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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol-cirrus interactions: A number based phenomenon at all?" *by* M. Seifert et al.

M. Seifert et al.

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1. One-to-one relation between ice crystals and residuals

Reviewer:

"To my opinion, the strong hypothesis concerning the interpretation of the CVI data (i.e. one cloud particle leaves one, and only one residual particle) is not enough justified for this study and, to my understood, is sometimes in contradiction with further hypotheses and conclusions in the paper. Not enough justified: The hypothesis is based on a previous study, Seifert (2003), where residual particle concentrations are compared with ice particle concentrations derived from FSSP-300. Fig.2 illustrates this result in the previous paper. The correlation between the two estimated concentrations is clear for a number of residual particles above 1 per cm-3. For lower concentration, the relation between the two estimated concentrations is not established. Another point

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is that data are relatively dispersed. For example, for a number concentration of 1 residual aerosol per cm3 measured from CVI, FSSP-300 counts between .2, and 2 ice crystals per cm3. Is it possible that the over or under estimation of cloud particles is lied to physical processes and bias the conclusions? “”

Reply:

In a previous study (Seifert et al., 2003) we assessed the accuracy of the CVI measurement and presented a systematic comparison of the crystal number density measured by the CVI and the FSSP-300 probe. The comparison includes more than 20 hours of concurrent in-cloud observations from the two INCA campaigns (a rather extensive data set in comparison to other aircraft in-situ campaigns). The comparison between these two instruments presented in Figure 1 (Seifert et al., 2003) clearly shows that the number density of residual particles observed by the CVI corresponds to the number density of hydrometeors observed by the FSSP-300. Note that the FSSP inverts the scattered light from a particle based on assumed properties of the crystal, whereas the CVI selects particles based on the aerodynamic properties of the crystal. The reviewer criticizes that the one-to-one relationship is only established for a number of residual particles above 1 per cm-3. In our opinion studying Figure 1 clearly shows that a linear relationship between FSSP and CVI data is also found at lower number density e.g. at least down to 0.2 cm-3. What regards lower number densities the leveling off by the FSSP is due to the fact that the detection limit is higher for this instrument than for the CVI. In other words the lower detection limit of the FSSP-300 restricts the comparison towards lower number densities. However, within the detection limits of the two instruments which span two orders in magnitude the two instruments agree very well along the one-to-one line.

What regards the reviewers objection concerning the dispersion of the data in Figure 1 (Seifert et al. 2003), we would like to point out that the broadening of the percentiles towards lower Ncvi,10 can be explained by counting statistics alone. At higher number densities the spreading of the data is likely to be a result of differences in cut-offs

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of the CVI and FSSP probe, the physical distance between the two inlets as well as differences in response times.

As pointed out already, the FSSP inverts the scattered light from a particle based on assumed optical properties of the crystal, whereas the CVI selects particles based on the aerodynamic properties of the crystal. For FSSP-CVI comparison purposes the FSSP crystal number density has been calculated for particles larger than 4 μm in size. However, an uncertainty of +- 1 μm the aerodynamic cut-off by the CVI and the size interpreted by the FSSP-300 may cause an offset in the crystal integral number density between the two instruments.

The CVI is mounted on top of the aircraft whereas the FSSP-300 was wing-mounted. The physical distances between the two probes may cause that the crystal population sampled by the CVI to be different from the FSSP in particular if the aircraft passes cloud edges or the investigated clouds are often patchy, a mixture of cloudy and non-cloudy air.

The two probes have different response times. Note that the typical speed of the Falcon aircraft is almost 200 ms-1.

Clearly, all this causes some spreading of the data around the one-to-one relation. Finally we would like to mention a study by Gayet et al. (2002) who presented an analysis where cloud probes used during the INCA experiment were compared. Besides the CVI and FSSP-300 probes, this analysis also included the PMS-2D-C probe and the Polar Nephelometer. The study shows a very good agreement between the different probes.

References:

Gayet, J.-F., Auriol, F., Minikin, A., Ström, J., Seifert, M., Krejci, R., Petzold, A., Febvre, G., and Schumannm, U.: Quantitative measurement of the microphysical and optical properties of cirrus clouds with four different in situ probes: Evidence of small ice

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crystals, Geophys. Res. Lett., 29, 2230, 2002.

Seifert, M., Ström, J., Krejci, R., Minikin, A., Petzold, A., Gayet, J.-F., Schumann, U., and Ovarlez, J.: In situ observations of aerosol particles remaining from evaporated cirrus crystals: Comparing clean and polluted air masses, Atmos. Chem. Phys., 3, 1-13, 2003.

2. Scavenging of ice crystals

Reviewer:

"in paragraph 3.5 it is state that the scavenging of ambient aerosol particles by ice crystal has a very small impact on the number of interstitial aerosols. I agree. But, in these conditions, one crystal leaves several aerosols. The impact on the crystal number concentration may be not negligible."

Reply:

It has been recognized that a transition layer exits on the surface of ice crystals (e.g. Flechter, 1973). Once a particle gets attached to this quasi-liquid layer, particles should not get released due to surface tension forces.

Nevertheless there exists a possibility that ice crystals leave more than one particle behind that is due to crystal break-up during cloud evaporation. It is known that crystals may break up in a sub-saturated environments (Dong et al., 1992). This effect is most pronounced for dendritic crystals, and less pronounced for needles and columns. For plates this effect is non-existent and in general the break-up due to evaporation decreases with decreasing crystal size. This process would be most important for clouds with temperatures above 250 K.

Since the observations used in this study where made below 235 K and ice crystals were typically small, ice crystal break during evaporation is not likely to be an important process.

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References:

Dong, Y., Oraltay, R.G., and J. Hallet. Ice break-up during evaporation. Proceedings of the 11th Intenational Conference on Clouds and Precipitation. Vol. 1. 5-8. 1992.

Fletcher, N. H., The surface of ice, in Physics and Chemistry of Ice, edited by E. Whalley, S. J. Jones, and L. W. Gold, pp. 132-136, Royal Society of Canada, Ottawa, 1973.

3. Aerosol production in the CVI probe?

Reviewer:

"Second, an interesting explanation of the result is that crystal evaporation may produce new aerosols (end of paragraph 4 and paragraph 5). Is it possible that, when crystal evaporate in CVI probe, aerosols are produced with a similar process? Then in this case the crystal concentration is probably overestimated by the interpretation of CVI data."

Reply:

In the discussion of Figure 10 in the article we suggested that two possible explanations. One was that evaporating clouds may be associated with a source of aerosol particles. Based on this the reviewer speculates if it is possible that when crystals evaporate in the CVI probe, aerosols are produced with a similar process.

Clearly, the conditions in the CVI cannot be compared with the conditions in evaporating cirrus clouds for various reasons:

a) The CVI inertially separates crystals larger than about 5 μm and smaller than about 60 μm (aerodynamic size) from the surrounding air into a warm, dry and particle free sample air flow. The carrier gas is nitrogen. For this reason the humidity in the sample line is significant lower than in evaporating clouds.

b) For the same reasons the sample air does not contain any ambient condensable vapors.

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c) The kinetics of producing particles of detectable size within the CVI from condensable gases is too slow. The time between a crystal first enters the probe until the residual is sensed by the CPC is ca. 4 seconds? In the ambient environment it could take the clouds hours to evaporate.

d) The sample is covered from sunlight, why photochemistry is not active.

In conclusion particle formation within the CVI-probe appears therefore to be unlikely.

4. Deriving crystal number density from the FSSP-300 measurements

Reviewer:

“Why FSSP-300 measurements have not been directly used to derive ice crystal concentrations?”

Reply:

The reason is simply that the FSSP-300 is not sensitive enough to observe thin cirrus (low number densities). The dynamic range of the CVI is two order of magnitudes larger than the range of the FSSP.

Interactive comment on Atmos. Chem. Phys. Discuss., 3, 3625, 2003.