Interactive comment on “Friagem Event in Central Amazon and its Influence on Micrometeorological Variables and Atmospheric Chemistry” byGuilherme F. Camarinha-Neto et al.

Anonymous Referee #1

We would like to thank all the reviewer's comments. Our answers are in blue font and part of them were added to the manuscript.

Question

General comments: The manuscript presents an interesting discussion of how the entry of a cold front or cold can interfere with micrometeorological conditions and the rates of trace gas mixture in central Amazonia. The combination of surface measurements with the simulations of the coupled model JULES-CCATT-BRAMS made it possible to understand the cooling effects, as well as their development and implications. Certainly, the results related to the effects on Lake Balbina are important for understanding the effects of cold on the ecosystem as a whole. In general, the work has an importante scientific contribution, as it clearly and objectively shows the ecosystem’s response to a cold event. With regard to the structure of the manuscript, it still needs adjustments in the text. Some structural modifications are needed to make it clearer to the reader around the methodological application used to achieve the proposed objectives. **(1)** The only point to be reviewed more intensively is the choice of the study period and the implications of this in the discussions. As the methodology of the work itself shows, this manuscript brings as results the case study of a particular event that occurred from July 6 to 11, 2014, however, no discussion about the meteorological characteristics of this year was held, it was also not clear whether any cold front arrival in the region will cause the same effects. The authors cite other studies on coldness in the Amazon, which are in agreement with their results, but do not make clear when these analyses were performed. **(2)** As much of the results are derived from simulations it would be interesting to discuss the possible annual variations or at least discuss whether such variations may exist or not, as well as answer whether the effects on atmospheric chemistry will

always be these, or if by different conditions, such as a year with high burn rates, these results may diverge, that is, my suggestion is a small restructuring of the results to include these discussions.

Answer

We appreciate the reviewer's comments. We will respond in parts:

(1): The reasons for choosing the case study shown in the manuscript (July 6 to 11, 2014), were as follows: i) July is one of the months with the largest number of cold fronts that arrive in the South-Southeastern region of Brazil (Prince and Evans, 2018). Consequently, July is also the month where a greater number of Friagem phenomena are observed in the Amazon region (Prince and Evans, 2018). ii) Throughout 2014, intensive activities of the GoAmazon project took place (Martin et al., 2016), that is, measurements of gases and the thermodynamics of the atmosphere were carried out in several sites investigated in this work (T2, T3 and T0z), and therefore this was the motivation for choosing the year 2014 for our case study. iii) The period between 06 and 11 July was chosen, as it was observed that a Friagem event reached the city of Manaus and its surroundings in those days. It should be noted that for a Friagem event to occur, it is necessary that a mass of cold air (cold front), coming from the South reaches the North region of Brazil. Friagem events do not always have the "capacity" to reach the city of Manaus. For example, on July 25-31 2014 there was also a Friagem event in the Southwest of the Amazon, but this event was not observed in the city of Manaus.

About the meteorological characteristics of this year, according to the CLIMANALISE Bulletin (http://climanalise.cptec.inpe.br/~rclimanl/boletim/pdf/pdf14/jul14.pdf), in July 2014, precipitation in northern Brazil showed positive and negative deviations from the climatological average (Figure 1a). In addition, the deviation from the maximum temperature in relation to its climatology shows a drop in the maximum temperature from the state of São Paulo to the Southwest of the Amazon, indicating the advance of frontal systems in this region (Figure 1b).

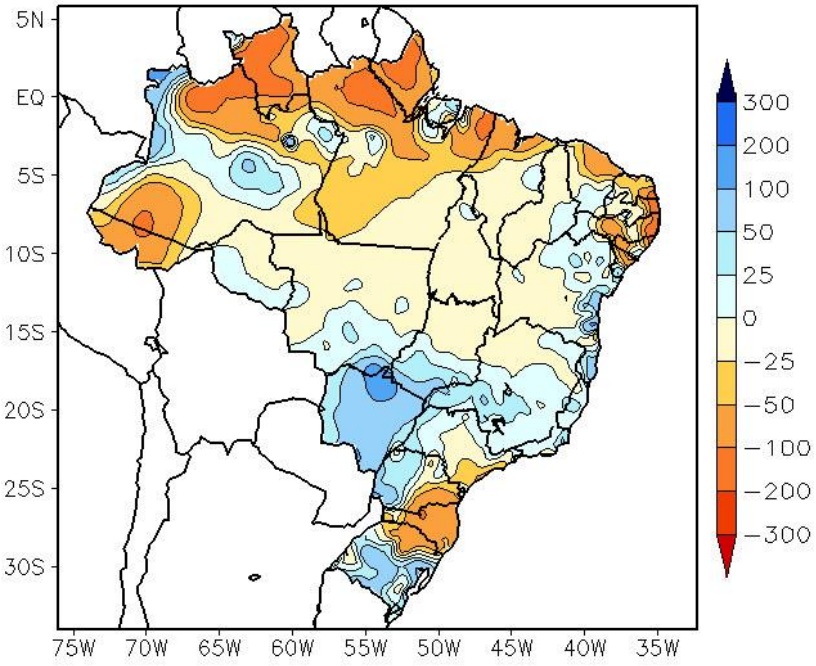
Regarding global scale phenomena, the South Oscillation Index showed that this month remained close to neutral, that is, without the occurrence of the El Nino and La Nina phenomena.

The main characteristics of the Friagem observed in this work seem very similar to those observed by Marengo et al. (1997) and Silva-Dias et al. (2004), both cited in the manuscript.

Marengo et al. (1997) investigated the two strongest Friagem events that occurred during the year 1994, being: June 26th and July 10th. For both events they observed that the main consequence of the Friagem in the City of Manaus was greater cloud cover and consequently less solar radiation reaching the surface, which is the main cause of the fall in air temperature. In addition, they noted that Friagens produced a shallower boundary layer. That is, the results by Marengo et al. (1997) corroborate part of our results - Friagem increases the cloud cover (Fig. 4), reduces the air temperature (Fig. 6) and produces a shallower boundary layer (Fig. 11a).

The work by Silva-Dias et al. (2004) showed that during the period from 24 to 31 July 2001, the arrival of a cold air mass in the western region of the Amazon increased atmospheric pressure to sea level in this region, resulting in a pressure gradient force pointing in the opposite direction of the trade winds, which is consistent with a deceleration of the trade winds and the consequent formation of more intense breeze circulations in the Santarém region. The main consequences of this Friagem in the city of Manaus were: drop in air temperature around 5 ºC, reduction in wind speed, confluence of a cold and dry air mass coming from the South region with a hot and humid air mass coming eastern Amazon. We emphasize that part of our results are corroborated by Silva-Dias et al. (2004), which are: (1) confluence of trade winds with westerly winds in central Amazonia (Fig. 3). We show that it was this confluence that was mainly responsible for the formation of clouds and the consequent reduction of solar radiation that reached surfaces, reducing the air temperature and the O3 concentration.

(a) Deviation of precipitation in July 2014



(b) Maximum temperature deviation (ºC) in July 2014

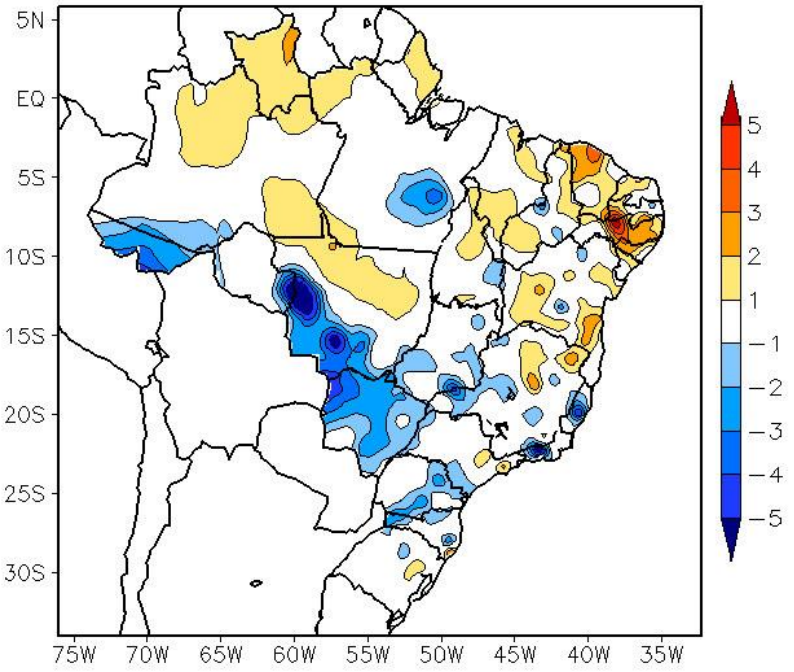


Figure 1. Behavior (a) deviation of accumulated precipitation in relation to climatological-mean (1961-1990) and (b) deviation from maximum temperature in relation to climatological-mean (1961-1990) for July 2014.

Source: Monitoring and Climate Analysis Bulletin (CLIMANASE). V. 29, No.07, July 2014. ISSN 0103-0019 CDU-555.5

(2): We agree with the reviewer that new simulations that show the impact of possible annual variations, such as the increase/decrease in precipitation and air humidity and decrease/increase in temperature, during atypical years, such as La Niña / El niño, among others, can influence the number of occurrences and the strength of Friagem events and, consequently, the chemistry and thermodynamics of the atmosphere near the surface. In addition, the performance of simulations with different burn rates conditions and consequently with different amounts of cloud condensation nuclei can influence the formation of clouds and the role of cooling above the central Amazon. However, the objective of this work is not to make comparisons between different annual conditions, but to demean a case study. The reviewer's suggestions are valuable and will be the subject of future research by this group. In addition, we will add these suggestions to the conclusions of the manuscript (suggestions for future work).

Question

Specific comments: About the abstract: Review the first sentence of the abstract, because it practically already brings, in a more generic way, the main conclusion of the work, that is, the authors begin the work stating that the cold event influences the variables and atmospheric chemistry. I suggest changing the sentence and leaving to make this statement at the end of the abstract along with the main conclusions of the work.

Answer

We decided to move this sentence from the abstract to the conclusions section.

Question

About the introduction: In paragraph 30, the authors evidence the influence of breezes on CO2 and O3 mixing rates, however, they mention a region of North America, Canada, and this is out of context in the manuscript because all other information collected in the introduction directly mentions works developed in the Amazon. If the authors want to talk more about these events around the world, they should include supplementary discussions on the effects of lake breezes.

The last sentence of paragraph 50 is a text that describes how the objectives will be achieved, that is, a text of methodology, I suggest removing or restructuring this text since this information will appear in the methodology.

Answer

We agree with the reviewer: We rewrite the paragraph 30 and we remove the last sentence of paragraph 50 that described how the objectives will be achieved.

Question

About the methodology: In paragraph 70 the authors say that this is a case study, it would be interesting at this moment to talk about the specific implications of this analyzed period.

Answer

We introduced a new paragraph to better explain the motivation for choosing July 2014 as case study and we made a brief comment about the specific implications of this analyzed period (L68-75).

Question

When talking about the O3 measurements in the analyzed sites, it is observed that these measurements were performed at different heights, ATTO at 79m, T3 at 3.5m, T2 at 12m and T0z at 39m. Can these different heights interfere with the measurements? The authors can make a brief discussion about this.

Answer

Yes, different measurement heights may affect the observed O3 concentrations in some cases, due to the process of dry deposition onto available surfaces and stomatal uptake by vegetation. In the case of T2 and T3 sites, which are not forest sites, the measurement height may not have a significant influence on O3 concentrations during the day in a well mixed boundary layer, provided that the inlets were set apart from surfaces like walls, roofs and trees. At forest sites, previous studies have shown a significant O3 vertical gradient inside the canopy, especially in its lowest half part (e.g., Rummel et al., 2007; Freire et al., 2017). However, the reported O3 measurements at T0z and ATTO were taken above

the canopy, where vertical gradients are expected to be close to zero if the boundary layer is well mixed. Based on previous studies, we estimate that the 40 m difference in the measurement height of ATTO and T0z may result in a 15% difference on O3 concentrations, with smaller concentrations at T0z due to the proximity of the canopy top. Nevertheless, this difference does not affect the main aspect discussed in Figure 11, which clearly shows a decrease in diurnal O3 concentrations at all sites in 2014 July 11th as a result of the influence of a cold front.

We put part of this comment in the main text of the manuscript (L95-101).

Question

On the results: the results are presented in a very clear and objective way, the only observation is made in relation to the period of analysis. As described in the methodology of the work, this manuscript brings as results the case study of a particular event that occurred from July 6 to 11, 2014, however, no discussion about the meteorological characteristics of this year was held, it was also not clear whether any cold front arrival in the region will cause the same effects. The authors cite other studies on coldness on Amazon, which are in agreement with their results, but do not make clear when these analyses were performed.

Answer

We inserted new paragraphs in the manuscript that make the meteorological characteristics of this year (L68-75) and in our citations about other studies on coldness on Amazon we make more clear when these analyzes were performed (L181-184; L214-218)

Question

As much of the results are derived from simulations it would be interesting to discuss the possible annual variations or at least discuss whether such variations may exist or not, as well as answer whether the effects on atmospheric chemistry will always be these, or if by different conditions, such as a year with high burn rates, these results may be different, that is, I suggest a small restructuring of the results so that these discussions are included.

Answer

We agree with the reviewer that new simulations that show the impact of possible annual variations, such as the increase/decrease in precipitation and air humidity and decrease/increase in temperature, during atypical years, such as La Niña/El niño, among others, can influence the number of occurrences and the strength of Friagem events and, consequently, the chemistry and thermodynamics of the atmosphere near the surface. In addition, the performance of simulations with different burn rates conditions and consequently with different amounts of cloud condensation nuclei can influence the formation of clouds and the role of cooling above the central Amazon. However, the objective of this work is not to make comparisons between different annual conditions, but to demean a case study. The reviewer's suggestions are valuable and will be the subject of future research by this group. In addition, we will add these suggestions to the conclusions of the manuscript (suggestions for future work).

Question

About the figures presented in the results: In general, give more detailed information of the figures in the subtitles. The figures along with their subtitles have to be highexplanatory. Another detail that the authors have to review are the titles of the axes of the figures, as well as the title in the "colobar" when necessary.

Answer

Thank you. We reviewed the figure captions and made some minor changes (in blue). In all the figures where there is “colobar” we indicate that they represents the shaded area. The axes that do not have a title are those that indicate the North/South and East/West coordinates.

Question

On the conclusion: In paragraph 320 the authors state that in general, the model satisfactorily reproduced the main changes caused by the cold phenomenon. Did the authors intend to evaluate the application of the model? Was that a goal, too? Just one observation in the last sentence of the conclusion: it is practically the

same initial sentence in the abstract, so is necessary to restructure this fragment in the abstract.

Answer

We would like to thank the reviewer for his comments. We decided to remove the sentence "*In general, the model reproduced satisfactorily the main changes that the phenomenon brought to the environment of interest*" from the conclusion and the sentence "*that is, the Friagem event has the ability to significantly change the microclimate and atmospheric chemistry close to the surface in the Amazon central region*" of the abstract.

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