Editor Initial Decision: Reconsider after major revisions (19 May 2015) by Prof. Pierre Gentine
Comments to the Author:

Dear authors, One of the reviewers still seemed dissatisfied by your responses. In particular you overlooked some of his/her comments. In particular I echo his/her comment regarding the discussion on land-atmosphere coupling.

In the manuscript there are many instances which I believe are incorrect. You mention that you are evaluating the full cycle Delta SM->Delta EF-> Delta PBL but this statement is incorrect. You do not have Delta PBL. In reality you are testing the correspondence of EF to the observed LCL (and thus PBL).

We agree that we do not actually simulate Delta PBL and have therefore rewritten the parts of the manuscript that previously implied our modeling included Delta PBL. We hope it is now clear that we do not claim we are diagnosing the strength of the land-atmosphere coupling in our study. Instead, we demonstrate that it is necessary to include the soil moisture that drives the relevant physical processes in order to characterize the land-atmosphere relationships. Therefore while we cannot say when land-atmosphere coupling is strong, we can state that future research needs to incorporate SMrz into statistical measures of coupling or risk missing periods when fluxes are driven by SMrz.

I believe the strategy is fine but I would not call a coupling because you have offline observations.
We agree and have meticulously evaluated the language in the manuscript to ensure that we don't imply or state that we are evaluating the land-atmosphere coupling. Instead we are looking at the statistical associations between SM or EF and the LCL in order to determine when and where this diagnostic measure is appropriate.

The term correspondence is also rather fuzzy.

We have gone through the manuscript and replaced many instances of correspondence with much more descriptive terms. For example, we have replaced correspondence and association in several place in the Abstract, which now reads as
"The similarity of the temporal variations of land and atmospheric states during the onset (September) through to the peak (February) of the wet season over Northern Australia is

statistically diagnosed using ensembles of offline land surface model simulations that produce a range of different background soil moisture states. We derive the temporal correspondence between variations in the soil moisture and the planetary boundary layer via a statistical measure of rank correlation. The simulated evaporative fraction and the boundary layer are shown to be strongly correlated during both SON and DJF despite the differing background soil moisture states between the two seasons and among the ensemble members. The sign and magnitude of the boundary layer-surface layer soil moisture association during the onset of the wet season (SON) differs from the correlation between the evaporative fraction and boundary layer from the same season, and the correlation between the surface soil moisture and boundary layer association during DJF. The patterns and magnitude of the surface flux-boundary layer correspondence are not captured when the relationship is diagnosed using the surface layer soil moisture alone. The conflicting results arise because the surface layer soil moisture lacks strong correlation with the atmosphere during the monsoon onset because the evapotranspiration is dominated by transpiration. Our results indicate that accurately diagnosing correspondence and therefore coupling strength in seasonally dry regions, such as Northern Australia, requires root zone soil moisture to be included."

We now more directly state exactly what the statistical measure evaluates (rank correlation).

IN fact in a paper I was trying to do something similar: inferring EF from LCL Gentine, P., C. R. Ferguson, and A. A. M. Holtslag (2013), Diagnosing evaporative fraction over land from boundary-layer clouds, J Geophys Res-Atmos, 118(15), 8185–8196, doi:10.1002/jgrd.50416.

I would suggest re-framing the parts mentioning the coupling to PBL and LCL.

You should rather mention an inference of an accurate EF and SM for CLM. You should also modify the title accordingly: What about: Inferring evaporative fraction and the role of root zone moisture though maximization of land-atmosphere correlation?

This would be an alternate way of looking at and interpreting our results that we had not previously considered. However the purpose of our manuscript is to demonstrate that care must be taken when diagnosing the land-atmosphere relationship. Previous work that focuses on SM_1 will miss regions and periods due to neglecting the SM that drives changes in EF. We have taken many steps to clarify our intent. We now only mention coupling in the

discussion and conclusion when we state how our work applies to other studies that use non parameteric rank correlation coefficients to infer coupling in either observations or fully coupled land-atmosphere models.

Specific comments: In the abstract I would remove correspondence it is rather fuzzy.
Done.

l122 is incorrect you are not evaluating Delta PBL, I would rather directly reframe this in terms of trying to maximize the EF and observed PBL/LCL information (see Gentine et al. 2012).

We agree and acknowledge that our methodology does not simulate the dynamic processes that relate the PBL/LCL to the land surface. To help clarify that we evaluate the simulated Delta SM and Delta EF to the observationally estimated Delta PBL we have rewritten L122 as follows:

" The statistical association is defined here such that the land surface processes in Equation (1) (ΔSM, ΔEF_{SM}) are simulated and evaluated in relation to the observationally estimated ΔPBL. The dynamic progression represented in Equation (1) are simulated for ΔSM and ΔEF_{SM} only. The physical mechanisms that drive ΔPBL from ΔSM and ΔEF are not simulated, while the sequence of events in the atmosphere (ΔEF_{ATM}, ΔCLD and ΔP) are neglected. This terrestrial derived statistical association captures how a model simulated ΔSM relates to state changes in the afternoon mixed layer (ΔPBL) by assuming that ΔPBL can be characterized using near surface atmospheric states. Strong association as defined here is a necessary but not sufficient prerequisite for strong ΔSM-ΔPBL or ΔSM-ΔP coupling because the full chain of events is not simulated."

l169 is incorrect: Delta SM to Delta EF instead of Delta PBL

The statement at L169 has been rephrased so that it doesn't imply that our methodology fully simulates the dynamics involved with the full land-atmosphere system. The sentence now reads

"The land surface model simulations and reanalysis products allow for the relationships

within the terrestrial leg (ΔSM-ΔEF in Equation (1)) to be diagnosed without fully simulating the land surface-atmosphere dynamics and feedbacks. "

Our new phrasing highlights that we are examining the relationship between the variations in SM, EF, and PBL with out directly simulating how the PBL changes as a result of SM or EF.

l295 which Tdew is used is unclear

We agree that Tdew was insufficiently described and rectify the situation by adding

"The atmospheric states P_{srf} and T_{air} are directly provided by both reanalysis products and the tower measurements. The measure of atmospheric moisture, T_{dew}, is calculated for GLDAS, MERRA, and the tower sites separately using the respective near surface humidity, temperature, and pressure data from each dataset."

l452-455: the SM-LCL association should be the way to go but it has to be clarified. You are really trying to maximize the information content between your simulated EF and the observed LCL.

The results from Figures 7 and 8 demonstrate that both SM_1 and EF (as simulated by the LSM) are significantly correlated to the estimated LCL during DJF. This result is in agreement with previous research that utilized satellite based SM and LCL estimates, and is what one may expect during the convective season. The important result, however, is that during the monsoon onset (SON), the simulated EF is correlated to the LCL while SM_1 is not. Following the methods of Ferguson et al. 2012 and applying satellite based SM_1 data to this time period one would 'discover' that there is no SM-LCL coupling (assuming that CLM is decently simulating SM_1). This conclusion may be erroneous, though, because EF and LCL are correlated.

l463: DJF coupling: you are not really looking at coupling here

While we don't actually simulate the atmosphere response to the land surface, the lack of statistically significant correlation between the model simulated SM1 and the LCL strongly suggests that in a fully coupled simulation SM1 and the LCL would also not be correlated (and thus one wouldn't see any coupling). Rather than refer to this point within the results section we have moved it to the discussion section. We have altered the sentence as follows to remove the reference to coupling:

“Therefore the relationship between the temporal variations in SM and the LCL in DJF (or other periods where the ET is largely comprised of soil evaporation) can be adequately defined using SM_1. “

same line 539-540

We have also changed this sentence to align with the previous response.
“The results indicate that while the mean ET and transpiration fraction is a strong function of mean soil moisture, the SM-LCL association diagnosed using offline simulations of SM and EF with an observationally estimated LCL is insensitive to the background state.”

IN the conclusions the land-atmosphere association is unclear. I would really suggest re-framing those discussions as a maximization of the EF correlation and a way to infer the soil moisture dynamics.

We have rewritten most of the conclusions to make the results and the importance of the work much more clear. While we haven't directly reframed the discussion towards a maximization of the EF correlation as a way to infer soil moisture dynamics, we have reframed it to highlight that the statistical measures we compute demonstrate the need to incorporate root zone soil moisture when using Kt (or other measures) to infer coupling strength. The conclusions now read as follows:

“ The feasibility of diagnosing the land-atmosphere relationship using a rank correlation coefficient is analyzed utilizing ensembles of land surface simulations and near surface atmospheric data. Using four forcing datasets, ensembles of CLM simulations over Northern Australia are performed, using configurations that intentionally span a range of mean SM states by either including or neglecting soil column-groundwater interactions. The seasonal dynamics of the simulated SM_1 is insensitive to the mean soil moisture state and all simulations compare favorably with the AMSR-E soil moisture product. Further, the simulated ET from December to February is similar between the CTRL and DRY runs, with both configurations largely consistent with the DJF ET estimated from three gridded ET products.

The strength of the temporal co-evolution of land and atmosphere states is diagnosed between both SM_1 and EF from the simulations and the LCL as calculated from the near

surface atmospheric data. In line with the coupling strength found in previous studies, during the peak wet season strong SM_1-LCL and EF-LCL associations are shown. The wet season onset (SON) shows large rank correlation coefficients between EF and LCL that contrasts with the lack of correlation between SM_1 and LCL. The contradicting correlations between EF-LCL and SM_1-LCL demonstrate that the SON land-atmosphere relationship is not properly characterized with SM_1. The land-atmosphere interactions during periods with non-negligible transpiration necessitates the use of root zone soil moisture instead of the surface soil moisture to properly capture the physical processes. The correlation between SM_{rz} and LCL differs considerably from that between SM_1 and LCL. The co-evolution of SM_{rz} and LCL is shown by strong statistical correspondence throughout the wet season, and is consistent with the co-evolution between EF and LCL. During the peak of the wet season SM_1 is sufficient to explain the SM-LCL association while during the monsoon season onset SM_{rz} is necessary. The results demonstrate that the root zone soil moisture must be considered when diagnosing the relationship between SM and the LCL.

Our results show that the statistically diagnosed land-atmosphere correspondence in offline simulations is insensitive to the mean vertical profile of soil moisture. It is however, sensitive to the depth of the soil moisture considered. While the strong soil moisture-atmosphere associations shown here are a necessary but not sufficient condition to diagnose full land-atmosphere coupling, the results demonstrate the need to describe SM-LCL coupling using the physically relevant soil moisture. Studies that explore the behavior of the land-atmosphere system should use a statistical measure which encapsulates the SM that is physically relevant to the dominant processes. Future studies that evaluate land-atmosphere coupling using a full land-atmosphere model environment risk not capturing regions of strong coupling if only SM_1 is considered. In order to evaluate coupling during periods when ET is dominated by transpiration SM_{rz} should be considered. We recommend that future studies of land-atmosphere coupling focus on root zone soil moisture rather than surface layer soil moisture.”

This will make your paper stronger and clearer.