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Authors' Response to Reviews of

Low-level buoyancy as a tool to understand boundary layer transitions

Atmospheric Measurement Techniques, 2021-68

RC: ***Reviewers' Comment***, AR: Authors' Response, □ Manuscript Text

1. Reviewer #2

1.1. General Comments

RC: ***The manuscript describes a method of using buoyancy in the ABL (in particular relatively close to the surface) as diagnostic parameter for process studies in ABL research and applies this method on rather limited data sets from RPAS and radio-soundings gained during two field campaigns (Flux-Capacitor and LAPSE-RATE). Although I clearly see the potential of the proposed method, I would like to be convinced a bit more on the usefulness by also providing some of the classical temperature/potential temperature plots as direct comparison with the more common way of looking into boundary layer development (that could e.g. be done by adding plots with the contours of buoyancy over the temperature/potential temperature field for figures 3, 8 and 9). Having in mind that there might be a radiation error in the temperature (and potentially also the humidity readings), in particular in the beginning of a flight during daytime, it might also be considered to use the observations of temperature and humidity from a fast installed and ventilated sensor at the ground to determine Tpar in equation 1, instead of the value taken from the lowest level of the CopterSonde. The language is not always scientifically concise and leaves some room for mis-interpretation/mis-understanding. I have stated some of the occurrences in the specific comment section, but I also suggest another round on that by one of the more senior co-authors of the manuscript. The figures are also not yet in a high-quality state for final publishing. Here I recommend (in addition to further comments in the specific section below) to consider the following changes: I suggest to remove the figure titles that are given in many of the sub-plots; this information is partly given in the axis text and in the figure caption I am not sure if the numbering/charactering of the figures in capital letters is the correct format for BLM The axis numbers/labels and legends/legend labels are often too small and hard to read I clearly see a potential of the proposed method, the manuscript will, however, require certain major revisions described above before qualifying for publication in AMT.***

AR: I have added plots of potential temperature, specific humidity, and wind speed for Flux-Capacitor and the CI case. Additional analysis was included to draw connections between buoyancy and the other state variables. All figures were improved to reduced title verbiage and align with BLM numbering.

2. Specific Comments

RC: ***Line 16: sounds like only warm air is transported vertically, I suggest removing "warm" here***

AR: "warm" was removed

RC: ***Line 20: I feel a bit complicated sentence structure at the end; could "are based off of decades old observation methods" be replaced by "are based on observation methods that are decades old"***

AR: suggested replacement accepted

RC: ***Line 58: "Buoyancy is a fundamental principle in fluids caused by density or temperature differences" one example for those scientific inconcise/incomplete statements; buoyancy is related to density, period! It's temperature and humidity that effect density! So mixing density and temperature as done in this sentence should be avoided.***

AR: "or temperature" was deleted

RC: ***Line 75: I feel there is a verb missing: "…but few studies have yet to substantiate…"***

AR: The line has been rewritten as "..yet few studies have substantiated the results with in situ observations."

RC: ***Line 121: CASS has already be used as abbreviation above, so no need to introduce it here again; but please check if it was introduced properly on first appearance***

AR: The spelled out abbreviation was removed from line 120 and added to its first mention in line 104.

RC: ***Line 131: the more appropriate reference here might be Kral et al., 2020: Kral, S. T., J. Reuder, T. Vihma, I. Suomi, K. Flacké Haualand, G. H. Urbancic, B. Greene, G.-J. Steeneveld, T. Lorenz, B. Maronga, M. O. Jonassen, H. Ajosenpää, L. Båserud, P. B. Chilson, A. A. M. Holtslag, A. Jenkins, R. Kouznetsov, S. Mayer, E. A. Pillar-Little, A. Rautenberg, J. Schwenkel, A. W. Seidl, and B. Wrenger, Innovative Strategies for Observations in the Arctic Atmospheric Boundary Layer Project (ISOBAR) — Unique fine-scale observations under stable and very stable conditions. Bulletin of the American Meteorological Society, Early Online Release, doi:10.1175/BAMS-D-19-0212.1, 2020***

AR: The 2018 ISOBAR citation was replaced with the suggested 2021 publication which provides a better description of RPAS involvement.

RC: ***Line 149/150: "with the lowest observed temperature and dew point used", this might be misleading and is at least unclear; do you mean (as I assume) the temperature and dew point at the lowest elevation of your flight, or do you mean the lowest absolute value of temperature and dew point of your profile?***

AR: The sentence was restructured to explain that the observation comes from the lowest elevation.

RC: ***Caption figure 1: for a) and c) are the colors messed up! CopterSonde should be blue and Parcel red!***

AR: The mistake was remedied to accurately portray the plots and agree with the legend.

RC: ***Figure 1, profiles for 15:15 UTC (lower panels): I assume the lowest 200 m indicate the mixed layer of the developing CBL after sunrise. I am a bit puzzled over the super-adiabatic slope of the environmental curve over the whole BL/ML depth. I can't explain this other than by a systematic bias from your measurements, e.g due to sensor time lag!***

AR: The superadiabatic layer only extends about 50 m. The remainder of the layer is dry adiabatic. Also, a

systematic sensor bias would have implications throughout the entire profile causing a linearly propagating error. Radiosonde data also supports a shallow superadiabatic layer during the day (attatch fig).

RC: ***Line 167: There should be an "and" before "then". Or did I mis-understand the meaning of this sentence***

AR: 'and' added prior to 'then'

RC: ***Line 175: replace "greater" by "higher"***

AR: replaced "greater" by "higher"

RC: ***Line 176: replace "radiosondes" by "radiosonde ascents" or "radiosonde releases"***

AR: 'releases' added to follow radiosondes

RC: ***Figure 2: legend by far too small font size! I also suggest to plot the CopterSonde data also only as dots (as for the radiosondes) and not as line; the time labels should be limited to hours:minutes and the font should be increased; this last comment applies for all plots with corresponding time axis labelling***

AR: All figures will be updated to reflect the suggestions made my the referee.

RC: ***Line 180/181: "This is a consequence of the shell being heated by the sun before takeoff." Could this be an explanation for the superadiabatic slope observed in figure 1; the enclosure leads to an overheating in the beginning of ca. 1 deg C that is then slowly reduced due to ventilation during ascent; would perfectly explain an artificial super-adiabatic slope.***

AR: The phrasing of when shell heating was impactful has been altered throughout lines 177-184. The 1 deg error is in the morning and not during the strongest insolation, but rather during the time the CopterSonde was sitting in the sun the longest. During the sunniest part of the day, there are some clouds but the difference in temperature readings is roughly 0.4 ºC.

RC: ***Line 182: "Moreover, the warm bias reduces to near-zero at 2103 UTC." For me this is already the case for 18:30! It would be nice to have the time series of global irradiance to see e.g., the effects of cloudiness in the afternoon reducing/avoiding this warm bias.***

AR: Figure 1 does not suggest that there is a correlation between irradiance and the warm bias. The timing of when the bias is reduced has been changed from 2103 to 1607 UTC in the text.

RC: ***Line 199/200: this sentence is very hard to read, I suggest to replace "as potential temperature method, CopterSonde derived heights" by "as those derived from the CopterSonde data.***

AR: The sentence is reworded as the referee recommended.

RC: ***Line 203/204: "The CopterSonde is more likely to find these sharp gradients near the surface because of the increased data resolution at lower levels." However, the CopterSonde could also pick up artificial gradients here, just due to the fact that the potentially overheated sensor compartment slowly adapts to real ambient temperatures during flight.***

AR: While possible, the authors find it unlikely that the CopterSonde picked up on artificial gradients. The CopterSonde's higher sampling rate and slower ascent rate collects more data than a radiosonde. The duplicate sensors also reduce the likelihood of all three sensors being overheated and lagged. It seems more likely that the radiosonde ascended too quickly to observe microscale changes to potential temperature since the data collection rate is 1 Hz and ascent rate of about 5 m s^{-1}. Furthermore, the CopterSonde is gathering measurements on a parcel scale. It is possible that the gradients are implications of measurements

transecting rising thermals. The new paradigm of these types of measurements open up possibilities to capture traditionally missed microscale features.

RC: ***Line 259/260: the statement "the potential temperature is independent of the surface conditions" is at least highly disputeable! Maybe you should specify in more detail what you wnt to achieve with this sentence.***

AR: This statement was rephrased to "Unlike potential temperature, buoyancy is directly impacted by surface conditions at each level of calculation. Such that microscale features can be recognized more readily using buoyancy." (lines 264-265).

RC: ***Lines 263 and 272: replace "Radiational" by "Radiative"***

AR: Both 'radiational' uses are replaced by 'radiative'

RC: ***Line 267/268: "Figure 9 shows how deep the stable layer is until 1400 UTC."; How deep would you diagnose the SBL at that time? At around 600 m where the buoyancy gradient seems to disappear, or somewhere between 200 and 400 m, where the gradient becomes distinctly weaker? I miss a bit more explanation how the buoyancy concept can be used as diagnostic tool for SBL height.***

AR: 'Deep' was supposed to be interpreted as a synonym for intense and not a measure of the ABL height. The lines have been rewritten to remove the confusion. Lines 266-271 were added to remark on features which show potential to mark the depth of the SBL based on Figures 9 and 10. The paragraph was also restructured to flow better.

RC: ***Line 269/270: "Not until 1530 does the wind direction shift to southerly, generating some positive buoyancy (Fig. 9, 10)."; This sounds like the wind direction shift is causing the change in buoyancy, I would argue that the change in wind direction is a result of the processes (e.g., differential surface heating) that affect buoyancy; maybe worth of rephrasing this sentence.***

AR: Lines 282-283 were altered to better explain the cause of the southerly wind.

RC: ***Line 279: replace "more" by "a more detailed" or "an in depth"***

AR: 'a more detailed' was added.

RC: ***Line 280/281: "below the ABL", that should either read "in the ABL" or even in the "mixed layer of the ABL" or "below the capping inversion"***

AR: 'below the capping inversion' was substituted for 'below the ABL.'

RC: ***Line 306/307: "There are countless applications for RPASs to sample previously difficult aspects of the atmosphere." This is a very oversimplified formulation, please write a bit more detailed what you mean, e.g. something along the lines "to collect atmospheric measurements for processes that are still not adequately understood"***

AR: Lines 307-309 were rewritten to summarize the paragraph more specifically than the previous version.

RC: ***General comment for the references; check citation of pages, sometimes with pp.! mostly without; so please homogenize***

AR: All citations were checked and the journals are all capitalized. Some citations were updated from Early Release to published which remedied the occasional 'pp.' accompanying the page numbers.

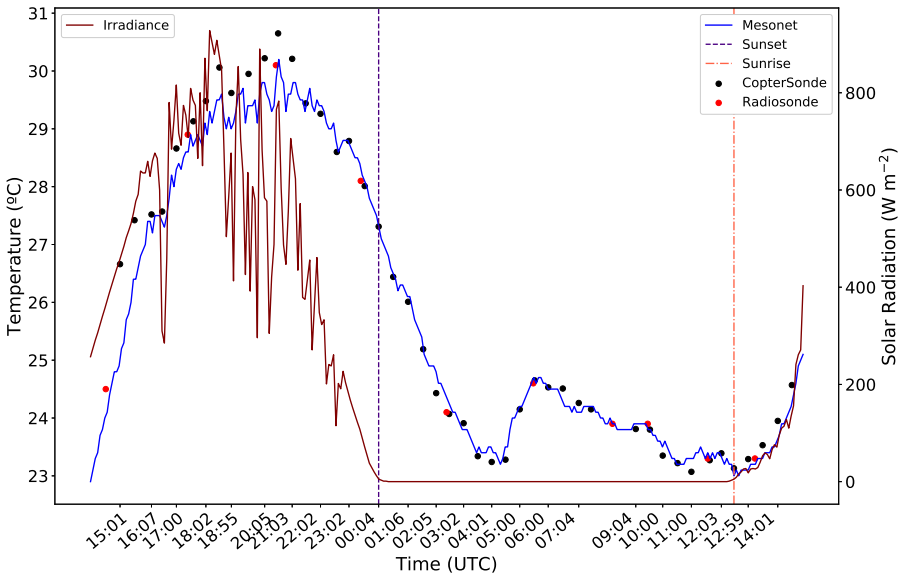

Figure 1: Time series of solar irradiance (W m^{-2}, brown line), Mesonet 9 m temperature (ºC, blue line), CopterSonde temperature (ºC, black dot), and radiosonde temperature (ºC, red dot) on 05-06 October 2018

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Line 330: journal name should be upper case

Line 333: reference Båserud is incomplete (journal name, volume, pages etc)

Line 345: journal name should be upper case

Line 354: journal name should be upper case

Line 360: journal name should be upper case

Line 373: journal name should be upper case

Line 396: journal name should be upper case

Line 406: journal name should be upper case

Line 407: journal name should be upper case

Line 419: journal name shouldn't been abbreviated

Line 429: journal name should be upper case

Line 434: journal name should be upper case

Line 439: journal name should be upper case

Line 457/458: journal name should be upper case

Line 464: journal name should be upper case