# Will the SST Pollute the Stratosphere?

The beleaguered supersonic transport received repast on 28 May when Congress appropriated—by a 14-vote margin—another $290 million for prototype development, but the project is still being attacked on several fronts. An environmental issue that has been intensifying in recent weeks is the question of whether exhaust products added to the stratosphere by the SST could produce significant environmental changes.

Statements on this issue range from that of Russell Train, Chairman of the White House Council on Environmental Quality, who testified on 12 May that the SST could have "serious consequences on climate," to that of the Department of Transportation that none of the charges have "any substantial basis in fact."

The information that is available to evaluate this issue is a detailed knowledge of the exhaust products of the SST and a general knowledge of the composition and dynamics of the stratosphere. During each hour of flight at cruising altitude (in the lower part of the stratosphere at 16 to 22 kilometers) the SST's will burn an estimated 66 tons of fuel. From this they will produce about 83 tons of water, 72 tons of carbon dioxide, and approximately 4 tons each of carbon monoxide and nitric oxide.

Most meteorologists agree that gaseous exhaust products other than water will present no special problems, although not enough is known about gas exchange in the stratosphere to completely rule out the possibility that stable layers of these gases would form. Water is more likely to be a problem because stratospheric water concentrations are generally low as the result of condensation in the troposphere. If water added directly to the stratosphere accumulates, it could (i) directly change the radiation balance of the earth, (ii) initiate cloud formation and thus increase the amount of solar energy reflected into space, or (iii) lead to a decrease in the ozone concentration of the stratosphere thereby allowing more ultraviolet radiation to reach the earth's surface (*1*).

The rate of injection of water vapor into the stratosphere from expected SST flights "is similar to that brought about by atmospheric motion" (*2*). In order to determine the behavior of water once it is injected, Lester Machta of the Air Resources Laboratory of the Environmental Science Services Administration (ESSA) has developed a dynamic model of the stratosphere. He assumes 500 SST's will fly each day, that the mean residence time of water vapor is 1½ years (this figure is based on measurements of radioactive elements injected into the stratosphere during nuclear tests), and that most flights will be in a band from 45° to 60°N. His calculations based on this model predict that water vapor in this limited region would increase from 3 ppm to 5 ppm and that natural circulation forces and changes in temperature would reestablish equlibrium at 5 ppm.

Using another stratospheric model, Syukuro Manabe (Geophysical Fluid Dynamics Laboratory, ESSA) has calculated that the water vapor increase predicted by Machta would cause a decrease of 1.5°C in the stratosphere temperature by radiating heat into space and an increase of 0.6°C in the temperature at sea level, as a result of the greenhouse effect. Both models are based on imprecise knowledge and contain simplifications, but Machta's model contains more uncertainties because so little is known about stratospheric dynamics. In view of these uncertainties Machta was unwilling to rule out the possibility that even higher water vapor concentrations could accumulate.

The role of the stratospheric ozone layer in shielding living organisms from much of the sun's ultraviolet radiation has long been known, and therefore the suggestion made several years ago that increased water vapor levels could decrease the ozone concentration generated considerable interest. The reactions, which involve the photochemical decomposition of water and the subsequent reduction of ozone to molecular oxygen, have been observed in the laboratory and can be used to explain measured ozone, oxygen, and water vapor abundances in the stratosphere.

Julius London (University of Colorado), who is working on computer models of ozone behavior told *Science* that, although many reactions are possible, conditions in the stratosphere are such that they are not likely to take place as the result of SST flights. One model showed that water vapor concentrations of 10 ppm would have little effect on ozone concentration. In addition, the photochemical reaction is most efficient at altitudes above the proposed SST flight, but it is thought that the vertical stability of the stratosphere would prevent significant mixing at these altitudes.

The question of whether clouds could form in certain regions of the stratosphere could probably be answered by direct observation. In the 1950's theoretical work and observations of military aircraft provided much information about conditions necessary for cloud formation.

Herbert Appleman (Scott Air Base), who set up the studies and directed the evaluation of the results, has concluded on the basis of these studies that the few clouds formed in proposed SST flight paths would produce no serious climatic changes (*3*).

There are, however, extremely cold areas at an altitude of about 17 kilometers in the tropical tropopause and high above the Arctic and Antarctic that are thought to be saturated. Because of the saturation, these are potential cloud-forming areas, but no predictions can be made on the basis of Appleman's work because humidity values are not well enough known. Present instruments do not work well below about −40°C, and even the supposition that the areas are saturated is based primarily on temperature measurements. No research flights have been made in these areas; thus there is not enough information available to predict whether persistent clouds will form or not.—VIRGINIA D. NUESSLE and ROBERT W. HOLCOMB

### References


1. In 1966 the National Academy of Sciences reported on "Effects of Supersonic Transport Aircraft on the Stratosphere" and concluded that there would probably be no ill effects [*Weather and Climate Modification—Problems and Prospects* (National Academy of Sciences—National Research Council, Publ. No. 1350, Washington, D.C., 1966), vol. 2, pp. 97–99]. This report has not closed the matter because new values for water vapor accumulation have been obtained, and the report did not include the problems of ozone diminution and cloud formation in very cold regions.
2. R. E. Newell, *Nature* **226**, 70 (1970).
3. H. Appleman, *Mtg. Amer. Meteorol. Soc. Amer. Inst. Aeronaut. Astronaut.*, March 1966, paper No. 66-369.