Manuscript number: **#ACP-2021-421**

Title: **Longwave Radiative Effect of the Cloud-Aerosol Transition Zone Based on CERES Observations**

Submitted to: **Atmospheric Chemistry and Physics (ACP)**

Dear Reviewer,

On behalf of all authors, I would like to kindly thank you for your very constructive comments and suggestions, and as well for spending your precious time on reviewing our manuscript.

We are very pleased about the fact that the reviewer finds our manuscript interesting, sound and well written. All suggestions for minor refinements will be considered in the potential future submission of the manuscript. Please find below our answers to your major inquiries.

Note that the list of references mentioned in this document is given in the last page.

Sincerely yours,
Babak Jahani

C#2.1) The "conventional" transition zone study focused on low level clouds such as Eytan et al. (2020) referenced in line 55. However, this paper does not mention if they looked at the transition zone near low level clouds. This is important because high thin cirrus could have similar LW effects but the cloud processes of thin cirrus clouds are completely different from low level clouds. This needs to be clarified.

A#2.1) As you mentioned the study of Eytan et al. (2020) is focused on the transition zone near low-level clouds, whereas our study involves, in principle, transition zone conditions at any given altitude. Specifically, in our study, we are proposing a method applicable for quantifying the longwave radiative effects of transition zone conditions with a wide range of characteristics present at various altitudes. This fact has been mentioned at different places in the manuscript and Figure 4 has been provided to prove the matter, as dT is connected with altitude.
In line with this comment and the comment **C#2.4** we will modify Figure 4 by adding an additional X axis at the top to associate dT with altitude (please see Figure 2.3 below, **A#2.4**).It can be seen that most transition zone situations (85%) correspond to suspensions with the top level at less than 2 km, and all of them, at less than 5 km, so still below the cirrus cloud levels.

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C#2.2) The classification of undefined pixels (Lost A, Lost B, Lost C) is useful. However, the paper lacks the description of how to match MODIS pixels to CERES footprints. Since this paper mainly presents a method to estimate the longwave effects of the transition zone, matching MODIS pixels to CERES footprints is a critical step, and it should be described.

A#2.2) Thank you for your constructive comment. Information about the matching of MODIS pixels to CERES footprints is given below and will be provided as an annex in the potential future submission of the manuscript (as we believe giving this information in the main text divert the reader from the main ideas of the research):

For all CERES footprints we approximated the coordinates of the edges of CERES footprints assuming that they are rectangularly shaped and then looked for MODIS pixels confined within the area scanned by CERES. To do so, we first determined CERES viewing zenith angle (θ') from the CERES viewing zenith angle at surface (θ) provided in the CERES geolocation data according to Eq. 1:

$$\theta' = \sin^{-1}(\frac{R_e \sin(\theta)}{R_e + h_{sat}}) \qquad \textbf{\textit{Eq. 1}}$$

where R_e and h_{sat} are the Earth radius (6371 km) and satellite altitude (705 km), respectively. To derive this equation, we have assumed the Earth as a spherical object and applied the law of sines as illustrated in Figure 2.1 given below. Then, we approximated the cross-scan length of the CERES footprints ($l_{cross\text{-}scan}$; km), according to Eq. 2, and assuming that Earth is flat on the footprint scale and that CERES footprints are rectangularly shaped (see Figure 2.2 given below).

$$l_{cross-scan} = h_{sat}\ (tan(\theta' + 0.8127°) - tan\ (\theta' - 0.8127°)) \qquad \textbf{\textit{Eq. 2}}$$

The along-scan length of the footprints ($l_{along\text{-}scan}$) was taken equal to 20 km (nadir resolution) as according to https://ceres.larc.nasa.gov/instruments/ceres-operations/ the CERES instrument onboard Aqua spacecraft was operated in cross-track mode for the study period. Afterwards, we integrated the processed MODIS data from 1-km resolution to CERES native resolution by looking for MODIS pixels confined within the area scanned by CERES, considering equal weights for all MODIS pixels.

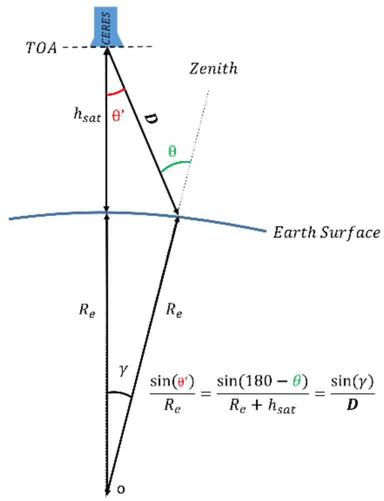

Figure 2.1. Schematic description of reasoning behind Eq. 1.

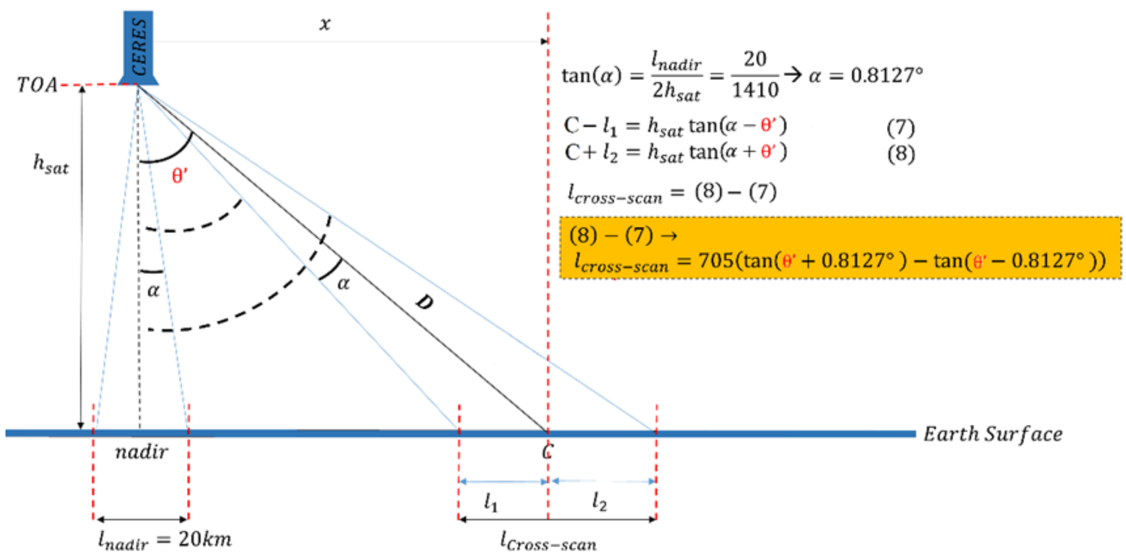

Figure 2.2. Schematic description of the reasoning behind Eq. 2. Point C in this figure indicates the longitude at the center of the CERES footprint.

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C#2.3) CERES products provide both radiances and fluxes. The authors used LW radiance without no mentioning the reason not using the LW in the product. Is the sub-footprint cloud variability that makes the radiance-to-flux conversion difficult? Some discussions are necessary.

A#2.3) We have chosen to use radiances in our study rather than fluxes to provide a more direct comparison between the simulations and observations regardless of the sky condition.

Specifically, CERES instrument directly measures radiances, from which the irradiances (fluxes) are estimated using the empirical Angular Distribution Models (ADMs) explained in Loeb et al. (2005). Also, as the reviewer points out, estimation of irradiance from the radiance measured in a given direction requires accounting for the angular dependence in the radiance field, which is a strong function of the physical and optical characteristics of the scene (such as suspension fraction, optical depth and phase). For this reason, to apply the ADMs, it is important to have information about the optical and physical characteristics of the suspension within the CERES field of view and such information is not available for the transition zone conditions.
According to your comment, reasoning for using radiances rather than fluxes will be provided in the potential future submission of the manuscript.

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C#2.4) The definition of temperature dT is not clear. It seems dT is the difference between surface air temperature and cloud top temperature (lines 227-235). It is hard for me to comprehend very small values of dT. What is the physical meaning when dT is very small? Is it because clouds are very low? Is it because of sub-pixel clouds in MODIS observations that makes cloud top temperature appears low? Some discussions are necessary.

A#2.4) Thank you for your valuable comment. According to your comment, additional (and clearer) discussion about how dT is computed and what it means will be provided in the potential future submission. Also, in line with this comment, we will add an additional horizontal axis to Figure 4. to link dT with altitude (please see Figure 2.3 given below).
Specifically, dT is the difference between the near surface air temperature and the suspension top temperature if the MODIS pixels labeled as “LOST A” were clouds. Let us further explain this: the MODIS pixels labeled as “LOST A” represent conditions that have been labeled as cloudy by MODIS cloud mask, whereas for them optical depth has not been retrieved (the algorithm has failed to retrieve). However, as they have been identified as cloud by the cloud mask, cloud top temperature has been retrieved for them.
As the reviewer says, the small values of dT correspond to transition zone conditions occurring very close to the sea surface. Indeed, according to Adebiyi et al. (2020), low-level clouds (cloud top height < 3 km) dominate the southeast Atlantic between July and October although mid-level clouds are as well relatively common over this region with cloud-top heights typically placed between 5 and 7 km. The information provided in Figure 2.3 (which will be the new version of current Figure 4 in the revised manuscript) also suggests that the majority of the transition zone conditions that we have studied are below 3 km.

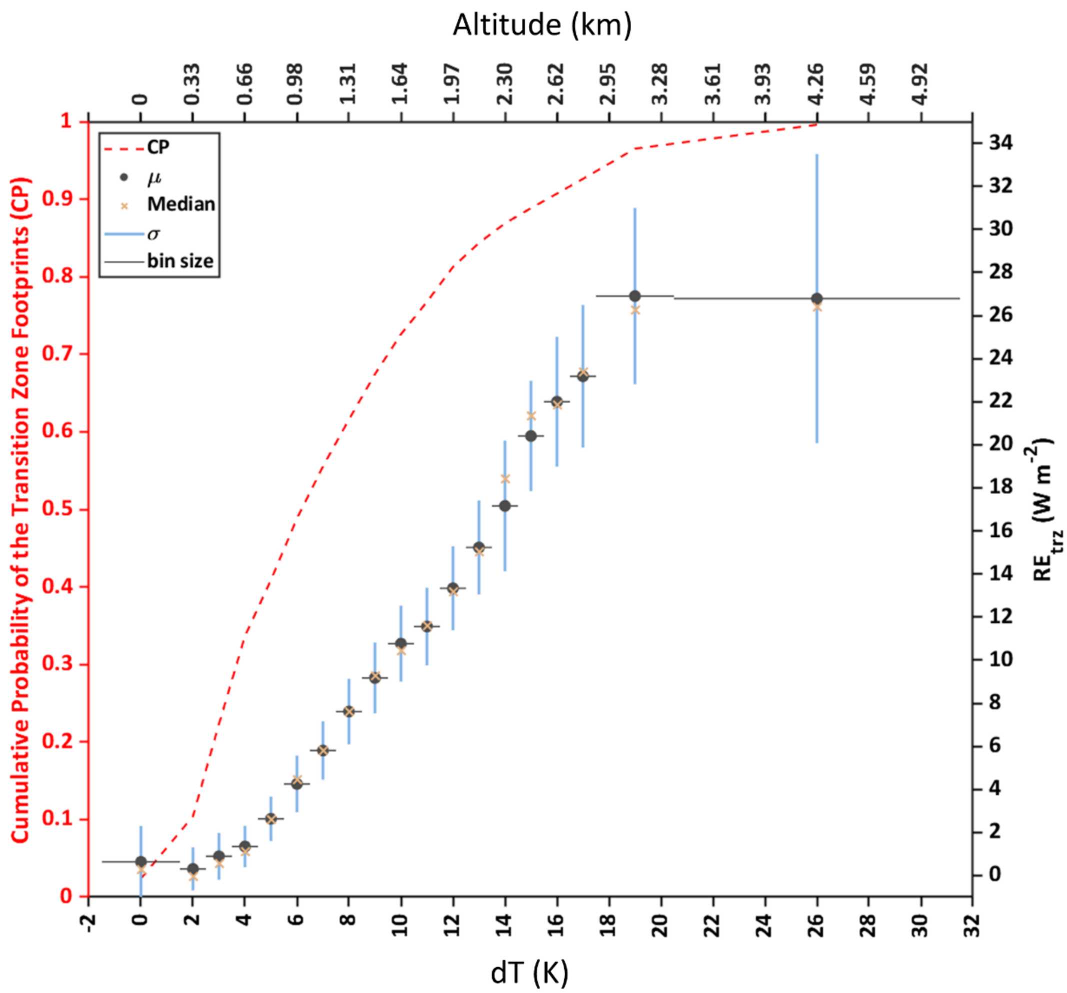

Figure 2.3. Cumulative probability (left axis) and REtrz (right) of the transition zone footprints analyzed as a function of dT (bottom horizontal axis). The vertical blue lines, black circles and yellow crosses indicate the standard deviation (σ), mean (μ) and median of the REtrz values in each dT bin, respectively. The horizontal black lines show the width of each dT bin. The top horizontal axis indicates the altitude associated with each dT value given in the bottom horizontal axis. Note: the altitudes given in this figure have been computed according to the tropospheric temperature laps rate given in Mokhov & Akperov (2006) for the study region (6.1 K/km).

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C#2.5) Line 34: “a phase called transition zone”. “phase” has been used several times for the transition zone (e.g., line 40, line 217: “a phase of particles between the cloudy and socalled cloud-free skies..”, line 289: “an important phase of particle suspensions..”, line 293: “intermediate phase of particle suspension..”.) To me the transition zone is not another phase of matters (e.g., solid, liquid, vapor). Even clouds contain liquid drops, ice crystals, and water vapor. I would use “a special region” to distinguish from clouds and cloud-free areas.

A#2.5) Thank you for your suggestion. We agree that the use of "phase" may be somewhat misleading, so we will avoid using it in the potential future submission.

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C#2.6) Line 81: "homogenous" -> homogeneous

A#2.6) The corresponding text will be corrected accordingly.

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C#2.7) Line 85: "These products were obtained for all MODIS-Aqua granules that contain data in the region 0° E – 15° E and 10° S –30° S during August 2010, which their data spreads over the area between 21° W – 21° E and 10° N –50° S." Not understand.

A#2.7) In this sentence we are trying to explain which granules (images) were used in our research. First, they corresponded to August 2010. Second, a granule was selected if it contained at least one data point (pixel) within the region 0° E – 15° E and 10° S –30° S. It turned out that the spatial extent of the data corresponding to the granules keeping these conditions covered an area between 21°W-21°E and 10°N-50°S.

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C#2.8) Line 85: "MODIS-Aqua". I would use Aqua MODIS (e.g, Minnis 2011).

A#2.8) The corresponding text will be corrected accordingly.

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C#2.9) Line 275: "3783 cases have been found…" I would change it to 3783 CERES footprints.

A#2.9) The corresponding text will be corrected accordingly.

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C#2.10) Not sure if the boxplot inset of Figure 3 is necessary since all information is already available from the cumulative distribution and median and mean values indicated. If it do not provide additional information, it would be better to remove it.

A#2.10) Thank you for your suggestion. As you mentioned, the box plot provides a summary of the results given in the main figure. Although it does not provide new information, it may make it easier for the reader to comprehend the results faster. However, according to your comment, we will remove it in the potential future submission.

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C#2.11) In the bar chart in Figure 3, should we expect to the sum of LOST A, B, and C to be one? I might have missed something. It would be nice to add some description in the caption so that the potential reader could see it immediately.

A#2.11) Thank you for your suggestion. In this bar chart, the sum of all classes ("Lost A", "Lost B", "Lost C", "Difficult", "Cloud", "Aerosol" and "Clear") equals one. According to your suggestion, we will modify the caption and the legend of the figure in the potential future submission, to make it clearer that the white section of the bar chart involves the latter classes (difficult, cloud, aerosol, clear).

References

Adebiyi, A. A., Zuidema, P., Chang, I., Burton, S. P., & Cairns, B. (2020). Mid-level clouds are frequent above the southeast Atlantic stratocumulus clouds. *Atmospheric Chemistry and Physics*, *20*(18), 11025–11043. https://doi.org/10.5194/acp-20-11025-2020

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Loeb, N. G., Kato, S., Loukachine, K., Manalo-Smith, N., & Doelling, D. R. (2005). Angular Distribution Models for Top-of-Atmosphere Radiative Flux Estimation from the Clouds and the Earth's Radiant Energy System Instrument on the Terra Satellite. Part I: Methodology. *Journal of Atmospheric and Oceanic Technology*, *22*, 338–351.

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