Replies to reviewer 3 comments

At the outset we would like to thank the reviewer for his encouraging comments and useful suggestions.

General Comments:
This paper give an interesting study of the afternoon to evening transitions (AET) over a tropical, rural site. Specifically, the paper seeks to answer three questions: (i) which state variable best identifies the onset of AET, (ii) does the onset of AET exhibit seasonal variability, (iii) does the onset of AET display height dependence? The researchers utilize an extensive, long term data set of both remote and in situ measurements throughout the entire ABL to address the questions. The researchers show that AET begins from the top-down and that there is some seasonal dependence due to high soil-moisture associated with the northeast monsoon. They assert that surface temperature and wind speed variance are the best signifier of the onset of AET at the surface and that the signal to noise ratio and spectral width are the best signifiers aloft. This is an interesting study and will be a welcomed addition to the literature. However, I do have several, general concerns that should be addressed before publication.
Reply: We thank the reviewer for his positive comments. We wish to inform that all suggestions given by the reviewer were considered and incorporated in the revised manuscript.

First, the thresholds for the onset of AET in each state variable (Pg 31493) seem somewhat arbitrary. For example, in Fig. 2a-b I feel one could also say that AET is beginning at the surface before it is aloft. This ambiguity may be inevitable but I feel that more explanation is merited. Perhaps a threshold sensitivity analysis could strengthen the authors' argument that the transition is top-down. Also, it'd be interesting to hear the authors hypothesize about any "universal" nature of the thresholds (i.e. would these apply at the mid-latitude sites).
&
31492 Ln 15: "On 11 May 2010, the temperature (Fig. 2a) starts to decrease monotonically, at the rate of 1–1.5 ^{o}C per 1 h, from 16:45 IST (dashed line), 118 min prior to the time of sunset (solid vertical black line). Though the temperature decrement starts little early, but is not consistent and also weak in magnitude". Again, I'm not sure I agree with this. To me, 16:10 looks more appropriate.
&
31492 Ln 16: "Another surface characteristic showing a significant change during the AET is the mixing ratio (Fig. 2b), which clearly shows a gradual increase from 16:10 IST". I do not think this is clearly shown.
Reply: The thresholds used in the present study are not chosen arbitrarily. We agree with the reviewer that the temperature decrement or mixing ratio increment starts at 1510 IST. But this decrement in 'T'/increment in 'r' is not consistent and the magnitude of decrement/increment is also small. As per our definition, the start time of evening transition is the time at which atmospheric state variables shows large and consistent increase/decrease (i.e., the increase/decrease should be significant and should persist for at least an hour). We examined 19 cases, for which we have the data from all our instruments, and identified the start time of transition in each parameter manually. We then estimated the gradients in each parameter and finally fixed the thresholds based on these gradients. Later, a sensitivity analysis is carried out to know the impact of the chosen thresholds on $Trans_{sunset}$ as obtained by different state variables at

different altitudes. We noticed that the results do not change much even if we vary the threshold by ±20%. This new figure (shown below for reviewers' reference) and the above information are included in the revised manuscript.

Some of the variations in state variables are typical of tropical sites. Though other variables can be used at non-tropical sites, some tuning of the thresholds may be required. It is necessary, because the solar zenith angle and the reduction of solar radiation are different at different latitudes. Qualitatively, we can expect similar variations (either decrease or increase) in most of the parameters at all latitudes, but the magnitude of variation could be different.

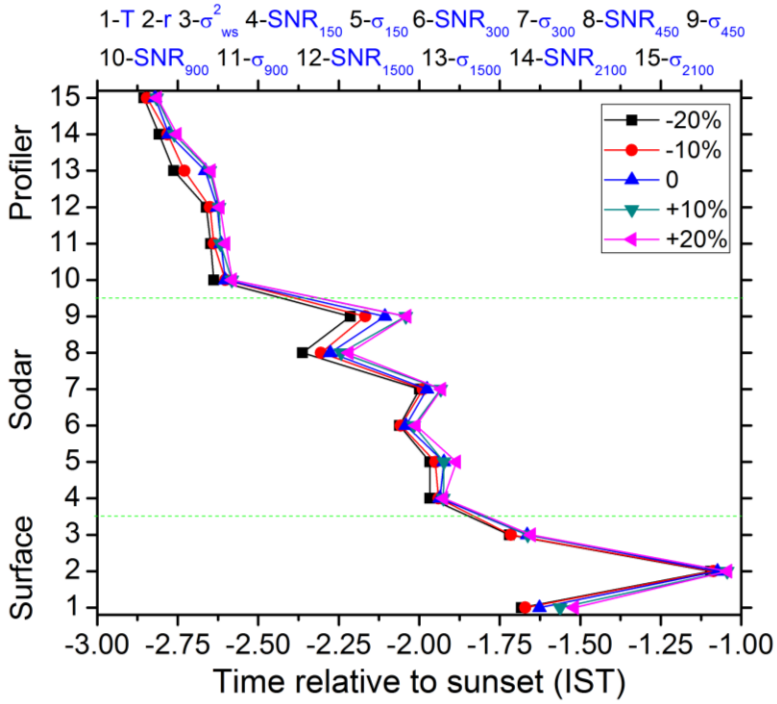

Figure: $Trans_{sunset}$ identified by different instruments employing a variety of atmospheric state variables by varying the thresholds, indicating the sensitivity of $Trans_{sunset}$ on the threshold.

Second, the explanation given for the top-down behavior, specifically the ratio of the entrainment to surface flux, is very interesting but also has a large degree of uncertainty. This should be addressed in the paper.

Reply: Yes. We agree with the reviewer that the entrainment flux estimation and its analysis is very complex. In fact, we have added advection term to entrainment flux term for the sake of completeness. But, still the results remain the same. As per reviewers' suggestion, the error in the estimation of fluxes is added as an error bar. Also, an uncertainty analysis is included in the revised manuscript.

Third, some of the subfigures are too small to be easily studied.

Reply: The size of figures is increased in the revised manuscript for better visualization.

Finally, the overall readability and English of the paper could use some improvement.

Reply: We tried our level best to remove the grammatical mistakes from the manuscript.

Specific Comments

31484 Ln 14-15: “The T at the surface and SNR aloft identify the signature of transition unambiguously”. Judging from Fig. 2, I disagree that it is unambiguous. Perhaps something like, “T at the surface and SNR aloft are the best indicators of transition”
Reply: The sentence is modified in the revised manuscript.

31488 Ln 17-24: I found the general description of the long-term and short-term data sets to be very confusing. Please re-word. Maybe something like, “dataset 1 was collected with a suite of non-continuously operated instruments, spanning a 3 year period. It is being used to examine AET seasonality and height dependence: : : Dataset 2 is comprised of the intensive observations which include the instrumentation of dataset 1 along with a flux tower and radiosondes launched every three hours. Dataset 2 was collected over two, three day campaigns (one during the monsoon and one during the winter).”
Reply: In fact, the present study consists of 3 datasets and they are treated as dataset 1, dataset 2 and dataset 3 in the revised manuscript as per reviewers' suggestion.

31489 Ln 24: Too bad the 50 m mast housed a single sonic at 8 m. It may or may not be worthwhile clarifying that in the Table 1 caption.
Reply: The 50 m instrumented tower hosts both fast sensors (sonic anemometer-RM Young (81000) and infrared hygrometer-LI-COR) at two levels (4 m and 8 m) and slow sensors for meteorological parameters (temperature, relative humidity, wind speed and direction) at six levels (2, 4, 8, 16, 32 and 50 m). The pressure and shortwave radiation are measured at 1.2-m height. The shortwave radiation sensor, soil temperature and moisture profile probes and a tipping bucket rain gauge were installed 20 m away from the tower towards the south to minimize shadow effects. Details of the sensors and their temporal resolutions are given in Sandeep et al. (2014).

In Table 1, only the sensors used in the present study are given.

31489 Ln 28-29: Please give a reference for the automated tests that were performed on the tower data. See comment 31499 Ln 22.
&
31499 Ln 22: “A stringent data quality check has been performed for the estimation of fluxes (Burba, 2013). These fluxes are evaluated at 30 min resolution.” This is more appropriate for section 2.
Reply: The text discussing the data quality tests with reference is given in page no. 31499. As per reviewers' suggestion, the text is included here.

31491 Ln 14: I’m not sure I see the increased backscatter in Fig. 1e.
Reply: We agree that in the case presented here, the SNR enhancement is not significant. But it is clearly seen in many other cases. We, therefore, changed the text in the manuscript accordingly. However, the enhancement is clearly seen in Sodar spectral width and profiler SNR and spectral width images.

31492 Ln 18: “The temperature gradient (Fig. 2c) also reverses from positive to negative, indicating the reversal of surface sensible heat flux, few minutes after the 5 m level 20 temperature starts to decrease”. This isn’t necessarily the case. See “Countergradient heat flux observations during the evening transition period” (http://www.atmoschem-phys.net/14/9077/2014/acp-14-9077-2014.html).

Reply: We modified the text by including this new reference and a note of caution.

31496 Ln 18-20: The questions the paper seeks to answer are given in the abstract, introduction, discussion and conclusion. Sometimes they are listed as 3 questions and sometimes as 4. While the general idea of the questions is approximately the same, it would help readability if they became more consistent.

Reply: Sorry for that. In the revised version, we highlighted only 3 questions throughout the manuscript and tried to obtain answers for those questions.

31497 Ln 8: “Though Gadanki receives 55 % of the annual rainfall in the southwest monsoon, rising instantaneous soil moisture levels, but the high insolation and temperatures immediately consume the soil moisture for latent heating. On the other hand, this region also gets good amount of rainfall during the cool northeast monsoon (Rao et al., 2009). The soil moisture levels, therefore, remain high in this season.” Intuitively I agree with this. However, I’m wondering if there is any soil moisture data to help support it.

Reply: Seasonal variation of soil moisture is shown below, as per reviewers’ suggestion, which clearly supports the text.

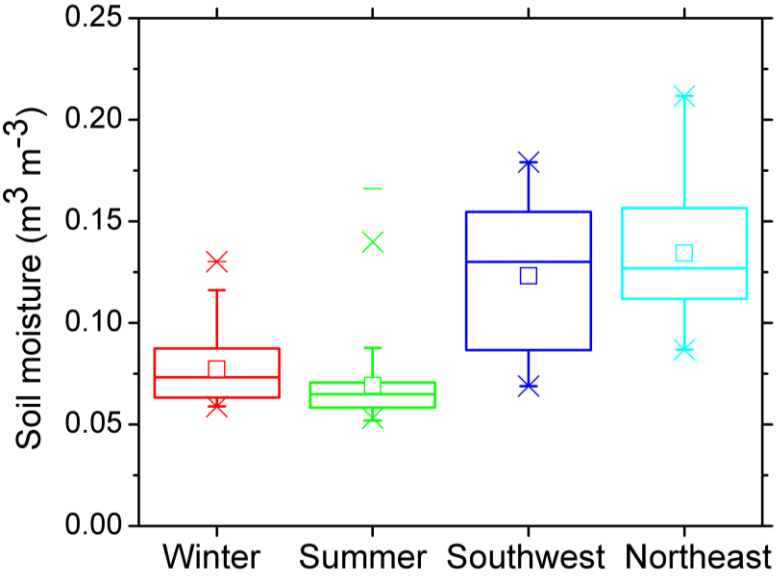

Figure: Distribution of soil moisture in different seasons

31497 19: “It is known from the literature that there exists an apparent contradiction between those who think the transition starts in the afternoon at high levels (Angevine, 2008) and others who believe the AET occurs around the sunset and follows a bottom-up evolution. The present study supports the former view, as similar evolution is seen in total and seasonal plots (Figs. 3 and 4).” Again, I’m not fully convinced that this isn’t at least partially due to the selected thresholds.

Reply: We believe the top-to-bottom evolution in the afternoon transition is true as the present study clearly shows this evolution. Even if we assume that the chosen thresholds are not exact, the sensitivity analysis has clearly shown that the results do not change much even if we vary the thresholds by ±20%. All the thresholds (within ± 20% of the chosen thresholds) show the top-to-bottom evolution of afternoon transition.

31500 Ln 4: "In contrast to large eddy simulations (LES) by Canut et al. (2012), who found an increase of the entrainment rate in the late afternoon, the present observations do not show any such increase, rather the entrainment flux remained constant throughout the day on all days" More discussion please. What are the weakness of the LES study vs yours?
Reply: We included this sentence only to indicate that the entrainment flux can exhibit significant diurnal variation at some places, unlike at Gadanki. We believe too much discussion on the comparison of entrainment flux as obtained by LES and the present study and limitations and strengths in each method will certainly deviates the reader from the main topic. We, therefore, drop this sentence from the revised manuscript.