NOTES

Nucleation of Ice Crystals in Supercooled Clouds Caused by Passage of an Airplane

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In recent papers Rangno and Hobbs (1983, 1984) have made the interesting and important observation that the passage of an airplane through a supercooled cloud can produce significant increases in the concentration of ice crystals. In discussions of the mechanisms that might be responsible for this effect they have considered various possibilities: particles in the engine exhaust might serve as ice forming nuclei, aircraft icing might cause ice splinter production, and, as suggested by Vonnegut (1948) and Ludlum (1958), cooling produced by adiabatic expansion of the air disturbed by the aircraft might increase the rate of ice crystal nucleation.

It is possible to make semiquantitative estimates concerning the last of these mechanisms on the basis of observations that have been made of the cooling produced in the center of a vortex generated by aircraft motion and also of the increase in nucleation rate that would result from such a decrease in temperature. Measurements made from an airplane with a thermometer mounted in the axis of a cylindrical, vortex-creating housing (Vonnegut, 1950) serve as the basis for estimating the magnitude of the cooling that might result in the vortices produced at the tips of the wings or propeller blades. These observations show that in the axis of the vortex the temperature can drop almost as much below ambient as it rises in the stagnation region. It was found up to the maximum speed of the airplane (125 m s^{-1}) that the temperature change in the vortex ΔT is given by $\Delta T = -3.5 \times 10^{-4} V^2$, where T is in degrees centigrade, and V is the true air speed in meters per second. An extrapolation based on this relation indicates that at the tips of propeller blades where the velocities are greatest—approaching or even exceeding the speed of sound (332 m s^{-1})—the temperature in a vortex conceivably might drop by as much as 35°C. In the light of Schaefer's observation (1946) that very rapid formation of ice crystals occurs in a supercooled cloud at temperatures below −39°C, it appears conceivable that the rate of ice crystal formation in the vortices might be sufficiently large to explain the increases in ice crystal concentrations observed by Rangno and Hobbs (1983, 1984) at ambient temperatures of about −10°C.

There are questions, however, whether the foregoing assumption is correct: that the temperature lowering produced by the tip of a propeller is of the same order as that which has been estimated from measurements made with the vortex-creating housing. The temperature drop will of course depend not only on the speed of the propeller blade, but also on other factors, such as the aerodynamic characteristics of the blade and its angle of attack.

It should be possible by experiment to see if aerodynamic cooling is playing a significant role when nucleation results from the passage of an airplane. This can be done by investigating the effect produced by changing the engine speed during aircraft penetrations. If aerodynamic cooling is important, the rate of ice crystal production should rise dramatically with increases in the tip speed of the propeller. This would be expected according to this mechanism, for the temperature in the vortex should drop in proportion to the square of the tip speed, and the rate of nucleation should increase by as much as a factor of 5 for each degree that the temperature drops (Wang and Vonnegut, 1984).

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