Atmos. Chem. Phys. Discuss., 7, S2479–S2482, 2007
www.atmos-chem-phys-discuss.net/7/S2479/2007/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aircraft measurements of microphysical properties of subvisible cirrus in the tropical tropopause layer" *by* R. P. Lawson et al.

R. P. Lawson et al.

Received and published: 18 June 2007

Large Particles: Reviewers #2 and #3 both question the significance of 2D-S and CPI measurements of the largest (i.e., $>$ 100 micron) particles. Both reviewers also call into question the significance of comparing our measurements with the 1973 measurements of Heymsfield (1986). Reviewer #3 states that there is a dearth of measurements and a difference in instrumentation between 1973 and 2006, so that there cannot be any special significance attached to the differing results. Our paper does not portend to be a complete climatological study of the TTL in the tropics. However, the WB-57F did cover 1800 km in most every direction from San Jose, Costa Rica, and this equates to about 100,000 L of air sampled by one channel of the 2D-S probe on the WB-57F. This is a substantial amount of sampling. The fact that only 18 ice particles $>$

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100 microns were observed suggests that these large particles are very rare, but this is not the same as a dearth of measurements. If there were more of these large particles the 2D-S probe would have seen them, so the measurements of low concentrations of large particles are significant. The significance of reporting that these large particles exist is mainly relative to water vapor measurements and the companion paper by Jensen et al. (2007). The point is that there is strong evidence that some large ($>$ 100 microns) particles are observed near the top of the TTL, and that this requires high values of water vapor, according to Jensen et al. (2007).

Particle Shape: Reviewers #2 and #3 both comment on our comparisons of the shapes of the particles reported by Heymsfield (1986) and in our study. Heymsfield (1986) report that the particles were mostly columnar and trigonal. If this were the case in our data set, then the CPI would have observed this, instead of finding that 84% of the particles are quasi-spherical. Reviewer #2 points out that the few replicator photos shown in Heymsfield (1986) may not be representative of the data set, and could be the result of human bias for selecting symmetric and interesting crystal shapes. We cannot comment on what Heymsfield decided to show in his paper, but the text does state that the composition was approximately 50/50 columnar and trigonal. Since our measurements of over 8,000 particles show a predominance of quasi-spherical particles, this is a significant difference from the 1973 measurements and needs to be noted. We do not suggest that possible differences in TTL chemistry and water vapor from 1973 to 2006 are responsible, only that these differences may exist.

Radiative Significance of SVC: We state in the Abstract that SVC clouds have been shown to have a significant impact on the earth radiation budget. Reviewer #2 points out that "significant" is not well defined, or defended our article. We agree and have changed the abstract to read: "Some studies suggest that SVC have a significant impact on the earth radiation budget." Later in the text we quote results from the literature. Reviewer #3 feels that we overstate the radiative implications of the McFarquhar et al. (2000) calculations. We have rewritten this portion so that it is clear that we are only quoting McFarquhar et al. and not exaggerating the radiative significance.

Photos of SVC, WB-57F and Instruments: According to Reviewer #3, the caption of Fig. 1 states that the photo of the WB-57F was taken during the ferry flight. However, this statement is in error as the caption actually states that the photo of the WB-57F was taken before the instruments were installed for the ferry flight. Regarding the photo of the instruments in Fig. 2, this is not advertising. The instruments are shown installed on the WB-57F so that readers can visualize the instruments and installations to discern for themselves if sampling issues may exist, such as airflow or crystal shattering.

2D-S Sample Volume, CPI and Small Particle Measurement Uncertainty: A JTech paper (Lawson et al. 2006) that describes the instrument response of the 2D-S and its response to small particles is referenced in several places in this manuscript. The reviewer seems to casually dismiss the significant time response advantage of the 2D-S, which allows it to measure particles from 10 to 100 microns that are undersampled or missed altogether by other digital imaging probes. Since the 2D-S can reliably image particles with 10 micron pixel resolution, the “donuts” can be re-sized. We use Korolev’s technique and show that this appears to improve particle sizing. We also reference Korolev’s paper that describes the technique in detail. The Lawson et al. (2006) paper describes the technique used to define the depth of field (i.e. effective sample volume) for small particles (i.e., DOF = 8 r2/l). It would be repetitious and outside the scope of this paper to repeat this information in detail. However, to satisfy the reviewer’s concerns, we have added a few sentences that briefly explain how sample volume is computed, and also give representative values for 50 and [3] 100 micron particles. Sampling statistics can easily be computed from this Information. We also present a detailed uncertainty analysis of particle sizing errors in the Appendices. This is germane to the water vapor measurements and the companion paper by Jensen et al. (2007). Analysis of particles in the “overlap” region of the 2D-S (i.e., the stereo region) is an ongoing task that is requiring considerable software development and analysis. Once completed, it is anticipated that this will further improve the quantifica-

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tion of sample volume for small particles. As shown in the Appendix, the error in CPI particle size measurement is considerably less than the 2D-S, but the CPI is a triggered instrument, while the 2D-S runs continuously, unless it goes into overload, which didn't happen in the low SVC particle concentrations.

"The Korolev algorithm corrects for the size but it also provide the distance of the "donut" from the center of focus, i.e. "donuts" corrected to a diameter of 50 um has a different sample volume than 50 micron in-focus particles. Were the concentrations calculated taking this into account?" YES

How are SVC defined in these measurements? How was the extinction calculated? As stated in the manuscript, the presence of SVC was "detected" using the CPI, which defined the physical boundaries of SVC encountered by the C-130. Because the CPI was operational on every SVC flight, this optimized the definition of physical boundaries of SVC encountered by the WB-57F. Also, as explained in the manuscript, quantitative 2D-S measurements of SVC were when the average 2D-S particle concentration was $>$ 5 L-1 for 5-km or greater without a containing continuous period of clear air (2D-S concentration $<$ 0.01 L-1) that was 1-km or greater. The methods for calculating extinction, IWC and effective radius are now explained in the text.

What is unusual about the particle chemistry? The PALMS instrument has certainly measured sulfate and organic carbon in mid-latitude ice crystals. In Fig. 6 shown in Murphy et al. (2006), one sees that sulfates and organics predominate in the TTL and barely show up in the mid-latitudes at 10 km.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 6255, 2007.