

Cirrus Cloud Seeding as a Trigger for Storm Development

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During the summer of 1966 The University of Chicago cloud physics group succeeded in documenting a type of precipitation system which develops as a direct result of cirrus seeding of supercooled clouds at middle levels. Long suspected as a source of ice crystals that could seed lower clouds, cirrus now take on added importance as a result of two separate findings: 1) airplane collections of cirrus crystals which have survived as much as 17,000 ft of clear air descent, and 2) observations that a field of disordered, chaotic, middle-level convective clouds can be organized by cirrus seeding into a single direct cell of considerable magnitude, obviously as a result of enhanced vertical motions following the release of heat of fusion.

The importance of seeding of middle clouds can be brought out by the following argument. A fundamental requirement for the formation of precipitation in any appreciable amount is an upcurrent of considerable vertical extent. What processes can bring about such an upcurrent?

In non-orographic situations, a root cause of convection is thermal instability resulting from differential heating (or cooling) at the bottom (or top) of a deep atmospheric layer. In tropical and subtropical regions, especially over land in summer, heating of the surface by solar radiation commonly produces thermal instability sufficient to initiate convective clouds and thunderstorms.

In more northerly latitudes thermal instability in the lowest layers of the atmosphere appears less frequently, but instability at middle cloud levels, as a result of differential temperature advection, is quite common. This middle level instability is usually indi-

cated by altocumulus, altocumulus castellanus, and patchy altostratus clouds.

However, as any practicing forecaster knows, thermal instability alone is not sufficient to insure vigorous convective cloud development. It is necessary, in addition, to have some means for organizing the convection elements into a few major centers, otherwise the instability is dissipated through weak, disordered convective clouds. It is at this point that cirrus cloud seeding plays an important role.

On several occasions during the summer of 1966, while studying middle level clouds from The University of Chicago's cloud physics airplane, I observed the development of a major precipitation system just at the point where ice crystal tails from cirrus uncinus dipped into a region of disordered supercooled middle level cloudiness. The role of the cirrus appears to be that of providing sufficient crystals to ice-out the supercooled middle cloud. The released heat of fusion in a local area then enhances the convective motions in that area and provides a stimulus for organizing the instability available over a much larger area.

In the cases studied, there was a gradual consolidation of the altocumulus castellanus and thickening of the associated layer clouds (altostratus and stratocumulus) at the point where the cirrus trail reached the supercooled middle clouds. At the same time the cloud bases gradually lowered. In one case the initial base of the altostratus-altocumulus was 17,000 ft MSL; after the seeding began the cloud bases gradually lowered to 10,000 ft.

These cirrus seeded storms are capable of producing moderate to heavy rain, and not infrequently they

develop into a full-fledged thunderstorm. The lifetimes of these storms appear not to depend upon continuous cirrus seeding; once the instability is channeled into a single well organized center, that center continues as a self propagating storm for several hours.

A total of eight such storms were documented with the cloud physics airplane during the summer of 1966. The measurements are mostly in the form of a series of stepdown passes between 20,000 and 6,000 ft from which we can construct vertical cross sections of cloud and precipitation parameters. Ground level RHI radar data and surface rain gauge measurements are also available for these cases. In addition, the same kinds of data were obtained on five other cases of this type storm during the 1965 operations, although the all-important role of the cirrus was not recognized at the time the 1965 data were taken.

In assessing the overall importance of these observations, one questions immediately the frequency with which cirrus crystals survive a clear air descent from cirrus to middle cloud levels in numbers sufficient to cause middle cloud glaciation. In an effort to provide a partial answer to this question a series of flights was conducted in clear air below cirrus clouds for the express purpose of collecting and measuring the concentration of any cirrus crystals that might be present. Collections were made with the Cloud Physics Laboratory cloud particle replicator. This replicator operates on the principle of encapsulating cloud particles in a continuously moving film of Formvar plastic.

On each of six different days beneath visible cirrus clouds we found cirrus crystals which had survived thousands of feet of fall in clear air in concentrations entirely adequate for seeding lower clouds. In the best

case so far analyzed we found cirrus crystal concentrations, in small areas, as high as 10^6 m^{-3} at 18,000 ft MSL, temperature -10C , on a day when cirrus clouds were forming at 35,000 ft and the cloud free intervening air showed a 20C temperature dew-point spread on a nearby radiosonde.

There can be no question but that natural cirrus crystals can, at least on occasion, survive a clear air fall down almost to the freezing level. It is not surprising then that they could initiate storm development by seeding an unstable middle layer.

There seems to be no doubt but that these storms which were observed visually and measured with the instrumented airplane are closely related to the winter storms studied by McGill University and Air Force Cambridge Research Laboratory scientists during the late 1950's. In a series of papers these scientists clearly describe the radar echo properties of what they called "generating cells and snow trails." [See papers by Plank *et al.* (1955), Douglas *et al.* (1957) and Marshall and Gordon (1957).] The University of Chicago measurements now extend the importance of the cirrus generating cell and show that cirrus seeding plays a causative role in the development of many summer rain storms at least in those latitudes where middle level instability is common.

REFERENCES

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