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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Observational analysis of the daily cycle of the planetary boundary layer in the central amazon during a typical year and under the influence of the ENSO (GoAmazon project 2014/5)" *by* Rayonil G. Carneiro and Gilberto Fisch

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Below are the answers to referee 2 (RC2)

2. Methods

a. Some instruments do not have the maker and/or model (SODAR, Lidar, EC, solar and terrestrial, soil heat flux).

Added in the document the makers and/or models

b. How high are the radiation and flux measurements? What is the landscape of the study area, and what is the landscape composition of the flux and radiation footprint?

Added in the document the height the radiation and flux measurements and landscape composition

c. Is there any data filtering or all data were considered (clear, cloudy/rainy days)? What are the data sample size in figures 3 to 6?

There was no filtering for cloudy / rainy days, since the instruments make measurements from surface to atmosphere, then cloudy days do not cause data changes. However, the data were verified and gap fillings was performed. The data sample size in figures 3 to 6 was 45 days, which corresponds to the intense observation period of the GoAmazon project (Lines 79-81).

d. Radiosonde PBL estimation, it only shows for the procedure for the convective boundary layer (CBL), what are the criteria for the nocturnal boundary layer (NBL)?

The Radiosonde PBL estimation showed CBL and NBL the criteria was used two profile method used for CBL and NBL by Santos and Fisch, (2007), Seidel et al., (2010) and Wang et al. (2016).

e. For the other remote sensing instrumentation, but SODAR. It seems that only the CBL detection are being shown. Do these methods also apply to the NBL?

The SODAR only was used for the NBL, because the vertical resolution of the instrument is 500 m.

f. Also, I believe that PBLH from MWR should be explained in more detail. Is this a novel method or is it based on previous studies? I wonder, because, from my experience, temperature profiles from the MWR do not show sharp gradients at the top of the CBL. Also, I am not sure how this interpolation works during the transition periods (mornings, and early night).

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Discussion paper

The method is based on previous studies.

g. NBL detection from SODAR: The use of the maximum of the wind profile is associated with the lower level jet. Have the authors consistently observed LLJ at the study site? If so, this should be written.

The height where the maximum wind value was found was considered the height of the NBL, according to Stull's definition, 1988 and applied in the Amazon by Neves and Fish (2015).

h. Why not use the temperature profile from WP to estimate the NBL?

Because our decision was to estimate the NBL and CBL by the same method in WP.

3. Results, discussion, conclusion: there are some parts that needs some work and/or clarification.

a. There are several comparisons among several parameter (precipitation, H, LE, PBLH) for wet/dry season or El Nino/non-El Nino years. However, averages are presented without any uncertainties, so the authors cannot affirm that those averages are different.

The averages are presented with uncertainties, where the shading in figures 3 to 6 indicates the standard error of the instruments. Which have been described in the captions of the respective figures.

b. I do not understand the PBLH time series for the ceilometer. According to the methods, the PBLH is the cloud base, not the aerosol mixing layer estimated from the aerosol backscatter profile. Thus, are the black lines shown in figures 4 and 6 the cloudbase diurnal variation? I do not believe that there will be boundary layer clouds during night time at such lower height (maybe fog – but not the cloud base). Also, there is a sharp drop during the afternoon, are the PBL clouds descending?

The Ceilometer PBLH time series does not refer to cloud base heights, but rather to measurements of boundary layer heights. Thus the black lines shown in figures 4 and 6 are the daytime variation of the height of the PBL. Since the Ceilometer provides the height of the cloud base, the retrieval of the particle backscatters coefficient and PBL height (Wiegner et. Al., 2014; Shukla et al., 2014; Morris, 2016; Carneiro et al., 2016 Geiß et al., 2017). Thus, to improve the reader's understanding of the description has been improved methodology instrument (P4, L 118-129, text below).

“The PBL was also monitored using a Ceilometer model CL31 from Vaisala Inc. (Finland). Ceilometers are a type LIDAR remote sensing instruments that operating through a maximum vertical range of 7700 m and register the intensity of optical backscattering at the near infrared wavelength between 900 and 1100 nm through an emission of a vertical pulse that is autonomously executed. The Ceilometer provid data the height of the cloud base, the retrieval of the particle backscatter coefficient and PBL height (Wiegner et. al., 2014; Shukla et al., 2014; Morris, 2016; Carneiro et al., 2016; Geiß et al. 2017).

The ceilometer is a high-frequency instrument with a measurement interval of 2 s, and a sampling rate of 16 s and is a powerful tool for measuring the height of the PBL during its daily cycle (day and night phases) to a high level of detail. The intensity of backscattering depends on the concentration of particles in the air, but also depends on the reflexive properties of the atmosphere, which are related to it level of humidity. Therefore, this instrument is useful for creating a tridimensional map of aerosols, air pollutants, and industrial and natural emissions of particles. Ceilometers use a retrodiffusion laser to determine the coefficient of the attenuated portion, and the coefficients for aerosols are obtained from these data, and subsequently the heights of the cloud base and the PBL are calculated.”

c. Are the CBL or residual layer (RL) shrinking for all remote sensing PBLHs during the afternoon? I wonder about this because H is still positive till about 16:30-17:00LT.

The CLC measured by the instruments showed a decrease in its height around 16 LT, where a reduction in H fluxs was also observed, but it is still positive. After 17 LT the H fluxs begins to become negative and the PBL begins its most stable phase (NBL).

d. Lines 205-206: The authors claim that there is no ground water at the root level. Is it a shallow root or deep root vegetation? Depending of the type of vegetation, this might not be the reason for lower evapotranspiration.

The T3 area was located was cover by shallow vegetation (pasture) (added in the description of the area in Material and Methods P2, L 72-73, text below).

“In order to conduct this observational study, data from the GOAmazon project 2014/5 were used. The article by Martin et al. (2016) describes the details of the experiment wherein these data were collected, its principal objectives, and some results. These data were collected using the structure that was installed at a research station called T3 (03° 12’ 36” S; 60° 36’ 00” W), located north of the municipality of Manacapuru in the State of Amazonas, about 9.5 km from the urban area, and about 11.5 km from the left bank of the Solimões River, at the confluence of the mouth of the Manacapuru River (Figure 1) in the central region of the Amazon basin. The T3 station is collocated in an area of pasture, surrounded by native forest with about 35 m of canopy height (Martin et al. 2016).”

e. Lines 208-211: Groundwater stress are not be the only reason for low evapotranspiration.

The Groundwater stress is not the only reason. Thus the text in question was improved (P6, L211-215, text below).

“The latent heat flux (LE) showed that the majority of the available net radiation (daytime conditions) was used for this flux. Both periods had similar maximum values, with 355.9 (IOP1) and 350 W $m-2$ (IOP2) at 12 LT. However, there was a reduction of net radiation converted into LE between the periods, with 75

f. Lines 223-230: So, how mechanical turbulence will affect the NBL for some instruments, and not for others? I believe a more in-depth analysis should be performed. Ifthere is a presence of LLJ, then more likely there will not be too much turbulent mixing,and the NBL is going to grow due to radiative cooling. Also, usually the local maximaof the LLJ is not co-located with the bottom of the residual layer, so using the levelof maxima wind speed will underestimate the NBL. Last, but not least, if there is rain,then most likely the remote sensing instruments do not work properly, and they will beunable to detect any mixing height.

Mechanical turbulence affected all instruments, however, each instrument has different measurement techniques, thus presenting differences in PBL height measurements at this range (00 - 60 LT). The study in question evaluated different PBLH measurement instruments, so the underestimation found for the NBL of the instruments that used the maximum wind speed level to estimate the height (SODAR, WP) showed that these sensors have limitations for measuring the NBL under mechanical turbulence.

g. The “erosion” of NBL discussion seems confusing and does not make any sense to me. Looking at figures 4 and 6, if the PBL is growing above 250m after 6am, thenit means that there is no more a stable layer. If not, then how the PBL is growing? Iguess the authors can check that looking at the SODAR RASS data: : :

According to Stull (1988), during the early morning the PBL is shallow. Its depth increases slowly at first because of the strong nocturnal stable layer that caps the young CBL. This first phase is sometimes referred to as the erosion of the NBL, wich begins after sunrise and the complete erosion occurs when the PBL has a growth rate above 100 m h−1.

The text in question has been changed for readers’ better understanding (P7, L248-253, text below).

“The phase of the erosion of the NBL according to Stull (1988) begins after sunrise (at 06 LT in Amazon) and the complete erosion occurs when the PBL has a growth rate above 100 m h−1. In the IOP1 (Figure 4A), the erosion phase was occur 3 hours after sunrise, where it was observed that in the first hours on this phase there is no increase in the PBL depth, only after 08 LT occured an increase in PBL heights (average rate of 22.8 m $h-1$). This occurs due to a lower H flux (Figure 3A), which causes the erosion of the NBL to progress slowly, and total erosion occurs only at 09 LT when average rate is 102 m $h-1$."

h. Lines 254-255, 300-302: H by itself does not contributes for the PBLH growth, orthe rate of change of temperature.

Positive sensitive heat flux (H) heats the air near the surface and by convection will rise, generating turbulent movements within the PBL which increases its depth. According to standard literature on studies of PBL (Stull, 1998; Holtslag, 1987; Foken, 2008), described below:

"During the daytime when H>0 the atmosphere is heated from below, while for H<0 the atmosphere near the surface is cooled (nighttime). This leads to unstable (daytime) and stable (nighttime) stratifications of the PBL. The magnitude and the diurnal cycle of H has important consequences on the height and the structure of PBL. During unstable conditions the air adjacent to the surface is heated and will rise. This rise continues as long as the air is warmer then the surroundings (up to an inversion layer). This process is know as convection, which is accompanied with the production of convective turbulence in the PBL."(Holtslag, 1987).

"The daily cycle is highly variable, after sunrise, the atmosphere is warmed by turbulance flux H from the ground surface, and the inversion layer formed during the night brakes up (erosion phase). The new layer is very turbulent, well mixed (mixed layer), and bounded above by an entrainment zone."(Foken, 2008; Stull, 1998).

i. Lines 255-257: Not sure about that a small H will decrease the PBLH. According tothe theory, if there is negative flux-divergence, the PBLH will increase. Also, how theentrainment at the top was calculated?

The decrease surface H reduce the PBLH as described in the above answer (h.). As the entrainment fluxes were not calculated, there is no way to indicate the values of this contribution. However, as answered by RC1, a next article is underway that will study the heating and cooling drivers of the layer through numerical modeling and observations.

j. Lines 310-312: If one connects the red dots in figures 4,6, he/she can see a diurnal pattern in the RS PBLH time series.

I agree, there is a daytime cycle pattern of the PBL, but it would not be correct to analyze the PBL variation by extrapolating the RS times, since the RS data range is long, and the PBL variation depends on many factors (H , Air temperature and etc.) which do not vary linearly and are highly variable throughout the day. So simply connecting the dots would not be representative of this cycle.

Some Minor Concerns:

Lines 81-82: Wind Profiler, ceilometer, SODAR, MWP, and Lidar are not remote sensing estimation methods, but the instruments that probe the lower troposphere.

Changed in the text

Table 1: Ceilometer vertical resolution is missing. I believe some of the instrumentationmeasure more than reported in row 3.

Changed in the Table 1

Figure 1: What is the location of the site? There are 2 red squares and red dots, arethey the instrument location of Manacapuru site? If so, where are the location of the instrumentation? If now, what are they?

Changed in the Figure 2

Figures 3 and 5: What are the error bars for the measurements? Changed in the Figure

Figures 4 and 6: What is the shaded area? The errors? If so, how the errors areestimated? Why RS points do not have error bars?

The shaded area is error. Put the error bars in RS

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2019-578/acp-2019-578-AC2-supplement.pdf

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