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Interactive Comment

Interactive comment on "Spectroscopic evidence for β-NAT, STS, and ice in MIPAS infrared limb emission measurements of polar stratospheric clouds" *by* M. Höpfner et al.

M. Höpfner et al.

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We thank referee 2 for her/his comments which contribute significantly to the clarification of various items. In the following we address them point by point:

1. *More effort should be expended to establish that, for each of the three case studies of PSC type, it is reasonable to assume the same composition throughout the entire PSC column. This is most important for the cases of ice and NAT. For example, ECMWF or NCEP temperature profiles presented along with the lidar measurements, compared with equilibrium temperatures for the PSC phases, based on the gas phase mixing ratios measured by MIPAS-ENVISAT, will help to*

convince the reader of the uniformity of the PSCs for each case day. This may be less important for the optically thick ice cloud if MIPAS is obscured below a certain altitude.

We have added temperature profiles and existence temperatures for ice, STS, and NAT in Fig. 3 of the revised manuscript where the Lidar measurements are shown. In general the altitude region where PSCs are expected from the temperature profiles are consistent with the Lidar data. Also, for STS and NAT the temperatures are above the ice frost point. During the detection of ice the temperatures fall below the ice frost point. Only in the upper part of this profile temperatures are at or slightly (1 K) above the frost point. However, the high Lidar backscattering ratio there (together with the strongly enhanced MIPAS infrared radiances) clearly show that ice was present also at these altitudes. This can be explained by a remaining uncertainty in the temperature profile. Mind that we have used ECMWF temperatures, which had to be corrected for an altitude dependent bias which we derived from McMurdo sonde data. We have extended the revised manuscript by an Appendix (B) which describes the applied corrections.

2. *How reasonable is the assumption of constant median radius and distribution width for the whole profile? Are there examples from the literature with little variation? Will the model calculations converge without imposing these restrictions? Does this limit the use of this technique to infer PSC phase?*

   (1) In case of small particles (less than 1 μm) the infrared signal is the same for many small or few larger particles. Thus, IR observations are only sensitive to volume density. The actual median radii and widths do not influence the analysis. Thus, for the STS case the comparison made in the paper is not affected by the constant radius and width assumption over altitude.

   (2) Also for larger particles, the IR signal is the same for various combinations of the width of the distribution and the median radius. This strong linear dependence

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has been shown by e.g. [Echle et al.(1998)], and we have tested this independently. Thus, we can fix the width of the distribution and simulate the measured signal by adjusting a median radius accordingly. Errors in both parameters compensate and do not propagate onto the inferred PSC composition.

Due to linear dependence of the Jacobian matrix with respect to size distribution width and median radius the retrieval would not converge when trying to retrieve all parameters simultaneously.

The technique of broadband spectroscopic calculations is used in this paper only to characterize single coincidences between Lidar and MIPAS. For large-scale phase identification the colour ratio method is applied to search for the existence of NAT through the 820 cm^{-1} band. This method is not affected by variation of particle radii as long as the particles are small enough to allow to distinguish the emission features as described in the paper.

3. *In the discussion of Figure7, perhaps it is worth mentioning again that sigma and rm are assumed constant with altitude. This will help the reader to understand that the aerosol volume is only controlled by N(h), thus the same curve can represent both number and volume. I found this confusing initially.*

   A description has been implemented in the text.

4. *What exactly does N(h) mean? For a standard definition of size distribution N represents the total number concentration for all particles $>$ some lower size, Rlower, but in the stratosphere at these altitudes this number, represented by condensation nuclei (r $>$ 0.01 μm) measurements is approximately 10 cm-3. Clearly here a different definition is being used which provides a range from $<$ 0.01 to $>$ 60 cm-3. Thus the authors have imposed some lower radius limit on the first moment of the size distribution integral to obtain N(r$>$Rlower) where Rlower changes with PSC phase.*

Compared to the investigated PSC phase with volume densities of several μm^3/cm^3, the volume density of stratospheric condensation nuclei with values of about 0.1–0.2 μm^3/cm^3 is below the detection limit of MIPAS. Since IR observations are essentially sensitive to the volume, we do not have to consider the condensation nuclei as a second mode. In the retrieval (as we fix radius and width) number (N)- and volume (V)- density are interchangeable parameters connected by the integral over the lognormal size distribution: $V(N) = \frac{4\pi}{3} N r_m^3 exp[9/2 ln^2\sigma]$. Thus, one has to keep in mind that the volume is the more natural quantity of the retrieval.

5. *10694.8: I would recommend that the phrase, "with the assumptions of a height-constant median radius between 0.2 and 9 μm, and height-constant distribution width of 1.35." be added at this point. A nearly similar statement in the middle of the following paragraph gets lost. But in either case some additional explanation, as mentioned above would be appreciated to say either why it is necessary or why it is justified to do this.*

   We have stated the assumptions used in our retrieval scheme more clearly in the related paragraph as suggested by the referee.

6. *10696.11- : Volume densities are also shown. This discussion of the derivation of number/volume needs clarification. Do the volumes shown arise from fitting the measured spectra to infer N(h), rm, and sigma, and then calculating volume from the lognormal size distribution parameters inferred, or does the volume arise from an altitude profile of aerosol absorption (emission) which is directly proportional to volume in the infra-red? At first it sounds like the former and then the latter. Please rework this paragraph to make it clear. If both are used do they give the same answer? What this consistency check completed?*

   (1) As explained above, for constant r_m and $\sigma = const$ the use of number and volume density is equivalent, thus, in accordance also with the suggestion of referee

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3, and since the volume density is the more basic quantities for IR observations, we have avoided the use of number density in the discussion.

(2) It has been shown in [Höpfner et al.(2002)] and [Höpfner(2004)] that there arise significant errors when volume density of particles larger than about 0.8 μm are derived from IR limb-emission measurements without consideration of scattered radiation. Thus, a consistency check in which the volume is directly inferred from profiles of aerosol absorption coefficients as proposed by the referee would be feasible for a solar-occultation instrument, but not in case of emission observations of larger particles.

7. *10696.16- : sigma to a constant value of 1.35. Why so exact for this assumption? Is there a basis for this value? It seems a bit narrow particularly for STS clouds.*

   As explained above, for small particles the derived volume densities from the spectral fit do not depend on the distribution width σ and the radius r_m. This is especially the case for STS. For larger particles (NAT, ice) there is some independent information on the size, however, σ and r_m are still linearly dependent, such that the result of particle volume and the spectral fit quality is weakly dependent on assumptions about σ. Independently, our choice of $\sigma = 1.35$, though a bit less than an average of typical observations (e.g. 1.6 from [Hofmann and Deshler(1991), Deshler et al.(1991), Adriani et al.(1992)]), lies well within the range of variability.

8. *10696.18- : Please use the correct gas phase mixing ratios for each case the first time. The readers don't need to be confused with an incorrect calculation. If you need to later explain a disagreement at low altitude for NAT then you could introduce alternate gas phase mixing ratios, but only if they lead to a useful conclusion.*

   We agree and have changed the related section accordingly.

9. *10700.24- :This paragraph is forced. Although the authors seem convinced that this was really an ice observation, the data presented and the arguments are not convincing. The authors argue that the temperatures and MIPAS observations surrounding this period all suggest ice, while the lidar saw NAT throughout its profile. So why didn't the lidar see ice? Also why are the authors so convinced ice was present? Region 4 includes NAT, STS, and ice, thus there is no compelling argument from what is presented to suggest ice was present instead of large NAT particles. I suggest reducing this discussion and include mention of the fact that the MIPAS measurements are equivocal while the lidar measurements clearly indicate NAT.*

   We only partly agree with the referee in this respect. It is true that R4 includes all three phases, however, there is also an observation of colour-indices located in R3 which shows such strong radiance values in the MIPAS spectra that can only be explained by ice and not by NAT as seen by the lidar. Also, the referee has misinterpreted the sentence '*The surrounding MIPAS measurements on both days indicate, that McMurdo had been located close to a region of ice PSCs in the south.*'. It does not mean that all MIPAS observations surrounding McMurdo suggest ice. In fact, only the observations south of McMurdo indicate ice, while northwards MIPAS does not see ice but NAT. We have tried to make this point clearer in the revised paragraph.

10. *10701.6- : There is again the indication that even though regions R2 and R4 are ambiguous, the authors use a more strict interpretation, i.e. that R2 indicates STS. According to Figure 9 R2 can be either STS or NAT, and R4 STS, NAT, or ice.*

    We have changed this paragraph and stressed that in R2 STS identification is more ambiguous. However, it has to be stated that ice must also have existed near McMurdo and, thus, the situation of PSC composition is likely to be inhomogeneous, thus, making comparisons between MIPAS and Lidar more difficult.

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11. *Minor comments/English suggestions:*

    We agree with all comments/suggestions and have implemented these in the revised text.

References

[Echle et al.(1998)] Echle, G., von Clarmann, T., and Oelhaf, H.: Optical and micro-physical parameters of the Mt. Pinatubo aerosol as determined from MIPAS–B mid–IR limb emission spectra, J. Geophys. Res., 103, 19 193–19 211, 1998.

[Hofmann and Deshler(1991)] Hofmann, D. J. and Deshler, T.: Stratospheric cloud observations during formation of the Antarctic ozone hole in 1989, J. Geophys. Res., 96, 2897–2912, 1991.

[Höpfner(2004)] Höpfner, M.: Study on the impact of polar stratospheric clouds on high resolution mid–IR limb emission spectra, J. Quant. Spectrosc. Radiat. Transfer, 83, 93–107, 2004.

[Höpfner et al.(2002)] Höpfner, M., Oelhaf, H., Wetzel, G., Friedl-Vallon, F., Kleinert, A., Lengel, A., Maucher, G., Nordmeyer, H., Glatthor, N., Stiller, G. P., von Clarmann, T., Fischer, H., Kröger, C., and Deshler, T.: Evidence of scattering of tropospheric radiation by PSCs in mid–IR limb emission spectra: MIPAS–B observations and KOPRA simulations, Geophys. Res. Lett., 29(8), 119-1, 1278, doi:10.1029/2001GL014443, 2002.

[Deshler et al.(1991)] Deshler, T., Adriani, A., Hofmann, D. J., and Gobbi, G. P., Evidence for denitrification in the 1990 Antarctic spring stratosphere: II Lidar and aerosol measurements, Geophys. Res. Lett., 18, 1999–2002, 1991.

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[Adriani et al.(1992)] Adriani, A., Deshler, T., Gobbi, G. P., Johnson, B. J., and Di Donfrancesco, G.: Polar stratospheric clouds over McMurdo Station, Antarctica, during the 1991 spring: lidar and particle counter measurements, Geophys. Res. Lett., 19, 1755–1758, 1992.

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