Importance of Including Time in the Specification of Ice Nucleus Concentrations

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It is generally recognized that the number of ice crystals that will be nucleated by foreign particles in a supercooled cloud is dependent not only on temperature, but also on time (Vonnegut, 1948; Vonnegut, 1949; Turnbull, 1950; Fletcher, 1958; Warburton and Heffernan, 1963; Isaac, et al., 1972; Schaller and Fukuta, 1979; Baldwin and Vonnegut, 1982; DeMott et al., 1983; Wang and Vonnegut, 1984). Notwithstanding, in most measurements of ice nucleus concentrations, such as those recently reported by Bowdle et al. (1985), only the supercooling, or supersaturation with respect to ice, is specified. In accordance with the prevailing custom, no information is provided concerning the *time* that the particles were exposed to supersaturated conditions.

In the case of measurements made at low temperatures on fast acting nuclei, such as silver iodide particles, this failure to specify time may have some justification, for practically all of the particles will serve as nuclei during even a brief exposure in a supercooled cloud. According to Langer and Rodgers (1975), whose technique was used, at −20°C the silver iodide particles acted to nucleate ice crystals "immediately." This is consistent with Vonnegut's (1949) estimate that at this temperature half of the silver iodide particles present will initiate ice crystal formation every few seconds.

On the other hand, the time of exposure cannot be neglected when measurements are made at higher temperatures and much longer intervals may be required for a particle to initiate ice formation. In this case the time interval required for nucleation may be much greater than the time of the test. For example, even silver iodide, which acts faster than most atmospheric nuclei, has been estimated to have a half life as long as hours at −13°C and days at −10°C (Vonnegut, 1949). When the half life is long, the fraction of particles that forms ice crystals over a period of an hour or more in a natural cloud may be many times larger than the fraction that acts in the brief time involved in many nucleation determinations. Failure to take this into consideration may be one of the several reasons that the concentration of ice crystals in a supercooled cloud is sometimes larger than the measured concentration of ice forming nuclei (Mossop, 1985).

Evidently, comparisons between the concentration of ice crystals in a supercooled cloud and the measured concentration of ice nuclei are valid only if the times of exposure as well as the temperatures are equivalent. It is desirable that Bowdle et al., and others who report measurements of ice nucleus concentrations, supply not only the temperature and supersaturation to which the nuclei were exposed, but also the time. This will provide some indication of the natural conditions for which their measurements are relevant.

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