Comments on "Cloud Droplet Coalescence: Statistical Foundations and a One-Dimensional Sedimentation Model"

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Warshaw (1967) has claimed that the usual kinetic equation for cloud droplet growth by coalescence treats only the average behavior of droplets and not the deviations from it. This conclusion is erroneous. It was shown previously in this JOURNAL (Scott, 1967) that the function used to describe the mean number of particles in a differential range of particle volume dv is also the probability of there being one particle in such a range, so that knowledge of this function obtained by solutions of the coalescence equation includes the probability of deviations from average behavior. What is not contained in such knowledge is information on correlations, which as Warshaw indicated, may play a role if very small fractions of a cloud are sampled.

Warshaw's own paper contains evidence for the above conclusion. If, in his Eq. (2.4), one takes $Kt \ll 1$, one finds that the probability of one collision between a size r and a size ρ droplet occurring in t is closely equal to $N(r)\Delta r N(\rho)\Delta\rho Kt$, the probability of more than one collision being negligible. This makes sense as a probability if it is seen as the product of a) the probability that there is one droplet in r to $r+dr$; b) the uncorrelated probability that there also is one droplet in ρ to $\rho+\Delta\rho$; and c) the probability $P(r,\rho,t)$ that given the two, they collide within t. The fact that his Eq. (2.5) gives the mean collision rate as the derivative of this probability bears out the assertion above relating means and probabilities for densities of distribution.

Figs. 1, 2 and 3 of Warshaw's paper illustrate well the $\nu^{-\frac{1}{2}}$ law of Poisson statistics, which as shown in the earlier paper (Scott, 1967) are almost certainly valid if any reasonable volume of cloud is sampled.

Warshaw's lengthy effort to average out the random function $N(r)dr$ and obtain an equation for $\bar{N}(r)$ does not appear to be meaningful. In the first place, he does not really use $N(r)dr$ as a random function, because he treats it as continuous and differentiable. In fact, the function for which (2.8) is written is just the expectation E_N of the random variable, so that the averaging operation he appears to carry out has already been done in writing (2.8). Strictly then, his kinetic equation (2.17) is identical in content with his (2.8).

A more explicit demonstration that solutions to the kinetic coalescence equation contain the probabilities of all possible histories of droplet growth, and not just their average behavior, will be presented in a later publication.

REFERENCES

Scott, W. T., 1967: Poisson statistics in distributions of coalescing droplets. *J. Atmos. Sci.*, **24**, 221–225.

Warshaw, M., 1967: Cloud droplet coalescence: Statistical foundations and a one-dimensional sedimentation model. *J. Atmos. Sci.*, **24**, 228–286.