"REVIEWED"

REPLY

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Berthoumieu and Morgan (hereafter BM) have raised a question about our previous paper (Henderson, et al; 1998 hereafter HWN) in which we suggested the observed graupel and hail production may have a consequence of seeding a cumulus cloud with pyrotechnic generated hygroscopic salts. BM argues that the described case is actually a heuristic demonstration of the effectiveness of the hygroscopic material in reducing damaging hail. BM continues with a description of the principal hypothesis of which most hail prevention cloud seeding programs have been performed over many years; "namely the generation, usually by seeding with ice forming nuclei such as silver iodide, of large concentrations of graupel and small hail, to create a condition of beneficial competition". We thank BM for their insights to hail formation and growth, including a refresher on the seeding hypothesis, as well as a few preliminary thoughts in regards their field observations of seeding cases.

First, beginning with one of our operational hail suppression programs in the mid-1970's, we essentially abandoned any further mention of "beneficial competition", particularly any reference to the intended generation of large concentrations of graupel and small hail as BM suggests. Instead, we chose to reference our hypothesis as "limiting supercooled liquid water (LSLW)". We have continued this reference since that time. The difference between "beneficial competition and "LSLW" is subtle but extremely important to the field of operational hail suppression, and quite likely to the scientific community as well.

The fundamental ingredient of *primary* concern in our hail reduction hypothesis is not hail embryos, but rather the actual concentration of supercooled liquid water within that specific cloud volume which allows the birth and growth of hailstones. Additionally, there is still considerable uncertainty within the scientific community as to whether or not silver iodide actually enhances the production of hail embryos, or simply produces billions of very tiny ice crystals from the supercooled liquid cloud droplets. These tiny ice crystals are not good hail embryos.

The admission of any intentional production of hail embryos such as graupel, frozen droplets, and small hail, raises a specter (a BM word choice) extremely unfavorable to the operational hail suppression community. Because supercooled liquid water is the fundamental requirement for the formation and growth of hailstones, attempts to limit this ingredient can only enhance the concept of less and smaller hail at ground level. The admitted artificial production of hailstone embryos is counter-productive and, in our view, unnecessary for the development of an acceptable hail suppression hypothesis.

Second, our described single seeding event was not associated with a field research program. Rather, it was one of several thousand seeding events within our operational precipitation enhancement programs conducted mostly, but not exclusively, with silver iodide. Within those silver iodide seeding events focused on orographic cumulus cells, it is rare to observe graupel or small hail falling at the same elevations as noted in the summarized case.

One of our very important concerns within the hail suppression community is that, in many large hail producing cumulus clouds, the intentional production of hail embryos may be insufficient to actually decrease average hail sizes at ground level *enough* to significantly decrease crop damage. Often in agricultural areas, the most damaging hail comes from high concentrations of smaller hailstones driven by wind, rather than a much lower concentration of very large hailstones. Intentionally increasing hail embryos is a scary thought.

In their Comment, BM proceeds with some of their interesting observations of seeded events in France, Italy and South Africa. They are important observations and we appreciate their inclusion. Additionally, we strongly support their plan to proceed with "cloud-physical" measurements in 1999 as part of a flare-seeded program in northeastern Italy. We look forward to summaries of their observations, further cloud physics measurements, and the apparent results from the applications of hygroscopic seeding materials by the BM and JFB groups.