New Insight For In Situ Quantification Of Cirrus

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SUMMARY

A key component of cirrus quantification is in-situ observations using meteorological aircraft. Instruments used for single cirrus crystal quantification can be classified grossly as operating by impaction of crystals on a substrate, or by optical scattering and imaging methods with no impaction. Impactors include the relatively well developed formvar replicator, and a cloudscope currently under development. The replicator provides casts of ice crystals that have impacted on a 16 mm substrate coated with a formvar solution, upon subsequent evaporation of the solvent. The cloudscope utilizes a portable video-microscope to view a 3 mm diameter sapphire window heated by the adiabatic compression of the flow at the stagnation point. Ice crystals impact on the window and sublimate. In conditions of sufficiently low crystal concentration, cloudscope video can be used to generate size distributions, and potentially to estimate crystal mass from the time for sublimation.

Data from two non-impactor instruments will be discussed. These optical instruments provide raw data that is much easier to reduce than the impactor data. First, the forward scattering spectrometer probe (FSSP) is considered. The FSSP captures light scattered in a narrow cone surrounding the forward scattering direction. This scattered light is converted into an equivalent water sphere by use of prior calibration using Mie scattering theory for spheres. The response of the FSSP to small (< 50 μm) randomly oriented ice crystals could be computed based on geometrical optics, though the crystal shape and orientation would have to be known by some other means. Given that FSSP data is readily available from many prior and future field projects, an obvious question is this: Is the FSSP data useful for cirrus? A second optical instrument is the 2DC optical array probe that images particles using a one dimensional diode array slaved to the aircraft speed to provide two dimensional images of ice crystals. If a particle in the 2DC laser beam lowers the power received at a diode by more than 50%, the time/space pixel associated with this diode reports a logical on. Otherwise, it is off (a 4 level optical array probe is also available). Diffraction by particles in the beam complicates the theoretical evaluation of instrument response.

The main point of this summary is to compare carefully analyzed data from these four instruments (Fig. 1). It is argued that the cloudscope and FSSP size spectra have some regions of

overlap, but also some regions of disagreement, and that in their overlapping size bins, the replicator and 2DC agree well, within the limits of Poisson counting statistics. The replicator apparently did not capture all incident particles having maximum dimensions below about 60 microns. Some images from the replicator are shown in Fig. 2. This data is from the unusual cirrus cloud associated with remnants of hurricane Nora (for more cases, see the following URL).
http://www.dri.edu/Projects/replica/DOE.ARM/doearm97iop/09_26_97case/09_26_97case.html
Many other examples of cirrus particle spectra and images can be viewed at the web site,
http://www/dri.edu/Projects/replica.

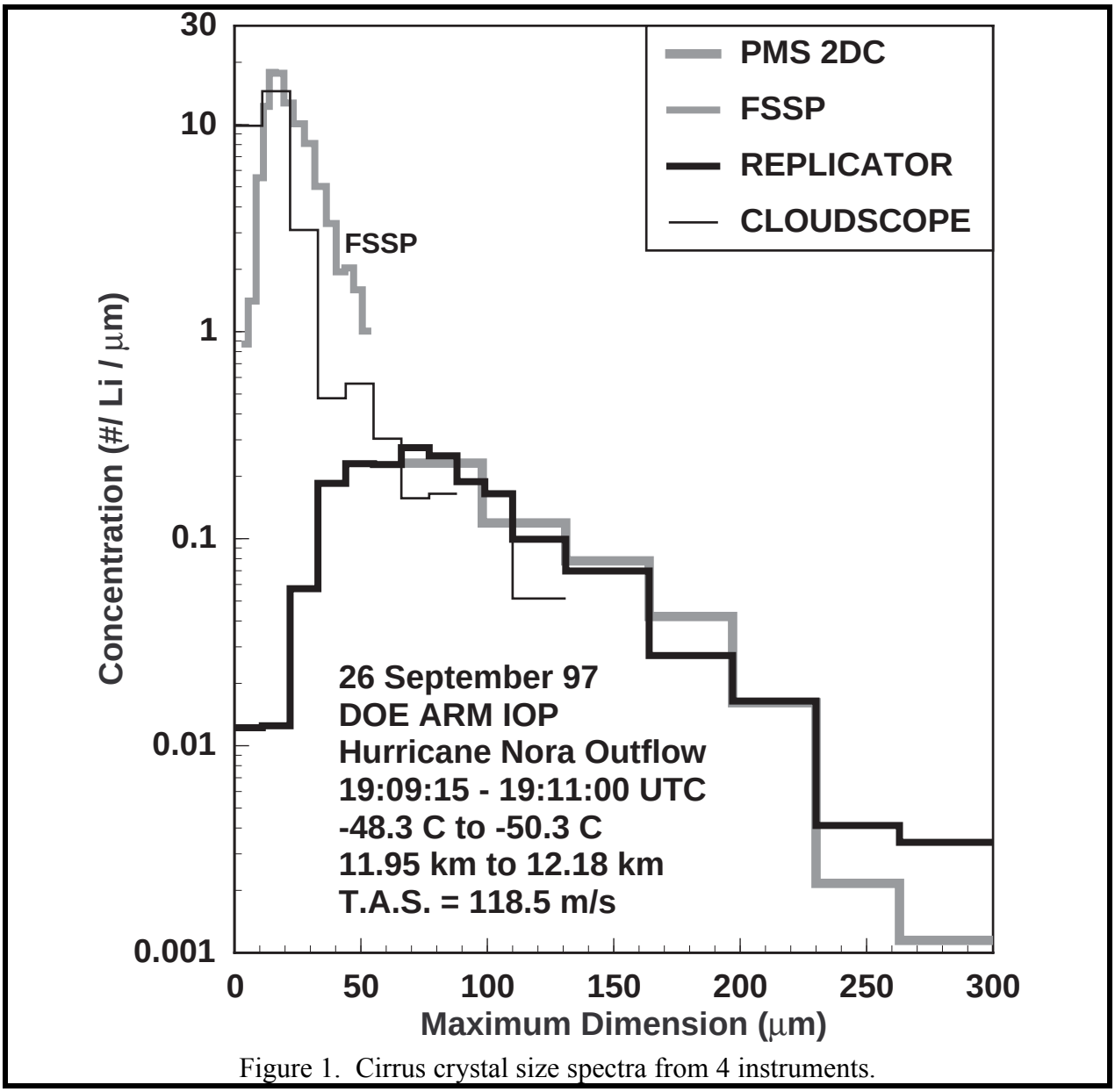

Figure 1. Cirrus crystal size spectra from 4 instruments.

It is very dangerous to draw conclusions from one data set, and the comparison presented in this summary should be considered part of an ongoing story. For example, many examples of poor and decent agreement between replicator and 2DC data can be found in the above mentioned URLs. However, given the dire need for cirrus information, and the great cost of field projects, it is perhaps most noteworthy that the FSSP data is in reasonable agreeement with the cloudscope result. While the FSSP has been criticized for malfunctioning in mixed phased clouds where large crystals are present, it is hard to conceive of large crystals influencing the FSSP response when their concentration is so low that the probability of the FSSP sampling them is neglibile (sample rates for the data above are: 0.21 L/s, replicator; 0.014 L/s, cloudscope; 1.25 to 5.94, ave. 3.83 L/s, 2DC; and 0.016 to 0.17, ave. 0.041 L/s, FSSP.) The data was obtained for a cloud path length of 12.4 km. The cloud was non-uniform over this path length.

Figure 2. Ice crystals obtained from the formvar replicator during the time of figure 1. This case had an anomalously high concentration of optically perfect ice crystals compared with usual cirrus. Note the exaggerated hexagonal symmetry of the crystal in the lower left.