with random noise added to both TWSA and atmospheric variables. The noise was randomly generated from a Gaussian distribution with a mean of zero and a standard deviation equal to 25% of the standard deviation of the original data. Comparing these results with the original metrics provided some indication of how much our feedback metrics are degraded by random noise as an approximation of observational uncertainty.

We plan to add the following paragraph to the end of **Section 3.3 Evaluating the CESM Large Ensemble**:

> Comparison of the original LENS forcing and response metrics with those calculated after adding random noise to LENS provided an estimate of the metrics' sensitivity to observational error. Adding random noise with 25% of the standard deviation of the original data does degrade the metrics slightly, causing areal averages to be closer to zero, but the difference is relatively small compared to the difference between observed and modeled averages as well as the spread of the ensemble itself (Figures S4 and S5). This indicates that we should expect observational error to have a relatively small impact on the quality of our satellite-derived metrics.

Finally, we plan to include the following revised paragraph in our discussion section:

> One factor that could contribute toward stronger feedback metrics in models relative to observations is the effect of observational uncertainty combined with a relatively short time series. Adding error to one or more variables in a correlation analysis will reduce the correlation coefficient, and this degradation has been shown to be sensitive to the length of data sets used to establish metrics of land–atmosphere interactions (Findell et al., 2015). Given the relatively short time series available for the current analysis, the correlation coefficients from remote sensing data may be reduced due to observational uncertainty, unlike those derived from internally-consistent models. We found that adding random noise to LENS at 25% of the variance of the original data causes a minor degradation of our area-averaged feedback metrics, but only by a small amount relative to the difference between LENS and the observations (Figure S4 and S5). This indicates that our

C3

> feedback metrics, when averaged across large areas, should be relatively insensitive to random error in the observational data.

We believe this additional analysis and the accompanying revisions to the text serve to demonstrate that the issue of observational uncertainty is not the serious issue that Referee 3 indicated they believed it to be.

Figure captions:

> **Figure 1 (Figure S4 in revised manuscript).** Ensemble histogram of forcing metrics from LENS (grey bars) and LENS plus 25
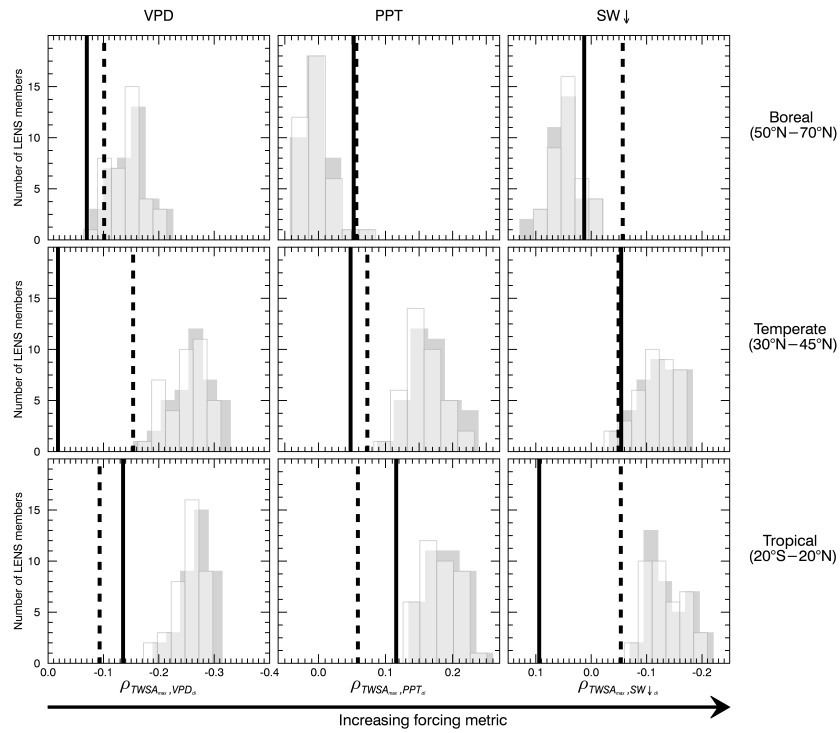
> **Figure 2 (Figure S5 in revised manuscript).** Ensemble histogram of response metrics from LENS (grey bars) and LENS plus 25% random noise (white bars), with the satellite observations from GRACE/AIRS/GPCP/CERES (solid black line) and the alternate observations from GRACE and ERA-Interim (dashed black line), averaged across land regions within different latitude bands.

References cited in this response:

Findell, K. L., Gentine, P., Lintner, B. R. and Guillod, B. P.: Data length requirements for observational estimates of land–atmosphere coupling strength, J. Hydrometeorol., 16(4), 1615–1635, doi: 10.1175/JHM-D-14-0131.1, 2015.
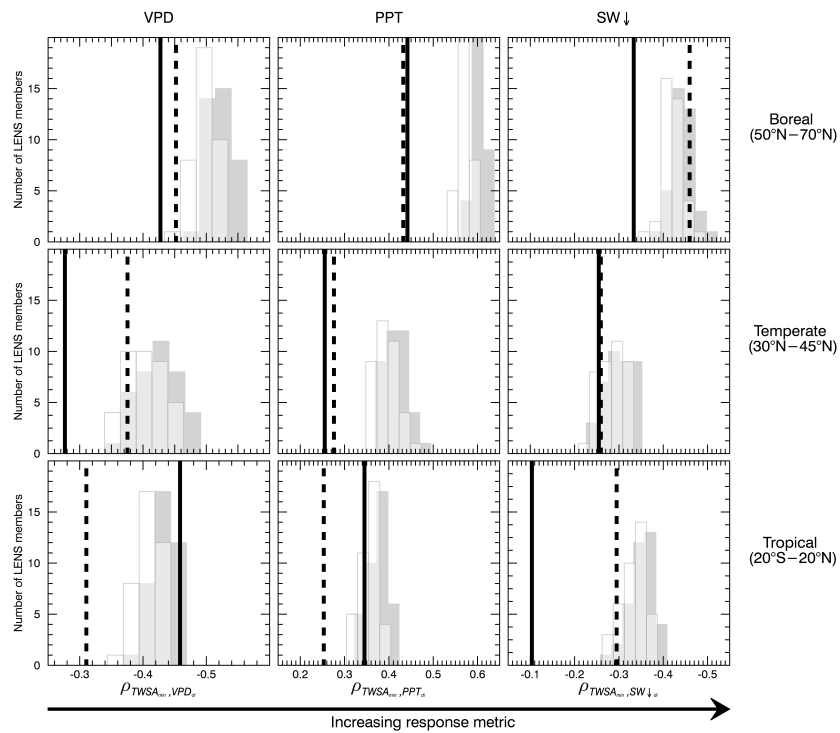
Fig. 1. Figure S4 in revised manuscript (see caption in text)

Fig. 2. Figure S5 in revised manuscript (see caption in text)