Answers to the second reviewer

The careful development of vertical gradients for ozone and CO with a focus on the boundary layer is a significant contribution to the community. The climatology developed in this work is unique in that the authors took the boundary layer height into account in their averaging. A very interesting finding is that the weakest ozone vertical stratification is observed not only at high temperatures when mixing is expected to be strongest, but also at the lowest observed temperatures, which the authors hypothesize as potentially being due to weak deposition to snow. Finally, this work clearly shows that an aircraft campaign like IAGOS can provide similar profile information to ozonesondes, which is a very useful result that can inform future more extensive CTM evaluation efforts. This manuscript should be published after minor revisions detailed below.

We greatly thank the reviewer for his/her positive feedback on our study. In the following, the comments are in blue and the answers in black.

General Comments

My main comment is that the climatology developed by the authors should be made publicly available for use in model comparison studies. Currently the paper does not provide a method for obtaining this climatology.

We agree that it would be useful for the modelling community to easily and freely access this climatology. For both O_3 and CO, the PBL-referenced profiles for all seasons and times of day are now provided as text files and properly identified with a DOI (http://dx.doi.org/10.25326/4). The DOI gives access to a brief description of these products. They are now publicly available on the IAGOS website.

We added page 15 line 3 : "In order to allow further studies, the mean climatological O_3 and CO PBL-referenced profiles analysed in this study are freely available on the IAGOS portal (http://dx.doi.org/10.25326/4), for each season and time of day."

In the data availability section : "The climatological O_3 and CO PBL-referenced profiles are available through the IAGOS central database (http://iagos.sedoo.fr) and are part of the ancillary products (http://dx.doi.org/10.25326/4) (Petetin et al., 2018b)."

And in the references : "Petetin, H., Sauvage, B. and Boulanger, D.: IAGOS ancillary data: PBL-referenced profiles of O_3 and CO, 2018b."

In addition, the authors should more carefully discuss the type of PBL they describe in their study due to the use of the EI method. This method would describe a certain type of mixing and exclude other situations and more discussion on the meteorology conditions not captured by this method would be useful.

In this study, we are excluding only the profiles with SBIs (16% of the profiles), the profiles with vertical differences of temperature below 0.3 K (13%) and the profiles that do not meet the quality criteria in terms of data gaps (8%). The PBL characteristics analysed here with the EI method are finally based on 63% of the profiles (58,706 profiles). Therefore, apart from the very specific situations of atmospheric stability at the surface, most of the available profiles are taken into account here.

Finally, I would comment that there are a large number of figures and the authors could consider moving figures such as Figure 5 to the supplement that may not actually need more than discussion in the text for the general purposes of the paper.

We agree with the reviewer that there is a quite large number of figures in this paper. As suggested, we thus moved Fig. 5 in the Supplement. We modified the sentence page 7 line 17 as follows : "We investigated some characteristics of the EIs, namely the temperature difference, width and temperature vertical gradient (see Fig. S-1 in the Supplement)."

However, we think that the other figures should be included in the main document. A reader more interested in the vertical stratification of one specific chemical compound or thermodynamical parameter can still easily skip some parts and go directly to the figures and text of interest for him.

Specific Comments

Page 3, line 14 – If MOZAIC includes NOx, it would be useful to comment on why NOx profiles were not included, also a very useful compound for CTM evaluation particularly due to the sharp gradients in the PBL and the enhancement in the FT due to lightning.

MOZAIC only included NOy measurements on-board one aircraft between 2001 and 2005. Conversely, IAGOS now includes NOx measurements (currently on-board one aircraft) but these data are not available yet due to on-going validation. Even for NOy, the amount of data available in the lower troposphere is considerably lower than for CO or O_3 (there are many data gaps in the profile in the first kilometres). In the near future, when a sufficient number of NOx profiles will be available, we fully agree that it will be interesting to investigate its vertical stratification. Note that there are some studies in preparation in the IAGOS group with the new NOx observations.

Page 7, line 25 – I think the titles on Figure 6 are swapped – diurnal variation vs seasonal variation seem to be on top of the wrong plots.

No, actually both panels in Figure 6 shows the same results but organized in a different way. For instance, the top panel depicts, for each season, the diurnal variations : the box-and-whisker for the different times of day are gathered in order to highlight the diurnal variations (and this is done for all seasons). This is why we denominate it "Diurnal variations".

Page 8, line 37 – In Figure 8, it looks like theta increases with altitude everywhere. Please clarify. Maybe the resolution on the plot could be increased?

As explained in the text, for some seasons and times of day, the potential temperature is decreasing with altitude but very weakly and only between the two first altitudes (i.e. z/h between 0 and 0.05). Although it is possible to see it, we agree that it is difficult to see (because the decrease is very weak). However, we do think there is no easy way to modify the figure in order to highlight this small feature more clearly (since we are trying to keep figures reasonably compact). But this is one of the reasons for which we also showing the vertical

gradient profiles (right panels) where this decrease of the potential temperature with altitude is obvious.

Page 10, line 2 – Could you comment on why the seasonality in RH is not in agreement between IAGOS and the ozonesondes?

Looking at the RH PBL-referenced profiles in the PBL, we can see that the vertical gradients of RH differ between IAGOS and ozonesonde (as mentioned in the text), but the seasonality remains in reasonable agreement with lower RH during spring/summer and higher RH during winter/fall. In contrast, larger differences are observed in the lower free troposphere. In this part of the troposphere, in contrast to IAGOS that depicts relatively similar RH during all seasons, ozonesondes display lower RH values. This is particularly true during spring/summer and to a lesser extent during fall but the differences are reduced for winter. This results in a change of seasonality compared to IAGOS. To our opinion, this may be explained by the already mentioned negative bias on RH sonde measurements due to the heating of the sensors by the solar radiation. As solar radiations are strongest during spring/summer and lowest during winter, this would be consistent with the seasonal differences observed here.

We added a sentence : "This is also supported by the fact the differences between IAGOS and sondes are largely reduced when considering only nighttime profiles, i.e. when radiosonde measurements are not affected by heating effects due to solar radiation (not shown). These sources of bias are also expected to vary from one season to the other following the seasonality of solar radiation that are strongest in spring/summer and lowest in winter/fall. This may (at least partly) explain the distortion of the seasonal variations of RH in ozonesondes compared to IAGOS in the lower free troposphere. "

Page 10, line 25 – Please explain the % hm^{-1} unit.

This is already explained page 8, lines 33-35. However, we modified page 7, line 22-23 (the first occurrence of "hm") : "This leads to mean temperature vertical gradients of 1.4 and 1.9 K hm^{-1} during these two seasons, respectively. Interestingly, none of these characteristics depicts a diurnal variation (whatever the statistical metric)." → "This leads to mean temperature vertical gradients of 1.4 and 1.9 K hm^{-1} (where hm stands for hectometre, i.e. 100 m) during these two seasons, respectively. Interestingly, none of these characteristics depicts a diurnal variation (whatever the statistical metric)."

Page 12, line 2 – Does the comparison suggest that this climatology is not representative of more polluted regions?

Yes the reviewer is right. More precisely, it may not be representative of the most polluted regions during episodes of O_3 pollution. We added this sentence in the text : "[…] thus in good agreement with Kaser et al. (2017). This suggests that our climatology may not be representative of the most polluted regions during O_3 pollution episodes. […] "