Dear reviewer,
I attach in this document the answers to your comments. But first of all, I would like to thank you for spending time with the review of this manuscript. The answers are in blue and the references made to the lines are made with respect to the new version of the manuscript.

General comment

According to authors, the detection of the cirrus clouds is made to fulfill two criteria, one about the temperature at the cloud top height and the other about the cloud base height. What about the signal to noise ratio, before applying the cirrus detection? The SNR should also be checked.

The detection of cirrus clouds as mentioned is performed with the cloud top temperature (T_{top}) and the cloud base height (CBH). For this, first the cloud cases are identified as 1-min vertical profiles where the MPLNET CLD product has a valid cloud base and top value. Then, using the radiosonde data, the cloud top temperature is estimated. Once the cloud top temperature and the cloud base height are obtained, it is checked if they fulfill certain conditions (CBH > 7 km; T_{top} < - 37ºC). If so, these clouds are identified as cirrus clouds.

For the cirrus cloud identification, we do not check the SNR, because we use the cloud base and top height variables of the MPLNET CLD product. MPLNET calculates these variables considering the SNR of the lidar signal (Lewis et al., 2016). Although the two-way transmittance method does not work successfully with noisy lidar signals.

In lines 352-354 the authors explain the conditions for the cloud identification with MPLNET CLD product and express their confidence in MPLNET's products and procedures.

What about the smoothing that the authors apply to the lidar signal?

The NRB signal profiles are temporally averaged to represent the merged cloud scenes. This average of the NRB signal is done according to the averaging that MPLNET has done to the 1-min profiles, being indicated in the variable "time_average" of the MPLNET CLD product. This multi-temporal averaging scheme is used to improve high-altitude cloud detection under conditions of a weak signal-to-noise ratio (Lewis et al., 2016, 2020). It is explained in line 113.

How can authors explain the detection of cirrus clouds with depolarization values less than 0.1? Figure 5 (right) is depicting linear cloud depolarization ratio in the bin between 0 and 0.1? Have you checked the SNR of these causes? The depolarization values are really surprising for cirrus clouds. Moreover, the 1-min temporal resolution could have restricted the accuracy of the depolarization ratio.

Yes, the explanation has been improved and can be found on line 439. I copy the paragraph. "The linear cloud depolarization ratio is typically between 0.3-0.5 (54%), with an average of 0.32, which is in agreement with (Sassen, 2005; Giannakaki et al., 2007; Kim et al., 2018; Hu et al., 2021). The lowest values of the linear cloud depolarization ratio may be due to a tendency of horizontal orientation of the ice crystals or a very thin or multi-layered cloud (Hu et al., 2009). It is mentioned above that in this study if there is another cloud lower, less than 1 km away, the two clouds are merged and treated as one cloud layer."

As explained in the previous question, in this study the multi-temporal averaging scheme is used to improve high-altitude cloud detection under conditions of a weak signal-to-noise ratio (Lewis et al., 2016, 2020). In this case, there are 13 merged cirrus scenes with depolarization values lower than 0.1. Of these 13 merged cirrus scenes, 6 are cloud scenes averaged over 1 min, 4 cases are averaged over 5 min and 3 are averaged over 21 min.

Do the authors apply any integration for the cloud retrievals?

No, we make averages of a half-cloud vertical profiles, centred at the maximum peak to calculate cirrus cloud retrievals. (Line 302)

Authors claim that "For example, one of the major advantages of this new approach of the method is that it is only necessary to assume a Rayleigh zone both above and below the cirrus cloud, without making any priori optical and/or microphysical hypotheses about the cirrus Cloud". The authors should provide more details and even calculations about the errors introducing in their statistics with this approach in detecting cirrus clouds.

No errors were calculated, but on request a section with the statistical study of the cirrus cloud retrieval errors have been added. The methodology is in Section 3.5 and the statistics of the error of the retrievals applied to the database is in Section 5.2.

"After the calculation of the cirrus clouds optical retrievals, their associated errors have been estimated. Where the COD, LR and LCDR errors have been calculated for each cirrus cloud scene with the classical error propagation equations (Ku, 1966). Similarly to the calculation of the LR and LCDR, their errors have been estimated by performing the average on half-cloud, centred at the maximum peak. In addition, the LR error has been calculated as the maximum possible error, since only the first iteration has been considered in its calculation. As the classical error propagation equations have been used, it has been necessary to establish the errors of some variables such as the temperature and pressure of the radiosondes, being $\triangle T = 0.2ºC$ and $\triangle P = 0.5 hPa$ (Servei Meteorològic de Catalunya, 2005). The MDR error has been quantified as 3.5% of its value (Behrendt and Nakamura, 2002). The NRB and VDR errors have been assumed to be the NRB and VDR uncertainties from MPLNET NRB product."

"After having shown the probability distributions and the mean and standard deviation values of the cirrus clouds optical retrievals, the basic statistical values of their associated errors are presented in Table 3.

Variables	Min	Mean	Median	Std	Max
COD	0.04	0.16	0.11	0.20	1.54
LR (sr)	0.00*	0.28	0.06	0.84	7.83
LCDR	0.01	0.18	0.08	0.31	2.06

Table 3. Minimum, mean, median, standard deviation and maximum values of the COD, LR and LCDR errors for cirrus cases from 2018 to 2022 in Barcelona. *Zero values are not exactly null, but if rounded to the second hundredth they can be considered null.

Table 3 shows that the error of the COD is 0.16±0.20 with a maximum value of 1.54, being considerably high for sub-visible cirrus clouds (COD < 0.03), but reasonable for visible and opaque cirrus clouds. In addition, the maximum COD error found is lower than the maximum COD calculated. The LR error is

0.28±0.84 sr with a maximum value of 7.83 sr. If it is compared to its magnitude (30±19 sr; see Figure 5) is negligible in most cases. On the contrary, the LCDR error is 0.18±0.31, which is considerable for the lowest values, since the LCDR ranges between 0 and 1. In addition, a maximum LCDR error of 2.06 has been calculated, being greater than unity. This error is so large due to the uncertainty associated with this vertical profile of volume depolarization ratio."

Line 17. The authors claim that: «Together with results from other sites, a possible latitudinal dependence of lidar ratio is detected: the lidar ratio increases with increasing latitude. » This sentence is not supported from the study retrievals. It must be removed.

Right, it was changed and it is explained in line 466. We see a positive trend of the lidar ratio towards the poles, but we admit that there is a large variability at each site. So, we have changed that conclusion to the following: "the effective column lidar ratio seems to have a generally increasing trend towards the poles, but no conclusion can be drawn, since the variability at different sites appears negligible relative to the variability at each site."

How is the calibration of the polar and cross-polar channel made?

MPLNET polarized MPLs use a ferroelectric liquid crystal to alternate polarization states between linear and elliptically emitted laser pulses, and the data are calibrated using the optical specifications of key optical components and determination of the offset angle between the crystal's primary fast axis and the lidar's fast axis (Welton et al., 2018). The lidar data are processed with the same procedure as used for the older neumatic liquid crystal design (Flynn et al., 2007) to calculate the volume depolarization ratio.

In the equation #6, the η factor is equal to 1 in your study. You should state this assumption.

Right, it was changed and not the multiple scattering effects are better explained in line 207.

"The multiple scattering factor, η, is introduced by (Platt, 1973, 1979). The multiple scattering effect depends on laser beam divergence, receiver field of view, the distance between the light source and the scattering volume (Wandinger, 1998; Wandinger et al., 2010; Shcherbakov et al., 2022). In this study the multiple scattering effect is considered negligible for lidar signal measured by the MPL system ($\eta = 1$) due to its narrow field of view, the mean distance between cirrus clouds and the MPL, the small cirrus cloud optical depth (generally COD < 0.3) and the magnitude of cirrus cloud extinction ($\alpha_p < 1\ km^{-1}$) retrieved (Campbell et al., 2002; Lewis et al., 2016; Shcherbakov et al., 2022)."

How CALIPSO accounts for the multiple scattering effect of the ice crystals?

At the first, the multiple scattering effect for CALIPSO signal was ignored but it was changed and now the multiple scattering effects are considered in CALIPSO lidar signal. In line 254, the value of the multiple scattering factor is explained.

"The multiple scattering effect cannot be neglected for spaceborne lidar signals because of the distance between the satellite and the cirrus clouds. For this reason, η is assumed constant throughout the cloud layer with a value of 0.6, as in the version 3 of CALIOP algorithm (Garnier et al., 2015)."

Therefore, in the case study where the two-way transmittance method is applied to the CALIPSO lidar signal, the effect of multiple scattering is considered and its COD is changed to 0.2547.

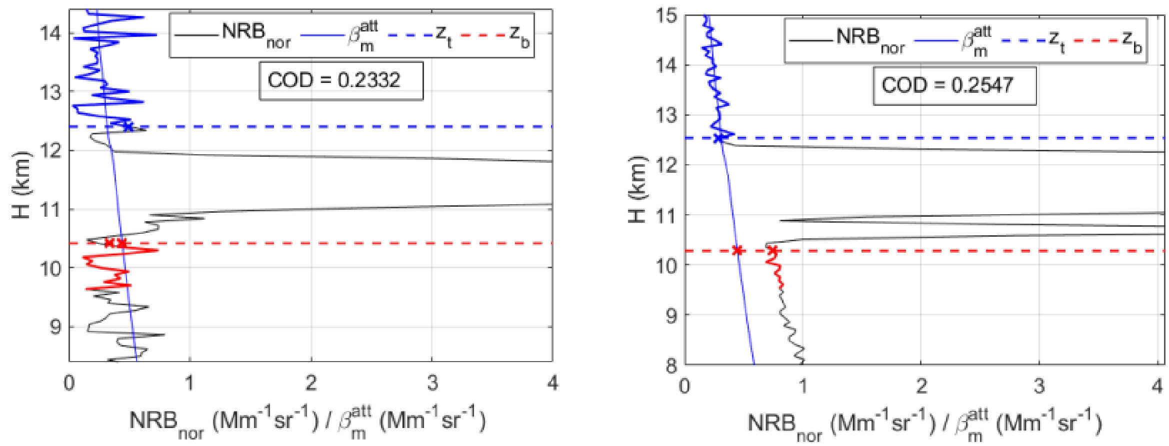

Figure 1. Application of the two-way transmittance method for (left) MPLNET and (right) CALIPSO data, for the case 11/02/2019 at 02:03:50 UTC. The height zb(zt) is the altitude corresponding to 0.2 km above (below) cloud top (base) height.

Table 1 and its description is now included in the section of results. It should be moved before Section 4.

Ok, we accept your suggestion and we have changed that section to a separate section called "Criteria for cirrus cloud identification" and we placed it before section 4.

I propose a reconstruction of the text. The title of Section 4.4 “Cirrus correlation” is misleading. It must be changed.

Ok, so as not to make a mistake in interpretation of that section, we have accepted your suggestion and renamed it as "Discussion".

Line 80-85. The novelty of the work needs to be discussed and detailed.

The introduction section was slightly changed to emphasize the novelties that this study brings in the current context. The conclusions have also been modified to emphasize the contribution of this study compared to the literature. For example, the possible causes of error found in the application of the two-way transmittance method and the errors associated to cirrus cloud retrievals have been studied.

__Specific comments__

Page 2 line 44-45. Reference is missing.

The introduction section was greatly changed. In fact, the following paragraph that you mention has been deleted.

"The Met Office (the national meteorological service for the United Kingdom; https://www.metoffice.gov.uk/) defines cirrus clouds as "short, detached, hair-like clouds found at high altitudes"."

Page 27, Line 590. Replace "Depolarizationratio" with "Depolarization ratio".

Right, thanks. It was changed.

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