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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Diurnal variability of the Atmospheric Boundary Layer height over a tropical station in the Indian Monsoon Region" *by* Sanjay Kumar Mehta et al.

Sanjay Kumar Mehta et al.

sanjaykumar.r@res.srmuniv.ac.in

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Response to Referee #1

Thank you very much for reviewing our manuscript and providing potential comments.

General Comment: This study presents an analysis of 3-hourly radiosonde data taken over 3-day intervals in each month over several years. The focus is on identifying the boundary layer height. This height is divided into convective and stable boundary layers and also residual layers. Several methods are used to identify the top of the ABL, but they are all based on gradients. These methods are appropriate, and the comparison of the methods is a nice aspect of this study. The diurnal cycle of ABL

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Discussion paper

height is described; the upshot seems to be that there is a strong diurnal cycle but the amplitude is affected by the season as well as the presence of clouds, which also appear to affect the phase. Overall, the presentation of the results is clear, but the weakness is that it is not clear whether the results provide novel insight. Instead, the novelty appears to be in the data set itself. There are several areas where some additional work could improve the analysis. These are relatively minor issues. The text is written well, but could stand another round of close editing for small grammatical and English issues (some examples listed below).

Reply: We have taken all the suggestions and incorporated into the revised manuscript.

Comment 1: Perhaps the main issue I have with this study is that it is quite focused on the radiosondes, with limited support from other observations. This becomes crucial as the text explores the impact of clouds on the ABL structure. There is a good use of IR brightness temperature to provide an estimate of cloud top height, but this is the only cloud observations that are presented. I found that to be surprising. Perhaps even more surprising once I visited the NARL website (https://www.narl.gov.in/) and found that there are several instruments that could provide useful supplementary data. One that could provide highly complementary data is the microwave radiometer; the web site says that it retrieves cloud base and liquid water path. These could be quite useful for more clearly defining the cloud layer. There are also radiation sensors and eddy covariance latent and sensible heat fluxes that could be used to construct a surface energy balance. There are also rain gauges and a disdrometer, which could be used to explore the ABL height as a function of rain rate. Such an analysis could bolster the conclusions about deep convection having little impact on the ABL height.

Reply 1: Certainly appreciate the reviewer's suggestion to utilize the microwave radiometer data for the cloud layer information and boundary layer tower data to calculate the surface energy balance. Unfortunately, these datasets is not available during observation periods used in this study. Reviewer 2 also pointed to obtain the cloud layer using relative humidity (RH) data (See response to reviewer#2). We have checked the

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rainfall data obtained from rain gauges (Automatic weather station data), but we could not find any relation between the ABL and rainfall.

Comment 2: The histograms of Figure 7 raise an issue about the statistics being used. Most of the histograms (which are NOT pdfs) look very non-Gaussian. The text mentions that the peak of the SBL histogram is at a substantially lower altitude than the mean (also true for RL in summer). Based on these histograms, I suggest also reporting the median and interquartile range, which provide a better estimate of the typical values and variability of the data.

Reply2: The distribution shown in Fig. 7 is non-Guassian especially for the SBL distribution which has longer tail on the right and hence positively skewed. As suggested, we have also included the boxplot of the SBL, CBL and RL heights for the annual, winter and summer monsoon as shown in Fig. 8 in the revised manuscript.

Comment 3: I found the definition of the residual layer (RL) to be a little unclear. It seems to be defined exactly the same as for the CBL, is that correct? It would be good to include an explanation in Section 2.3.

Reply 3: The method to obtain the RL is similar to that of the CBL. As the RL is the part of the daytime ABL, its characteristic is entirely similar to that of CBL except RL does not connected to surface whenever SBL is present. However, for the case when the SBL is absent RL is connect to the surface and generally referred as neutral RL (NRL) (Liu and Liang, 2010). However, we have referred it simply as the RL. This aspect had already been mentioned in the manuscript.

Liu, S. and Liang, X.-Z.: Observed diurnal cycle climatology of planetary boundary layer height, J. Climate, 23, 5790-5809, 2010.

Comment 4: One aspect of the residual layer that has been pointed out as being important for the diurnal evolution of the ABL is that it provides the potential for "explosive growth" of the ABL as a CBL forms in the morning and grows into the RL. This was not

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mentioned in this paper. Is it possible to quantify whether this explosive growth occurs, or are the 3-hourly observations too infrequent?

Reply 4: This is a good point. We have included this information in the revised manuscript. One can simply obtain the difference between ABL height before and after the sunrise, in order quantify the CBL growth. However, from typical diurnal variations (See Fig. 4), it can be seen that the transition from RL to CBL is not always explosive.

Comment 5: The correlation analysis among the ABL height definitions is quite nice. I was surprised there was not a similar correlation analysis between the surface temperature and the ABL height (around lines 427-455). In particular with regard to the seasonal variation that is mentioned, it would be nice to see whether the ABL height is related to the, say, the absolute maximum temperature or the diurnal temperature range.

Reply 5: We have obtained the scatter plot of the surface temperature and ABL height. The scatter diagrams of the surface temperature and the different ABL regimes such as the CBL, RL and SBL indicate that their relations are random in nature. Though CBL and RL become higher with higher surface temperature and vice versa, there are several occasions when they vary randomly.

Comment 6: Several places in the text seem to indicate that the presence of clouds might alter the evening transition (ET). This was never made completely clear. Is there a relationship or not? If there is, can it be understood in terms of the longwave effect that is mentioned, or is the mechanism unclear?

Reply 6: The presence of the cloud could be one possible reason to alter the evening transition. Since there are occasions, the SBL forms, even in the presence of the clouds (See Table 1). So at this juncture, it is not possible to provide a clear mechanism only based on cloud information.

Technical Comments

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Line 32: Start the sentence with "The"

Reply: Corrected

Line 36: change to "balance between the surface"

Reply: Changed

Line 37-38: change to "The ABL height is a key parameter, providing a length scale for..."

Reply: Changed

Line 51: insert a dash ("–") between maintenance and rather

Reply: Inserted

Line 54: delete the extra "m"

Reply: Changed

Line 66: I think there are many more studies of the diurnal variation of ABL height than this sentence would lead the reader to believe. There are recent examples using ARM sites (Santanello et al, 2007, http://dx.doi.org/10.1175/JHM614.1; May et al., 2012, http://dx.doi.org/10.1175/JCLI-D-11-00538.1), but there are also older examples from field studies (Brill & Albrecht, 1982, http://dx.doi.org/10.1175/1520-0493(1982)110<0601:DVOTTW>2.0.CO;2) or observation sites (Hashiguchi et al., 1995a, Boundary-LayerMeteorology 74: 419-424; Hashiguchi et al., 1995b, http://dx.doi.org/10.1029/95RS00653), and even in more exotic settings (e.g., on a glacier, van den Broeke, 1997, Boundary-Layer Meteorology 83: 183–205).

Reply: We have cited these papers in the revised manuscript.

Line 72: Also see Seidel et al. (2012, http://dx.doi.org/10.1029/2012JD018143).

Reply: Cited

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Line 90: change to "... days in each month..."

Reply: Changed

Line 100: delete "continuously"

Reply: Deleted

Line 106: delete "at"

Reply: Deleted

Line 184: delete "convective"

Reply: Deleted

Line 192: insert "as" before easy

Reply: Inserted

Line 231: change "is" to "are"

Reply: Changed

Line 239: Doesn't this ABL structure seem similar to a shallow cumulus profile, or a decoupled cloud-topped ABL, as is often described over the ocean in the transition from stratocumulus to cumulus?

Reply: Yes, it seems like a shallow layer cloud decoupled from the surface. The surface moisture is very small and the LCL is observed at about 0.6 km and CTH is at about 0.81 km indicating that a shallow layer cloud of thickness about 0.2 km decoupled from the surface.

Line 291-292: change to "... ET process was not delayed and ..."

Reply: Changed

Line 292: I think this should read "On the third night the SBL was detected at a height

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near 0.45 km."

Reply: Modified as suggested

Line 298: Delete "till"

Reply: deleted

Figure 6b: This bar chart is difficult to read, the format in Figure 9 is much better.

Reply: Figure 6b is modified as Figure 9.

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