Dear Reviewer and Editor,

here below our answers to your comments (reported for your convenience) are presented as a one-to-one reply and highlighted in yellow. We would like to warmly thank the Reviewer for the detailed revision of our work. In particular, we noted that the Reviewer's comments are in some cases scientific considerations (and not only criticisms) which open for new discussion and ideas. We really appreciated this approach.

Please note that a new version of the Article accounting for the Reviewers comments, is also attached as a reply in the discussion section.

This is a very interesting study of cloud type and frequencies of occurrence observed from MIR and FIR spectra over the Antarctic Plateau. The study is fairly well written and informative; I recommend acceptance after these comments have been considered by the authors.

Relatively minor questions:

1. It would be quite interesting to provide an analysis of the surface-based lidar measurements for cloud occurrence, thermodynamic phase, cloud heights and layers, even if the measurements are limited to a height of about 7km. The lidar analysis would be complementary to the REFIR-PAD analysis, if there was enough data collected.
We agree with the Reviewer about the scientific interest of the proposal. Nevertheless, we believe that the proposed work should, in case, be the topic of a new research and not included in the present paper. At the moment, an automatic classification algorithm based on surface lidar measurements is not available. Thus, we visually inspected all the available lidar backscatter and depolarization profiles to classify first 202 REFIR-PAD spectra used as elements of the training sets and an additional set of 1726 REFIR-PAD spectra used as test set for CIC. The application of the CIC algorithm to the test set results in a 98% of correctly classified spectra meaning that there is an excellent agreement between the lidar and radiometric information in this regard. For this reason, it is expected that a classification based on surface-lidar data only (that is in any case unavailable at the moment) would provide very similar results (to what obtained by CIC) if applied to the entire 4 years dataset. Note also that the lidar range in altitude is not a limitation in this case since the Concordia base is placed at 3,3 km a.s.l. and the Tropopause height is usually lower than 10 km in that region.

2. I have two questions about the lidar data:

a. does multiple scattering above a liquid layer or at the cloud top impact the interpretation of the results? There is some evidence for this in the upper panel of Figure 7.
As observed by the Reviewer, the liquid layers show an increase in the depolarization ratio as we move from cloud bottom to cloud top. This is observed both in Figure 2 and Figure 7. This increase is intrinsically related with liquid water layers, where multiple scattering determines a depolarization that increases with the depth of penetration, in the lidar backscatter. Nevertheless, the liquid water layer is neatly identified by the lidar due to the very small depolarization ratio observed at cloud base. For a classification point of view, the identification of liquid particles in the layer is the key information which makes the observed cloud to pertain to a specific category (mixed-phase in our nomenclature) that is different from 'pure' ice clouds. The two categories (ice and mixed phase clouds) show peculiar radiometric features in the REFIR-PAD spectrum which are captured by the CIC classificator. For this reason, we believe that multiple scattering above the liquid layer does not affect the classification results.,

In response to the Reviewer comment the sentence at line 138 has been deleted and substituted by:
"The 15% depolarization ratio value is selected to account for the impact of multiple scattering within liquid clouds. It is observed that in presence of mixed-phase clouds the depolarization ratio shows very small values at cloud base, characteristics of liquid spheres, and increases towards values typical of ice crystals near the cloud top. An increase is, in part, intrinsically related with liquid water layers, where multiple scattering determines a depolarization that gradually increases with the depth of penetration, in the lidar backscatter. For this reason, in some conditions, the phase of the upper part of the cloud cannot be unambiguously defined based on the analysis of the depolarization ratio profile only. Nevertheless, the presence of liquid phase at bottom is unequivocally identified and the cloud is categorized as mixed-phase."

b. Is there evidence of ice particles falling through the base of the liquid layer? How often does this happen? This question arose when I read lines 290-296, and studied Figure 7 and related text.
This is a very interesting point. The frequency of occurrence of this process has not been quantified yet. M. Del Guasta (one of the authors), who is responsible for lidar data, reports that falling ice from mixed-phase clouds is a common situation at Dome C. It is also noted that, in the summer season, liquid water cloud layers with no associated precipitation are observed close to the surface (in the firsts hundreds of meters). A sentence describing this possible condition is reported at the end of the section indicated by the Reviewer. Note that, from a classification point of view, the presence of a liquid layer is sufficient to imply the conditions for 'mixed-phase' clouds.

"Another common situation is the presence of falling ice from mixed-phased cloud layers, as shown in the mid panel of Figure 2 between 18 and 20 UTC. Typically, the quantity of the precipitating ice crystals is very small and the CIC algorithm is able to capture the radiometric signal from the upper liquid water layer as it will be shown in the case reported in Figure 7."

3. In the paragraph beginning on line 437, I am puzzled by the lack of cloud fraction information in the winter (dark) months for the combined Terra and Aqua MODIS cloud product. If the information is available for the MODIS product from each of the Terra and Aqua platforms, there must be a problem with the combined data product. This seems to be something that the MODIS cloud team has to resolve. Suggest leaving out the combined Terra and Aqua data product until it has been resolved.
A new Figure 10 is generated accounting for two different MODIS cloud products. This is explained in the text as follows:
"Two types of MODIS L3 products are used in this study: MCD06COSP and MYD08/MOD08. The first one combines the observations from both AQUA and TERRA platforms (MCD06COSP_L3, MODIS Atmosphere Science Team, 2020). This product is based on a cloud mask which uses bands at visible and infrared wavelengths. Thus, the cloud fraction information (solid blue in Figure 10) is not available in the Antarctic region during the dark season (between May and July). The second product is derived from each MODIS sensors on platforms separately (MYD08 for AQUA, and MOD08 for TERRA, MODIS Atmosphere Science Team, 2017). The MOD08/MYD08 L3 product is based on a cloud mask which exploits infrared bands when in absence of solar illumination. In this case, the monthly mean cloud fraction is available for all the seasons (dashed and dotted blue curves in Figure 10, for MODIS TERRA and AQUA L3 products, respectively"

The combined data product (MCD06COSP) was developed by the MODIS team in the context of the project "Level 3 Atmosphere for CFMIP (Cloud Feedback Model Intercomparison Project) Observation Simulator Package or COSP". The COSP (Bodas-Salcedo et al., 2011) products have been extensively used to evaluate and validate climate trends (Saponaro et al., 2020; Zhang et al., 2019), and for this reason we think that it should be considered in the comparison.

The product MCD06COSP has some differences with respect to individual L3 satellite product (MOD08/MYD08). As said, in our case the main difference is that the Cloud Fraction of the combined product (MCD06COSP) is computed by using the Cloud Mask flags from L2 products of each satellite for daytime only while in case of MOD08/MYD08 L3 products the cloud mask exploits infrared bands when in absence of solar illumination.

Note also that the entire Section 4.3 is improved and the differences among the diverse satellite L3 products and CIC results are analyzed in terms of different area extensions and sensor sensitivities to cloud features.

References:
Bodas-Salcedo, A., et al. (2011). COSP: Satellite simulation software for model assessment. Bulletin of the American Meteorological Society, 92(8), 1023-1043. doi: 10.1175/2011BAMS2856.1.
Saponaro, Giulia, et al. (2020). Evaluation of Aerosol and Cloud Properties in Three Climate Models Using MODIS Observations and Its Corresponding COSP Simulator, as Well as Their Application in Aerosol-Cloud Interactions. Atmospheric Chemistry and Physics, vol. 20, no 3, p. 1607-1626. doi:10.5194/acp-20-1607-2020.
Zhang, Yuying, et al. (2019). Evaluation of Clouds in Version 1 of the E3SM Atmosphere Model With Satellite Simulators. Journal of Advances in Modeling Earth Systems, vol. 11, no 5, p. 1253-1268. doi:10.1029/2018MS001562.

Other comments:

Title: “on Antarctic Plateau” —> “on the Antarctic Plateau”
Done

Line 114: does 1928 refer to the number of REFIR-PAD spectra that are collocated with LiDAR measurements?
Yes. Rephrased: “A set of 1928 REFIR-PAD spectra are co-located with LiDAR measurements.”

Line 126: I think there’s a problem with the reference “Sassen and yu Hsueh”. Should be Sassen and Hsueh.
The reference is updated.

Line 142: Radiosondes Vaisala RS92 —> Radiosondes (Vaisala RS92)
Done

Line 176: are arranged —> are prepared
Done

Line 188: generally small cloud —> generally low cloud
Done

Line 199: that can be different —> which can be different
Done

Line 228: “window wavenumbers, that results in a very”—> window wavenumbers, and the measurements can have very
Done

Line 286: “if for the 8.3” —> if for 8.3
Done

Line 302: (c) —> or (c)
Done

Line 345: as TS —> for training
Following also suggestions from reviewer #1, this sentence was rephrased to: “From this set, only 202 spectra are used for training the CIC algorithm, and the other 87758 are ingested by the CIC to evaluate the cloud occurrence over the Concordia station.”

Lines 361-363: A third possibility is suggested by the authors but not included in the sentence: The temperature and mixed-phase cloud correlation could indicate that warm temperatures are favorable for mixed-phase clouds formation or that the presence of warm liquid clouds implies a stronger cloud forcing at the surface and, consequently, an increase in the temperature values near the ground. The third possibility is warm air advection of moisture. If the authors agree on this point, this third possibility should be included here and also in the Conclusion section.
The possibility is mentioned: “Another favorable condition for liquid cloud formation consists in the advection of air from warmer and more humid regions such as the Ross Sea and Southern Ocean.“

Line 391: in correspondence of cloud sky conditions —> when clouds are present
Done

Line 412: in presence of different —> for different
Done

Lines 409-410: please mention where the winds from the NE originate to provide some potential insight as to the origination of the moist layer that is being advected over the Plateau.
The sentence is rephrased: “Note (see back to Figure 1) that South and West directions at the Concordia station point to the inner Antarctic Plateau, where the drier air is supposedly found. Otherwise, the South-East and East directions are towards the Ross Sea and the Southern Ocean which are characterized by warmer and more humid air. The correlations are far from being conclusive since the upper level winds and the back trajectories of the air masses have not been analyzed yet.”

Line 434: by both satellites platforms —> by both satellite platforms
Done

Line 439-440: Thus —> For some reason... Note: the MODIS cloud mask should always have a result regardless of solar illumination because it includes infrared measurements.
See the answer to point 3 of the “Relatively Minor Comments”, which deals with the same argument

Line 456: in case of —> in the case of
Done

Line 460: In months in which —> In the months where

Done

Line 460: CALIOP products in green —> CALIOP products as shown in green
Done

Line 461: maximum of —> maximum in
Done

Line 497: in presence of —> in the presence of
Done

Lines 499-500: Potential explanations for this are this could be due... —> Reasons for this could include...Actually, this entire sentence is a bit awkward and should be reworked.
The sentence is re-phrased: “Note that when mixed-phase clouds are present, the daily thermal amplitude is smoothed with respect to the other sky conditions. The main reason for this could be related with the averagely larger optical thickness of liquid water clouds with respect to ice clouds \citep{dinatale20} which implies a decrease in surface insolation and thus a dumping of the diurnal cycle of surface temperature due to the reduced solar warming.”

Line 512: classification —> classifications
Done

Line 515: set up —> optimized
The sentence is modified as follows: “For this study, the algorithm is arranged and optimized to classify a REFIR-PAD spectrum as clear sky, ice cloud, or mixed-phase cloud.”

Line 525: sets in two —> sets into two
Done

Lines 545-547: could include warm air advection as a third option
The sentence is now: “This result suggests that (a) warm temperatures due to meteorological conditions (including warm and humid air advection) are favorable for the mixed-phase clouds formation or that (b) the occurrence of warm cloud layers enhances the cloud radiative forcing at the surface with a consequent increase in the surface temperature. Further work is needed for a better identification of the key atmospheric conditions and understanding of the physical processes driving to mixed-phase clouds formation in the Antarctic.”

Line 564: intense insolation —> higher insolation
Done

Line 565: CALIOP collocates the —> CALIOP data indicates that the
Done

Line 566: similarly to what derived —> similar to what is derived
Done

Line 572: a hourly —> an hourly
Done

Line 572: with maximum —> with a maximum
Done

Line 573: and minimum —> and a minimum
Done

Line 579: but it is reduced —> but smaller
Done