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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Optical and geometrical characteristics of cirrus clouds over amid-latitude lidar station" *by* E. Giannakaki et al.

E. Giannakaki et al.

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Details:

1. P9284: Title: ....over a southern European lidar station ... would be appropriate. Almost all lidars around the globe are Mid-latitude lidar stations.

The title was changed as proposed

2. P9284: Abstract: must be improved after all revisions.

The abstract was improved after all revisions

P9284: Introduction:

3. line 23: There is a CIRRUS book (edited by Lynch, Sassen .....) with several chapters on lidar, but also on the role of cirrus regarding climate... that book should be

referenced.

The book is referenced in the revised introduction

4. P9285: line 2-5 should be omitted, this is speculation.

lines 2-5 was omitted

5. line 10: chemical...? what do you mean?

The word chemical was removed

6. line 13-15: list of references... please include a HSRL reference, may be Grund and Eloranta, Month. Wea. Rev. 1990? (Fire experiment 1986 results).

An HSRL reference was included in the list references:

Grund, C.J, and Eloranta, E.W.: The 27-28 October 1986 FIRE IFO Cirrus Case Study: Cloud Optical Properties Determined by High Spectral Resolution Lidar, Month. Wea. Rev., 118, 2344-2355, 1990.

7. line 16: why is the backscatter coefficient of importance? why not mention the depolarization ratio (water/ice discrimination), why not mention the lidar ratio (for spaceborne lidars like CALIPSO).

The revised text has been modified according to the reviewer's suggestions giving emphasis to lidar ratio and depolarization ratio.

8. line 27: I personally found Goldfarb et al. (2001) rather questionable. There is another European cirrus long term data set from Reichardt, (Physics and Chemistry of the Earth, Part B, 1999).

The results of Reichardt (1999) are now mentioned in the text.

9. P9286: line 10: mention Reichardt (1999) too.

Reichardt (1999) in now mentioned in the text.

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10. line 15: Eloragini and Flamant published a paper concerning cirrus retrieval in Appl. Opt. years ago (1995-2000), please check.

Elouragini and Flamant (1996) was also mentioned.

11. P9287: Line 1: The underlying dataset of 65 cloud cases observed during 6 years of regular measurements does not seem to provide enough material to call the resulting statistic a climatology.

The word 'climatology' was replaced by 'statistical analysis'.

12. line 2: According to JGR web page, Seifert et al. is now 'in press'. Provide JGR number of this article, move it to the reference list.

Seifert, M. P., A. Ansmann, D. Muller, U. Wandinger, D. Althausen, A. J. Heymsfield, S. T. Massie and C.G Schmitt (2007), Cirrus optical properties observed with lidar, radiosonde, and satellite over the tropical Indian Ocean during the aerosol polluted northeast and clean maritime southwest monsoon, J. Geophys. Res., doi: 10.1029/2006JD008352, in press (accepted 31 May 2007)

We provided JGR number of the article of Seifert et al. and it was moved to the reference list.

P9287 - Instrumentation and data.

13. line 5-18: The actual vertical resolution of the lidar should be mentioned. Please stateclearly whether the lidar is pointing to the zenith or not. If the lidar is pointing vertically, specular reflection is an important issue (bias) to be considered in the interpretation of cirrus observations. The related effects must be discussed in this section and the resulting bias in the cirrus statistics must be discussed in the result section.

The vertical resolution of the raw lidar signal in now mentioned (7.5 m). Also, it is clearly stated that our lidar is pointing to the zenith. A first reference about the specular reflection effect is mentioned in this section, while later, in methodology section, we mention the influence of this effect to Raman and Klett-Fernald retrievals. Finally in the result section a discussion is made about the possible influence of this effect to our results (see also our response to comment no. 22).

14. line 26: Improve the numbers of measurements after introducing the threshold height of 9 km.

The number of measurements was improved after introducing the threshold mid temperature $<$-38oC which leads to mid-height$>$ 8.6 km. The number of night measurements is 15 while for daily measurements is 38. The total number of cirrus cases is 53.

P9288 - Methodology

15. line 11: It is mentioned that the signal was smoothed by a sliding average smoothing routine but the authors did not point out which smoothing length was usually applied during data analysis (for the three different methods).

The vertical resolution of the elastic raw signal at 355 nm is equal to 7.5 m, while of the inelastic raw signal at 387 nm is equal to 15 m. The fitting and/or smoothing windows used for the application of the Klett-Fernald, transmittance and Raman methods are additionally referred in the revised text. Klett-Fernald method: smoothing window of 300m Transmitance method: smoothing window of 300m Raman method: linear least square fit with a window of 600m

16. line 18: If there were different cirrus layers (in one observation session), did you separately count these layers? In case that you distinguish different layers, what criteria for separation did you use? Anyway, please state what you did in the case of several layers with cirrus.

There was only one such case in our measurements where two distinct and separated by at least 500m layers were observed. Otherwise there was few cirrus clouds observed with a double peak structure which were treated as one layer.

17. P9289, line 4, check also Eloragini and Flamant, Appl. Opt....

Elouragini and Flamant reference was also mentioned.

18. line 10, the mean lidar ratio.... please clearly state that this quantity is the effective lidar ratio and not the vertically mean lidar ratio that would be obtained in the case of averaging of the lidar ratio profile obtained with the Raman lidar. Give the definition for the effective lidar ratio: the optical depth divided by the column backscatter. This is then a backscatter-weighted lidar ratio (layers with strongest cirrus backscattering have the largest impact on the the effective lidar ratio). This in turn is then a serious problem in the case of a vertically pointing lidar where you may often observe very strong backscattering by layers with falling horizontally aligned crystals (large specular reflection). These layers strongly influence the cirrus effective lidar ratio and introduce a strong bias towards small lidar ratios.

the 'mean lidar ratio' was replaced by the 'effective lidar ratio', as lidar ratio is not the vertically mean lidar ratio but the optical depth divided by the column integrated backscatter. This is clearly stated in the text. The word effective is referring to the calculated lidar ratio and optical depth before taking into account multiple scattering correction. This was clearly mentioned in the text. The possible effect of specular reflection was mentioned.

19. line 24: the effective lidar ratio is not defined yet...

The effective lidar ratio now has been clearly defined before starting the discussion.

20. P9290, line 8: I guess the Chen et al. method is the same as the Eloragini and Flamant method...? Please check!

The method applied by Elouragini and Flamant is an iterative method that based on Klett's inversion, constrained by the total optical depth (that is known through transmittance). However, we use the transmittance method in order to find out the optical depth and not to retrieve the extinction profile. In this frame, we want to use the two methods

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independently from each other to found out the optical depth of cirrus clouds.

21. line 12: Standard Atmosphere...Is no actual radiosonde available? no Numerical Weather Prediction model output for grid point Thessaloniki? Did you also use Standard Atmosphere Profiles in the Klett aproach before? Later (result section) the authors use actual radiosonde data (temperature profile) in the lidar data analysis. It should therefore be justified why there was a standard atmospheric model used in the case study that illustrates the transmittance method.

For 53 of our cirrus cases, we have available measurements to 49 cases. This is the reason why a US standard atmosphere was used for this case study (and to the rest 3 where no radiosonde measurements were available). The US standard atmosphere was also used in the Klett approach, when no radiosonde measurements were available.

22. P9291, line 8: How did you obtain the lidar ratio of 26 sr? Did you vertically average the Raman solutions? As mentioned, the Klett lidar ratio is the effective lidar ratio, mainly influenced by the strongly backscattering parts of the cirrus (so, the lidar ratio is typically low because of specular reflection). The Raman lidar ratio does not suffer from this effect (there is no influence of the backscatter coefficient strenght). All cirrus parts contribute equally to the lidar ratio. That seems to be the reason that the Raman mean lidar ratio is much larger than the Klett effective radius. Please comment on that. This effect is also described in that CIRRUS book of Lynch et al., if I remember right.

The lidar ratio of 26 sr was obtained by the averaging the effective lidar ratio (here the word effective refers to no multiple scattering correction) of Raman solution. The difference on the lidar ratio that obtained by Raman and Klett-Fernald method is attributed not only to the assumption of a vertically constant lidar ratio for the solution of elastic differential equation but also to a possible effect of specular reflection. It is important to state that the effective lidar ratio obtained by Klett-Fernlad method maybe biased to

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lower values, since the layer with the strongest cirrus backscattering have the largest impact on the effective lidar ratio

23. P9291 - Section 3.2: Multiple scattering is an important issue when dealing with cirrus data, or more common, when dealing with lidar signals returned from large scatterers with diameters greater than approx. 10 um. However, it should be taken care on an accurate multiple scattering correction. In comparison to the MS-corrections calculated by the models of Eloranta and Hogan the parametrization of Chen 2002 produces ms factors that stand in contradiction to these models. Whereas Chen accounts almost no multiple scattering effect to optically thin and thus geometrically thin cirrus (see Sassen and Comstock 2001 for the almost linear relation) the models calculate the strongest ms effect (eta around 0.5 because of forward-scattering peak of ice crystals) for geometrically thin clouds which decreases with penetration depth. The authors should mention that the parameterization of Chen is in contradiction to the model results and why this is the case.

The approach for multiple scattering correction used in the transmittance method is very simplified and this was mentioned in the text: 'However, we should keep in mind that this approach is very simplified since we assume that multiple scattering factor is only depending on optical depth, not taking into account, the receiver field of view, the laser beam divergence and the size of the scatterers.' Later, a discussion is made about the contradiction between the results of this approach with model results.

24. P9293/9294, lines 20 to lines 8, The discussion on multiple scattering consequences is not satisfactory. The approaches done for the Klett and Raman solutions appear reasonable. Factors of 0.67 and 0.64 are ok. In contrast, the factor of 0.93 is not just trustworthy. At least, explanations are required, why this ms factor is so different from the two other factors, although one and the same lidar with fixed laser beam divergence and RFOV is used.

A paragraph was added in the text referring to the difference between multiple scat-

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tering approaches 'The difference for multiple scattering correction between the two approaches as discussed previously was found also to the rest of the cases. Some typical values of multiple scattering factor, as given by Chen et al. (2002), are: 0.58 for optical depth of 1 and 0.95 for optical depth of 0.1. Sassen and Comstock (2001) assume that multiple scattering factor is of 0.9 for subvisual cirrus clouds, of 0.8 for relatively thick clouds and of 0.6 to 0.7 for optically thick clouds. However, these assumptions are in contradiction to the model results. Multiple scattering simulations show an increase of the multiple scattering factor with optical depth. The values of multiple scattering factor is approximately 0.6 for optical depths lower than 0.1, while for optical thicker clouds this factor ranges from 0.6 to 0.8. Thus, we should mentioned that the approach for dealing with cirrus clouds when the transmittance method is used is very simplified and may lead us to wrong results. However, when the transmittance method is used, neither the extinction coefficient nor the backscatter coefficient profiles are available in order to use model simulations.'

Result section:

25. P9295, lines 9-10: As mentioned above, the authors have to present the method how they distinguish cirrus clouds from water and mixed-phase clouds at temperatures between -25 and -38 oC. Alternatively, they may just include the clouds above a certain height, e.g., above 9 km height, in their statistics. This is often done in cirrus papers.

As suggested by the reviewer we have inserted a threshold of -38oC for mid-cloud temperature to distinguish water and mixed phase clouds, since there are no depolarization measurements available at our site.

26. P9295, line 15: Cirrus cloud base is always rather variable, thus mean values of 7.4 and 7.8 km are almost the same when keeping the standard deviation (not given) into account.

As cirrus cloud base is rather variable we have removed the sentence: 'Platt et al. (1987), had studied mid-latitude cirrus clouds and found that winter cirrus clouds base lies at 7.38km, while for summer cirrus clouds base found a larger value of 7.79 km.'

27. P9295, line 19: As long as lidar-radiosonde observations are not done simultaneously and at the same place, the statement concerning cirrus top above the tropopause is speculation. Speculations should be avoided.

Following the comment of the referee, we have removed the comparisons between cirrus clouds boundaries and tropopause. However, we consider that the temperatures achieved for cloud boundaries from radiosondes are trustworthy since the lidar measurement is within 2 hours from radiosonde launched and LAP lidar is approximately 10 km from Thessaloniki airport where the radiosondes are launched.

28. Section 4.2: Care should especially be taken in this section (and afterwards) where the results of the different retrieval methods are compared. It should be mentioned in the previous sections, what an 'effective' lidar ratio, optical depth, and extinction-coefficient is.

Effective lidar ratio and optical depth have been previously defined.

29. P9297: Please compare your findings with Reichardt (1999). Further comments are not possible as long as a new set of trustworthy cirrus clouds (clouds above 9 km or so) and respective results are not available.

As mentioned before a new set of cirrus clouds with mid-cloud temperature below -38oC and mid-cloud height above 8.6 km has considered in the analysis and presented in the revised text. In the discussion the new results are now compared with Reichardt et al, 1999, showing a good agreement.

30. Table 1: Tropopause heights (radiosonde observations) should not be compared with lidar data (taken at different time, different site). Absolute numbers of observations per season are required to get an idea how trustworthy the statistical results are. The numbers seem to be rather low after Fig.4, thus Table 1 is generally questionable.

Tropopause heights were excluded from the table. Table 1 was changed. Instead of

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seasons, we have separated our data to 2 periods (warm and cold period) in order to increase the number of cases for each period considered . We have assume as warm period the months: Apr, May, Jun, Jul, Aug, Sep, Oct , while the cold period are the months: Nov, Dec, Jan, Feb, Mar. Also, we mentioned the absolute number of cases for each period.

31. Figure 5 is trivial and should be left out.

We have removed figure 5. In order to present the range in which cirrus clouds were observed we have plotted the distribution of mid-cloud height and mid cloud temperature. Both the absolute numbers and the percentage are shown in graphs.

32. Figure 6 is questionable because of the point mentioned above that radiosonde time and site is different from lidar time and site.

We have removed fig 6.

33. Figure 8a: Again absolute numbers per month are needed.

Fig. 8a was removed. We have changed figure 8b (now is fig. 7). Both the absolute values and percentage are shown in the graphs.

34. Figure 9: Message is: No Message, no dependence? How many cases per temperature interval?

Fig. 9 has become now Fig. 9 (a). We have calculated the thickness of cirrus cloud on 5 oC degrees (and not on 10 oC). The pattern is the same. To show the number of cases we have also plotted histograms at the top of the graph, presenting both the absolute number and the percentage of cirrus cases. The purpose of this plot is to show in which temperatures, thicker clouds are observed. Also, we describe the pattern of this plot. Other studies, which are mentioned in the text, have also shown this pattern. However, the dependence of thickness on mid cloud temperature is not clear and for this reason we follow the advice of referee and also plot the mean extinction coefficient (Fig 9 (c)). Also, for the figure 10 (b) (now becomes fig. 9(b)) we have plot histograms to show the

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number cases which were observed per interval of temperature.

35. Figure 10: How many cases per thickness interval, per mid cloud temp interval?

As mentioned above the dependence of optical depth on mid-cloud temperature was moved to figure 9 (b). Figure 10 (b) (thickness VS optical depth) is moved to figure 8. At the top of this figure is also presented the histogram of cirrus events per thickness interval

36. Remaining question: If you have the optical depth and the geometrical depth, what about a mean cirrus extinction coefficient? May be you plot that as a function of temperature. This relationship is most interesting for modelers.

We followed the advice of referee and plotted also the mean extinction coefficient (Fig 9 (c)) which seems to decrease with decreasing temperature.

37. More generally: May be you leave out all the questionable figures, because the number of cases per class is too low, and just provide some histograms considering all 65 cases (or may just 50 cases after introducing a threshold height).

We have removed or added some of the figures but we have also presented histograms showing the absolute number of cirrus occurrence and the corresponding percentage.

38. May be you separate winter (Oct to March) and summer data (April to September) only. The numbers per half year may be high enough.

Instead of seasons we have separate the year to warm and cold period.

39. All parts of the paper: Spelling needs improvement

The text was improved for grammar and spelling corrections.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 9283, 2007.