Reply

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Gokhale and Rao have stated that the growth calculations in Musil (1970) are seriously in error. They have even gone so far as to specify a certain programming mistake; namely, the substitution of updraft speed for terminal speed in the growth equation as the source of the error which is asserted to exist. The computer program used to simulate hailstone growth in the feeder cloud model has been reviewed carefully and we find that terminal speed *was used correctly* in the growth equation as shown in (A6) of the Appendix. Hence, the results and conclusions stand.

The objection of Gokhale and Rao to Musil's results may stem from the fact that his model permits some hailstones to grow and fall out of the cloud without ever rising above the updraft maximum, a situation not encompassed by their recently proposed hailstorm model (Gokhale and Rao, 1969). They imply that the calculations of Ludlam (1958) and Srivastava and Atlas (1969) preclude such a hailstone history. While examination of the cited papers shows that growth and fallout below the updraft maximum can occur if sufficiently large embryos are introduced, the predominant tendency for embryos to be carried above the updraft maximum, and indeed above the supercooled region of the cloud in these earlier models before achieving precipitation size, is readily admitted. The occurrence of echo-weak vaults in actual clouds is usually considered to be due to such a process. However, it was precisely the tendency for this to occur in steady-state models which led us to develop the feeder cloud model,

which is a time-dependent model with initially weak updrafts. Obviously, the results of Ludlam and of Srivastava and Atlas would have been different if they had used a time-dependent model.

In addition it should be noted that Srivastava and Atlas introduced embryos 3 km above cloud base, rather than at cloud base. Musil's (1970) results show this difference can be crucial to the embryos' subsequent trajectories. The fates of embryos introduced 3 km above base in the feeder cloud model after it approaches steady state are much the same as those of the Srivastava and Atlas embryos.

As the times required to grow hailstones in the feeder cloud model (20–40 min) are comparable to those derived elsewhere and to times required in actual clouds, and we have found no error in the computer program used to derive hailstone growth rates and hailstone trajectories, the assertions by Gokhale and Rao are rejected.

REFERENCES

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