Toward an Empirical Definition of Virga: Comments on "Is Virga Rain that Evaporates before Reaching the Ground?"

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Traditionally, *virga* has been viewed simply as falling ice or water particles that have failed to reach the ground. According to the definitive *Petersen Field Guide Series* (Schaefer and Day 1981), virga is "falling precipitation, usually ice, that evaporates before reaching the ground." Similarly, the *World Meteorological Organization International Cloud Atlas* (1956) defines virga as "vertical or inclined trails of precipitation (fallstreaks) attached to the under surface of a cloud, which do not reach the earth's surface." Hydrometeor evaporation is a natural consequence of descent through drier subcloud air, although under conditions in which the precipitation processes are very active or prolonged (thereby moisturizing the subcloud environment), virga particles can reach the ground, thereby producing *precipitation.* We accept these definitions, which are demonstrable through remote-sensing measurements using radar or lidar. Take, for example, the remotely observed progression of winter mountain synoptic storms (Sassen et al. 1990). Typically, a thickening, primarily ice-phase overcast generates virga that gradually approaches ground level. The instant those surviving ice particles reach the surface, the virga is transformed into precipitation that begins to accumulate on the ground. The views espoused by Fraser and Bohren (1992, hereafter FB) regarding the nature of virga, however, leave us only two narrow definitions for virga. They are that virga is either what has long been recognized as a visual radar brightband analog (Vonnegut and Moore 1960; Sassen 1977) or a precipitation shaft "that has not yet reached (rather than does not reach) the ground." Indeed, one gets the impression from FB that the traditional virga definition can rightly be inverted to say that *virga always reaches the ground.*

In considering the occurrence of virga in connection with summer convective clouds (as in FB), it is clear that the survival of hydrometeor shafts depends on such diverse factors as the rainfall intensity and duration, the height above ground of the cloud base and freezing level, and the aridity of the subcloud environment. Under some conditions microbursts can occur below the cloud, and it is interesting to note that numerical simulations have shown that, despite the evaporatively driven downdrafts, raindrops associated with microbursts do not necessarily reach the surface (Krueger and Wakimoto 1985). Under other conditions, visual bright bands [analogous to the lidar bright bands described by Sassen (1977)] can be observed under high cloud-base thunderstorms, as is shown in Fig. 1. This telephoto view of a thunderstorm forming over mountainous terrain depicts a number of interesting lighting effects. Note that the cumulus cloud base at the top of the image is illuminated from below by sunlight reflecting off the surface of the Great Salt Lake (visible at bottom right). The storm at this stage is producing light rainshowers on the mountain slopes, although only virga is readily apparent in the photograph. Thus, this is a classic example of a visual radar brightband analog, in which the only indication of rain reaching the surface is seen at right because of direct illumination in shafts of sunlight. However, it is also revealed that virga (which has not yet or may never reach the ground) is also present just to the right of the rain shaft.

When precipitating clouds are viewed by active remote sensors, such distinctions are made much clearer than when relying on the naked eye. For example, microwave radars are quite capable of detecting subvisual virga and rainfall (e.g., Wakimoto and Martner 1992). Similarly, polarization lidar studies show that supercooled droplet clouds like altocumulus commonly produce virga that is invisible except under favorable, oblique lighting conditions. Referring to a recent review of polarization lidar cloud measurements, we point to Fig. 10 of Sassen (1991) as a typical example of visually undetected ice virga extending approximately 2 km below a supercooled altocumulus layer before completely evaporating. Nor is virga necessarily a mixed ice- and water-phase phenomenon, since Figs. 3 and 13 of Sassen (1991) show virga composed of drizzle drops below marine cloud bases that were formed by the droplet coalescence precipitation mechanism. And what of pure ice-phase virga? According to FB, "by

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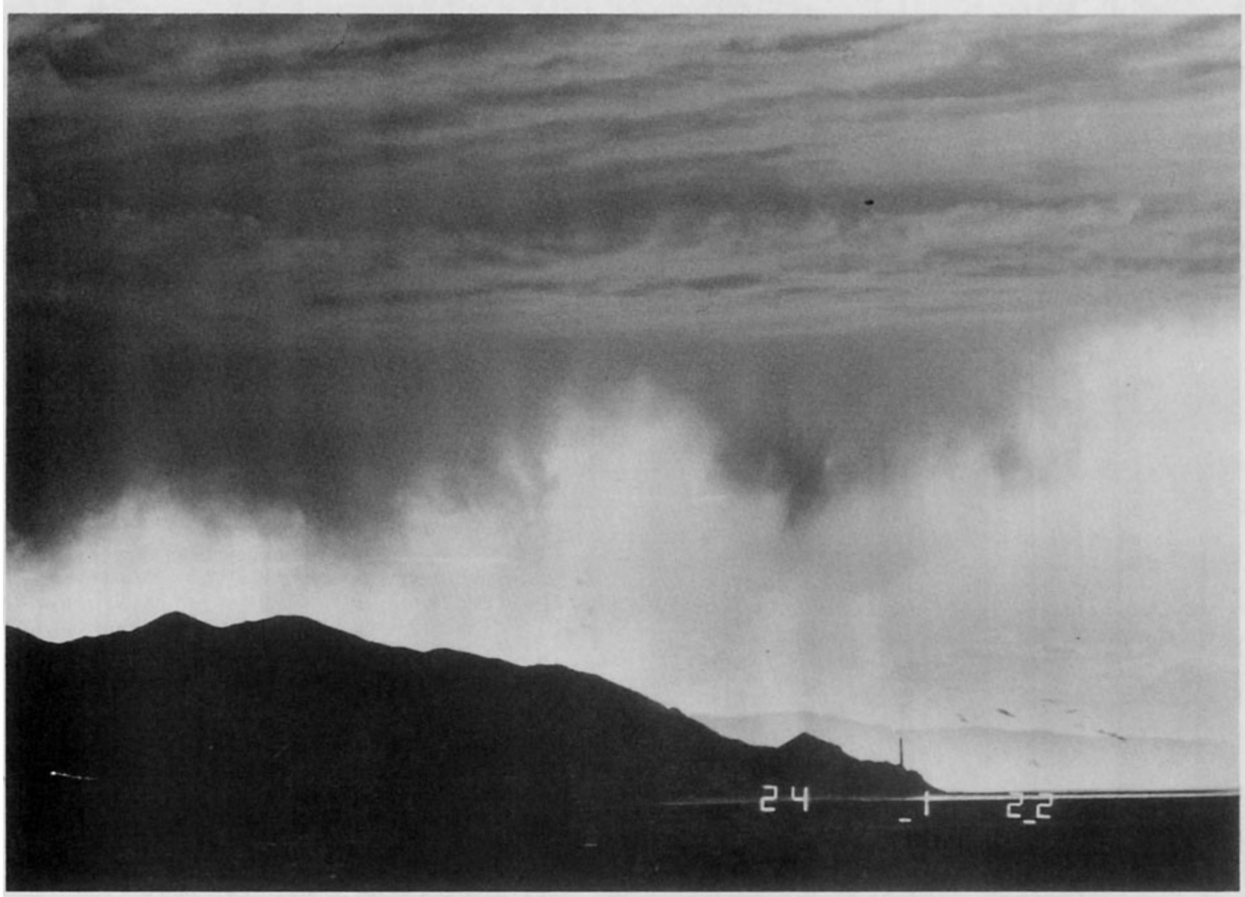

FIG. 1. Telephoto view (taken at 0122 UTC 24 August 1991) of a developing thunderstorm that is producing a visual radar brightband analog from melting snow below the cloud base. The sunlit region to the right illuminates both rainfall reaching the ground and virga, which otherwise would not be visible. Scale is provided by the approximately 370-m-high smokestack at the tip of the Oquirrah Range of northern Utah.

virga we do not mean fallstreaks." Again, remote sensing observations indicate the contrary, as is shown in Fig. 2. In this startling high-resolution view of virga, the cirrus uncinus cell heads generating the curved crystal fallstreaks are apparently composed of a mixture of homogeneously freezing haze particles and ice crystals (Sassen 1992).

The reason that such mechanisms were ignored by FB seems to be the unfortunate definition of virga they adopted—"by virga we mean a sudden change in brightness of a precipitation shaft below a cloud." *Brightness* is a vague quantity dependent on what part of the electromagnetic spectrum we are probing with. Clearly FB refer to the visual perception of contrast as the key criterion, which depends on a number of factors such as sun angle and background illumination. In essence, however, their definition is akin to the "tree falling in the wilderness" argument, for is virga sensed at other wavelengths really there? Moreover, one may ask if the "cloud" referred to by FB has to be a liquid convective cloud, or would an ice-phase cirrocumulus cell qualify?

Toward a more expansive, empirically based definition of virga, let us acknowledge that virga is the result of a variety of colloidal cloud microphysical processes that lead to the production of a gravitationally unstable subset of larger particles (i.e., some stochastically favored particles fall out of the cloud). Thus, virga can in the most general sense be defined as a collection of hydrometeors that in having attained sufficient fall velocity to precipitate out of the generating layer or cell, evaporate while finding unfavorable growth conditions below. Although precipitation processes are by their very nature episodic, if they are sufficiently long-lived we agree with FB that at some point virga may evolve into rain or snow. This is a correct deduction, as is the suggestion by FB that virga is probably often incorrectly identified because of various factors related to visual observations.[1] Nonetheless, in

[1] Trained meteorological technicians, however, are taught the distinction between virga and RWU, which as I remember, stands for distant rainshowers, intensity unknown.

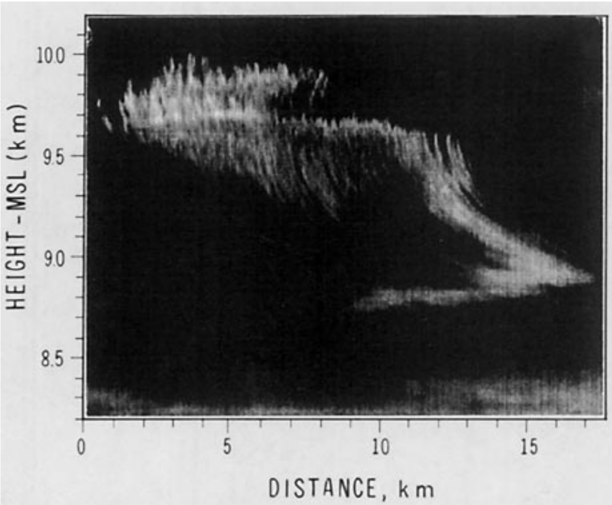

FIG. 2. A complex of cirrus uncinus cells (between −40° and −45°C) measured during the recent FIRE IFO II experiment are shown in this display of range-normalized, returned laser (0.532 μm) power. The numerous ice-crystal fallstreaks illustrate the very common occurrence of virga in cirrus clouds. The length of the zenith lidar data record used to construct this image is 400 s, where time has been converted to distance on the basis of the mean cirrus wind speed.

limiting themselves to a type of virga that admittedly has been erroneously popularized [see, e.g., the "virga" photographs in Schaefer and Day (1981)], FB have provided a misleading view of virga that ignores a variety of cloud microphysical processes and the potential of modern remote sensing instrumentation for elucidating the nature of precipitating clouds. We assert that the quantitative capabilities of remote sensors must be taken into consideration to provide the rationale for discriminating between virga and precipitation on the basis of traditional definitions.

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