Atmos. Chem. Phys. Discuss., 8, S11914–S11918, 2009
www.atmos-chem-phys-discuss.net/8/S11914/2009/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evidence for ice particles in the tropical stratosphere from in-situ measurements" *by* M. de Reus et al.

M. de Reus et al.

Received and published: 31 March 2009

The authors would like to thank the referee for his/her helpful comments and suggestions. All issues raised by the referee are discussed below and have been incorporated in the final version of the paper.

p. 19315 - This statement has been made less strong.

p. 19328 - This line refers to model calculations with a one dimensional microphysical model by Chen et al., 1997. The reference has been added to this line additionally. The possible explanation for the decreasing effective radius with height is added to the text in section 3.2.

p. 19330 - The calculation of the IWC has been changed according to a more recent publication by Baker and Lawson, 2006. After this change, the two measurements of

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

IWC also agree very well at high IWC values. At lower IWC, the IWC determined by the microphysical measurements is lower than the IWC determined by the hygrometer measurements. Since the discrepancy between hygrometer IWC and size distribution IWC appears mainly at low IWC, where the IWC is determined by the size range of the FSSP, the main problem might be the FSSP measurements. In this case, the ice crystal number concentration is underestimated by the FSSP, probably due to the very small sample volume of the FSSP, which is insufficient at these low number concentrations and small particles. We can, however, not exclude that the hygrometers have a larger uncertainty in this IWC range (at these low IWC values, two large numbers of the same order of magnitude are subtracted to get the IWC). This has been added to the text in section 3.2.

p. 19331 - There are five distributions displayed in the top panel of Figure 2, however the average distribution (red line) covers parts of single distributions, so that it only looks like four. The possibility of in-situ ice formation due to uplift in a gravity wave has been added to the text in section 3.3.

p. 19332 - We used a combination of the ozone mixing ratio, temperature and total water content as indicator for tropospheric air masses. For this small fluctuations in the ozone mixing ratio, temperature and total water content within the time periods where the ice crystals were observed (grey areas) were evaluated in Figure 6. The correlation of the ice crystal number concentration with the total water content and the slight but visible anti-correlation with ozone, but above all the evidence from the lidar image that the ice crystals are observed down to the tropical troposphere is, to our opinion, enough to conclude that the ice crystals originate from the troposphere. In the text we put more emphasis on the lidar measurements. We do agree with the referee that the signal in ozone is hard to see at this level of zoom. Without making an additional plot, we cannot increase the zoom.

We changed the statement in: the ice crystals in the stratosphere likely result from overshooting convection of the Hector system, and discussed the Lidar and total water measurements here as well. We also included the reference to Corti et al., 2006 at this point in the paper. In the Figure caption of Figure 6 it is mentioned now that the tropopause corresponds approximately with the bottom of graph 6b. We also added that the total ice water content is much too high for in-situ ice formation.

p. 19333 - In order to make an estimate of the ice water which will evaporate in the stratosphere, evaporation times of ice crystals of a certain size have been calculated according to Pratte et al. (2006) using the different evaporation rates reported in this study. For event 1 in Figure 6 between 77 and 92% of the observed IWC will evaporate within the stratosphere, showing that this incident of overshooting convection causes a humidification of the stratosphere. This has been added to the text in section 3.3 and Figure 7 has been changed accordingly.

For clarity we removed the average aerosol concentrations from Figure 8. In the discussion about the interstitial aerosols, the same 90 ice clouds are selected as have been discussed in section 3.1 - 3.2 (Figures 2 and 3).

p. 19334 - We have re-written the paragraph about the origin of the ultrafine particles according to the suggestion of the referee.

We added a Figure showing probability density functions of the aerosol number concentration in and out of clouds. It was found that the distributions do not differ much in the upper troposphere and stratosphere, but a significant difference was found in the middle troposphere. Here higher aerosol concentrations were found within clouds compared to out of cloud measurements, which shows the influence of the convective system. Higher aerosol concentrations are lifted up from the boundary layer within the clouds, whereas due to the lack of significant outflow of the convective system in the middle troposphere, the clear air samples show relatively low aerosol concentrations at these altitudes.

The possible sources for the high aerosol concentrations observed in the stratosphere (both in and out of clouds) are discussed and added to section 3.4. These high concentrations might origin from volcanic eruptions, aircraft emissions, or by the updraft of aerosol from the troposphere in overshooting convection.

p. 19335 - Although Seifert et al. shows similar relations between the interstitial aerosol concentration and the ice crystal number concentration, we cannot compare our results directly to the results of Seifert et al., since they investigated this relation within one cloud, and related it to the development stage of the investigated cloud. In our study, however, we show the relation in many different clouds (the relation in one cloud is given by only one data point).

p. 19336 - This sentence has been changed.

p. 19337 - The parameterisation of McFarquar and Heymsfield (1997) show that the relation between the IWC measured by the FSSP and CIP is linear at lower IWC but starts to be non linear at higher IWC. This relation has been determined using a large set of measurements in high altitude ice clouds with instruments which were not affected by shattering. Heymsfield (2007) showed that shattering will cause this relation to shift to higher FSSP IWC and also become linear at higher prevailing IWC, since the more large particles exist the more shattering will occur and the FSSP will detect more particles. The data of our study shows a nice agreement with the parameterisation of MH97 up to an IWC of about 10-4 g/cm3 , indicating that the FSSP and CIP instruments seem to do a proper job. At higher IWC, the FSSP underestimates the IWC compared to the MH97 parameterisation. Shattering should have caused an overestimation in the FSSP instrument. Note here that the CIP measurements have been corrected for shattering events using the interarrival time measurements and the FSSP measurements not (no interarrival times are recorded in the FSSP instrument). The problem with shattering is that it cannot be measured directly with the widely used FSSP instruments. Therefore, we have to live with these kind of arguments.

The summary and conclusions section has been improved according to the suggestions of the referee.

ACPD

8, S11914–S11918, 2009

The authors like to thank the referee for the proposed technical corrections.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 19313, 2008.

ACPD

8, S11914–S11918, 2009