Atmos. Chem. Phys. Discuss., 7, S7799–S7806, 2007
www.atmos-chem-phys-discuss.net/7/S7799/2007/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Cirrus, contrails, and ice supersaturated regions in high pressure systems at northern mid latitudes" *by* F. Immler et al.

F. Immler et al.

Received and published: 20 December 2007

We like to thank the referees for their detailed comments that helped a lot to improve the manuscript. Here we document all changes made for the revised manuscript based on the detailed comments of the referees.

1 Corrections and remarks based on the comments of referee # 1

1.1 major comments

- p 13179 l. 28.: The following sentences were introduced: "Cirrus clouds, from the lidar perspective, are layers of particles above 6 km altitude with a well defined

upper and lower boundary and a large vertical and temporal variability, that depolarize light and have a close to zero colour index. The latter is the backscatter related Ångström coefficient and expresses the wavelength dependence of the backscatter coefficient. White clouds (colour index =0) scatter equally efficient at all visible or near visible wavelengths."

- p 13185 l. 2.: The following sentences were introduced: "The correction algorithm we were using generally yields higher humidities in the upper troposphere than the algorithm used by Spichtinger et al. (2003). This is one reason for this discrepancy in the frequency of ISSRs, because our correction algorithm quite often yielded supersaturation with respect to ice in the UT while this was not obtained when no or the Leiterer algorithm was used."

1.2 Minor comments

- p 13178 l. 16.: "formation conditions" deleted
- p.13179: Header for subsection introduced: "The Mobile Aerosol Raman Lidar (MARL)"
- p.13180 l. 9-16: The paragraph was changed in order to explain more accurate how we derived the optical depth of thin cirrus.
- p.13183 l.7: the sentence "On average, ..." was moved to section 2.1. The following sentences were inserted in order to explain more clearly the relevance of the observed PDF. "The propability of encountering a cirrus with an optical depth between OD and $OD + dOD$ decreases rapidly with OD. The change of the propability is more gradual when considering the logarithm of OD. In other words, it is about as likely to detect a cirrus with an optical depth between OD

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and fOD, with f being some factor > 1, for any value of OD within the detection limit of the lidar"

- p.13183 l.13: replaced "smooth" with "more even"
- p.13183 l.15: deleted "form and/or" line 16, replaced $\pm$ with minus sign. In principle, clouds the optical depth can also grow in an exponential way in order to yield a PDF as was observed. It is not possible to deduce from the observation whether growth, decay, or both obey an exponential law. However, for simplicity, we consider only the decay which is most likely the more relevant process.
- p.13183 l.24: Line feed and the following sentence inserted: "In summary, the shape of the PDF of the optical depth of stratiform cirrus suggests that their live cycle is dominated by an exponential decay."
- p.13184 l. 25: "climatological" deleted
- p.13190 l.14: Unit changed to μm

2 Corrections and remarks based on the comments of referee # 2

Introduction

- p.13178 l. 10: Reference (Liou, 1986) deleted
- p.13178 l. 24: Introduced: "The humidity data of the radiosondes were corrected using an algorithm suggested by (Miloshevich et al., 2001) which provides an accuracy of about 5% in the upper troposphere at high humidities. "

Section 2

- p.13179 §2: The beam "footprint" on the cirrus is divergence times the altitude + its initial diameter. At 10 km altitude the laserspot would be about 2 m in diameter while the field of view of the telescope was 5 m wide.
- p.13179 l. 20-25: We think that for lidar people this is an important information.
- p.13180 l. 9-17: This paragraph was changed to make the point clearer: the absolute error of 0.05 only holds for the Raman and shadow method.

Section 2.1

- The paper Treffeisen et al. was accepted
- All the details about the accuracy of the different sensors are described in Miloshevich et al, 2006.
- p.13181 l. 10: The following sentence was added "Based on a comparison with the NOAA frostpoint hygrometer, the accuracy of the corrected RS-80 humidity data was shown to be about 5% in the upper troposphere at high humidities (Miloshevisch et al., 2006)."
- p.13181 l.10: The following sentences were added: " Coincident here means that the radiosondes, which were launched just a few 100 meters away from the lidar, flew in the upper troposphere during the time period of the lidar measurements. Since for this analysis we are using 1 hour averages of lidar data, it is guaranteed or at least very likely that the radiosonde flew within the temporal and horizontal frame of the lidar observation."

Section 2.2

- Paragraph 2 and 3 of this section were moved to the introduction.

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Section 3

- First paragraph changed: 1st IOP no longer mentioned. and some more details on the second IOP are given.

Section 3.1

- p.13183 l.5: The header was changed to “Cirrus occurrence and live cycle”
- p.13183 l.10: “universal” replaced by “ a general feature”
- The general feature refers to the long tail towards thin clouds. This is refined in this paragraph. The maximum of the PDF indeed is determined by the measurement technique, namely its upper detection limit.
- The entire section was revised. We hope that the point we wanted to make is clearer now.
- p.13184 l.3: A header was introduced “Cirrus and synoptic pattern”
- p.13184 l.8: Sentence in brackets changed to “isobars curve towards the right hand side, looking in the direction of the flow”
- p.13184 l.8: The value of 67% is derived by taking the average of all days marked with an H in fig. 2

Section 3.2

- A plot showing the altitude distribution of cirrus and ISSRs is added. And a sentence explaining the information shown in this plot is added to the last paragraph of this section.

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Section 3.3

- The upper panels of fig.4 show a fairly small fraction of the sky directly above lindenberg.
- As far as contrails are concerned, the lidar is indeed less sensitive than the bare eye, because the contrails “hide” in cirrus clouds. As far as the clouds are concerned the lidar is by far more sensitive than the bare eye.
- The term subvisible cirrostratus is more accurate since most subvisible clouds are extended “laminar” type clouds. Therefore we now use sCs consistently in our manuscript for subvisible clouds.
- The most important finding of this section is that contrails in general are embedded in preexisting cirrus. To give more emphasis on this point, this section was rearranged: the last paragraph was moved forward, with its last sentence deleted. And a paragraph summarising the results was added to this section.

Section 3.4

- Fig: 4: The plot shown in fig. 5 is a typical example. We have analysed all the data of the IOP in fig.6.
- p. 13188 l. 8: The following sentences were added to the second paragraph: “The good agreement between the observation of stratiform cirrus and its prediction in the ECMWF model supports the conclusion that ice particles are present in air that is saturated with respect to ice. Since upper air radiosonde observation are not assimilated to the analysis, the humidity of upper tropospheric air and consequently the occurrence of clouds in the model are consequences of vertical transport and cooling of air masses. As we have pointed out in section 2.2 stratiform clouds are formed by the model when saturation is reached. The

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agreement between model and observations demonstrates that this simple concept works well in the conditions that were investigated here."

- We wrote, "more than 100 μm" in the text which corresponds to the 150 μm given in the graph. We expect to be able to determine the size of particle to its order of magnitude, not better. Therefore this difference is not significant.
- We did not take the pressure and temperature dependence of the ice density into account. This is definitely not the most significant source of error.
- Cirrus ice particles are frequently reported to be in the range of 10 to several 100 μm in diameter. Lawson et al. (1999) reported sizes of typically 600 μm and occasionally up to 1 mm. The sizes we have retrieved are therefore not exceptional.

Conclusion

- p.13190 l.10: The follwing sentence was inserted to the third paragraph: "Radiosonde humidity measurements, lidar observations of ice clouds and prognostic model output thus provide a consistent picture of the occurrence of stratiform cirrus clouds at mid-latitudes."

References:

Lawson R. P., A. J.Heymsfield, S. M.Aulenbach, T. L. Jensen (1998), Shapes, sizes, and light scattering properties of ice crystals in cirrus and a persistent contrail during SUCCESS,*Geophys. Res. Lett.*,2(9),1331 -1334,

Miloshevich, L. M., H. Vomel, D. N. Whiteman, B. M. Lesht, F. J. Schmidlin, and F. Russo (2006), Absolute accuracy of water vapor measurements from six operational radiosonde types launched during AWEX-G and implications for AIRS validation, *J. Geophys. Res.*, 111, D09S10, doi:10.1029/2005JD006083

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Interactive comment on Atmos. Chem. Phys. Discuss., 7, 13175, 2007.

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