Cirrus Cloud and Climate Modifications due to Subsonic Aircraft Exhaust

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NASA has recently initiated a program to evaluate the potential effects of current and future commercial aircraft fleets on atmospheric chemical processes and climate. As part of this program, we are modeling the effects of subsonic aircraft exhaust on upper tropospheric cirrus clouds. Using sophisticated computer programs, we have developed a detailed ice cloud microphysical model here at NASA Ames Research Center. The model simulates cloud processes such as ice crystal formation, growth, and transport. The formation and evolution of aircraft-generated contrails is simulated to determine what processes and environmental conditions control the growth, spreading, and dissipation of contrails. In addition, the formation of natural cirrus is simulated with and without aircraft exhaust soot particles to predict the impact of commercial air traffic on the frequency of cirrus occurrence and their impact on climate.

Recent observations of cirrus clouds have shown that clear air in the upper troposphere is often supersaturated with ice. Cirrus do not always form in these regions due to the lack of natural nuclei to provide a foundation on which ice crystals form. If aircraft exhaust soot particles are efficient ice nuclei (as shown in Fig. 1) , then the frequency of cirrus may be significantly enhanced in regions with heavy air traffic (see Fig. 2) . As a result, the aircraft exhaust may increase the frequency of cirrus occurrence and increase the number of ice crystals in cirrus. As cirrus clouds absorb infrared radiation emitted by the Earth's surface and reflect sunlight, changes in cirrus properties would produce heating of the upper troposphere and cooling at the surface. Also, precipitation of cirrus ice crystals removes upper tropospheric water vapor. Because water vapor is a very important greenhouse gas, changes in cirrus and the upper tropospheric water vapor budget due to aircraft exhaust may substantially influence climate.

Currently, the properties of soot generated by aircraft exhaust are not well understood. We do not know how effective these particles are as ice nuclei. We are using our cirrus cloud microphysical model to simulate the impact of soot particles on cirrus cloud frequency and climate for a wide range of assumptions about the soot properties. We are evaluating these effects for a range of environmental conditions, including cirrus anvils generated by strong convective storms and thin cirrus generated in fair-weather conditions. A final determination of the exhaust impact on cirrus and climate will require aircraft observations of natural and anthropogenic upper tropospheric particles, laboratory studies of ice nucleation on soot particles, and numerical modeling of the formation of cirrus altered by

exhaust soot particles.

Figure 2. Image courtesy of Steve Baughcum (Boeing Aircraft Co.), Don Maiden (Langley Research Center), and M. Metwally (McDonnell-Douglas Aircraft).

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