Atmos. Chem. Phys. Discuss., 8, S11910–S11913, 2009
www.atmos-chem-phys-discuss.net/8/S11910/2009/

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 Darrel Baumgardner for his helpful comments and suggestions. All issues raised by the referee have been discussed and incorporated in the final version of the paper. Below the main questions are answered.

This paper deals with the observation of ice crystals in the stratosphere. The ice crystal size distribution as measured by two instruments, including its potential uncertainties, have been analysed in detail. In addition independent measurements of the ice water content have been shown and compared to the IWC derived from the size distribution measurements, which also gives an indication of the data quality. As second part of the paper measurements of the aerosol number concentration are discussed in and out of cloud. In addition, supportive measurements of lidar, ozone and several atmospheric parameters have been shown in the paper. The large amount of data of different instruments presented in this paper is the main reason for the high amount of co-authors.

During several conferences and workshops the data presented in this paper was strongly criticized, mainly because of potential shattering effects. Therefore, we decided to have a quite lengthy discussion about the data quality. Also we found a thorough discussion about the used data analysis method, which is often missing in the literature, very helpful for the judgement of the value of the data. We totally agree with the referee that these data can be the basis of more scientific studies, for example to humidification of the stratosphere, formation and evolution of ice clouds or radiative impact studies. In order to not make the paper more lengthy we decided to focus on the data analysis and leave the proposed studies to following papers. We hope to have presented the data in such a way that it can also be used by other scientists for further modelling studies.

Part 2.2: For the analyses of the FSSP it is assumed that the ice crystals are spherical, the T-matrix method has not been applied, since this method is developed for falling water droplets and we do not believe that this is better as assuming spherical ice crystals. This misleading sentence has been removed from the text.

Part 2.3: The explanation about how we reconstructed the missing first slice of each image is given in section 2.3 and has been improved. The ice crystal size distributions have been recalculated using the Korolev correction for out of focus particles. All data derived from the ice crystal size distributions have been changed accordingly. Although the size distributions change slightly, the main conclusions of the paper do not change by this recalculation.

Part 2.4: We changed the title of this section to combined number size distributions from the modified FSSP-100 and CIP. How we calculated the mass (ice water content) from the size distribution is given in section 3.2, where the IWC is discussed in detail. A direction to this section has been added to the text in section 2.4.

Part 2.5: The sampling characteristics of the FISH inlet on the Geophysica research

ACPD

8, S11910–S11913, 2009

Interactive Comment

aircraft have been determined by computational fluid dynamics modeling (Krämer and Afchine, 2004). As shown in this publication, the aspiration coefficient (or enhancement factor) of the aircraft inlet increases from its minimum value (i.e. 1-2) for particles with radii smaller than 0.3 μm to its maximum value Emax which is typically achieved for particle radii larger than 3-4 μm. Since the IWC is mainly determined by particles larger than 3-4 μm in diameter (see Figure 2) a constant enhancement factor can be applied. This has been added to the text in section 2.5.

Part 2.7: No measurement of vertical velocity was performed on the Geophysica aircraft.

Part 3.2: We changed the calculation of the IWC to the mass to area relationship presented by Baker et al., 2006. For small prevailing IWC this makes no large difference, at higher IWC the IWC calculated from the ice crystal size distributions decreases slightly and compares better with the IWC measured by the two hygrometers.

The non-linear relationship between the IWC from the hygrometers and microphysical measurements at low prevailing IWC can not be explained by the uncertainty in enhancement factor of the FISH. It has been shown that the enhancement factor of the FISH inlet is constant for particles larger than 3-4 μm in diameter, which is also the lower detection limit of the FSSP. See also the discussion above at Part 2.5. 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. Here, the size determination of the FSSP might be wrong (we assume that the ice crystals are spherical, size thresholds also for spherical particles) or an underestimation of the ice crystal number concentration by the FSSP. 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

ACPD

8, S11910–S11913, 2009

Interactive Comment

has been added to the text in section 3.2.

Part 3.3: The units have already been changed in the online ACPD version.

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. Plotting the potential temperature in stead of ambient temperature would give exactly the same picture, since the pressure does not change over these short time periods (the aircraft normally flies on constant pressure levels). 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.

Part 3.4: Figure 9 has been made in order to find out how many aerosol particles out of the measured total number of available particles would end up as cloud ice particles. The lack of a correlation between the two variables and the large range of ratios shows that no simple relation can be found. We found this information important enough to show in the paper.

We examined the images of the stratospheric ice crystals and found that the large particles seem to be columns and aggregates. This has been added to the text in section 3.3.

We would like to emphasise again that lots more can be done with the data presented in this paper and we invite interested scientist to use this observational data for further studies. In this paper, however, we would like to concentrate on the presentation of the ice crystal and aerosol data.

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