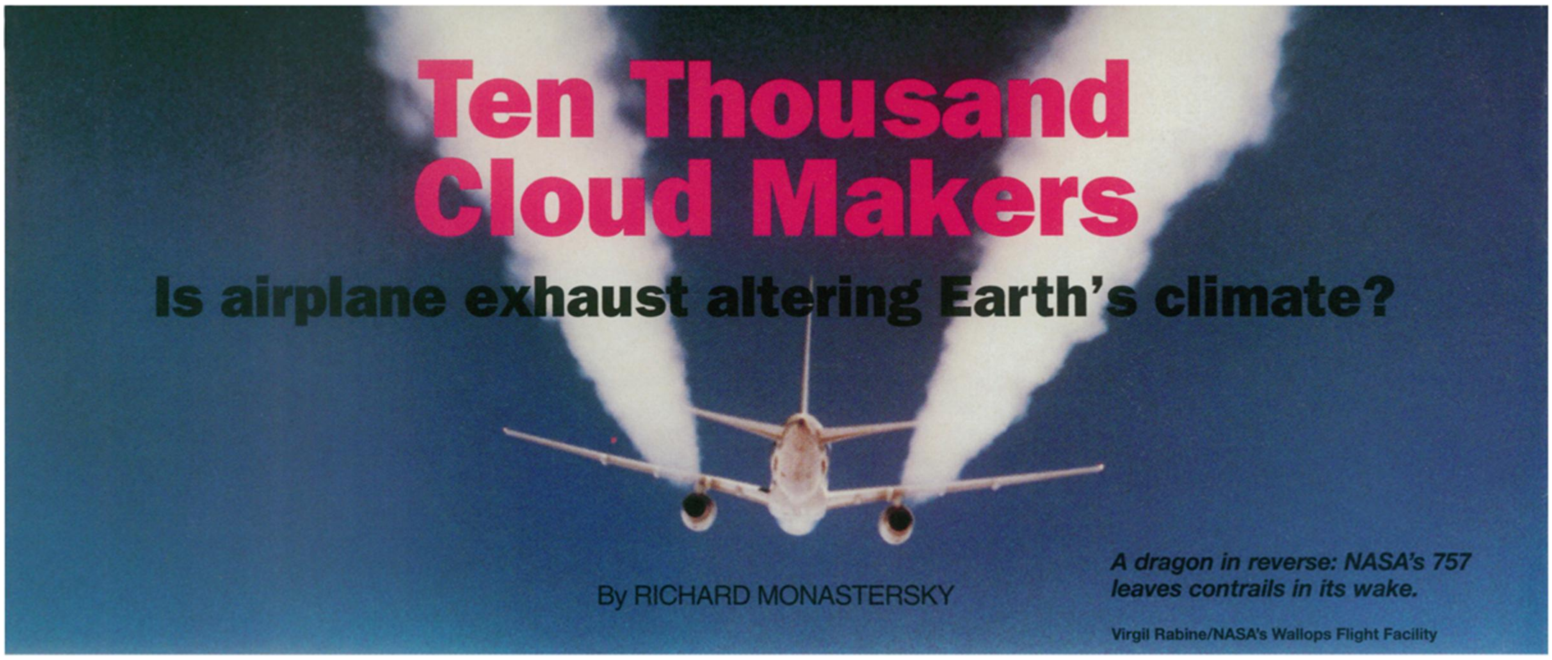
Ten Thousand Cloud Makers

Is airplane exhaust altering Earth's climate?



By RICHARD MONASTERSKY

A dragon in reverse: NASA's 757 leaves contrails in its wake.

Virgil Rabine/NASA's Wallops Flight Facility

When the small Saberliner jet carrying Bruce E. Anderson rolled almost completely upside down, the atmospheric scientist saw his dessert, rather than his life, pass before his eyes.

Seconds earlier, the NASA researcher had been munching on some cookies when his plane entered the wake of a DC-8 jet just a few miles ahead. The backwash—a tight horizontal tornado whirling at more than 100 miles per hour—spun the light Saberliner 140° and sent it into a dive, causing Anderson, his food, and everything else in the plane to go temporarily weightless.

"It seemed like forever," says Anderson, an atmospheric scientist at NASA's Langley Research Center in Hampton, Va., "but it was probably only 5 or 10 seconds before the pilots righted the plane and were back in control." Then they nosed up behind the DC-8 for some more punishment.

Although it sounds like military flight training, Anderson and his colleagues were actually conducting a high-tech emissions check—measuring the gases and particles spewing out of jet engines. Their mission resembles the pollution tests that states routinely perform on cars, except that the NASA-run experiment happened at 400 miles per hour, 40,000 feet above the ground. And whereas car emissions are well understood, scientists have little information on the pollution from jet engines. Toward that end, NASA gathered four planes and 120 scientists in Kansas during April and May to make the most detailed measurements yet of jet engine exhaust at cruising altitude.

This project and future ones are addressing the question of whether aircraft emissions are increasing the number of clouds and are perturbing atmospheric chemistry—both of which could affect the weather down on the ground, says project scientist Randall R. Friedl of NASA headquarters in Washington, D.C.

"There are 10,000 large-size commercial aircraft in operation today. It's expected that this number will double by the year 2020. It's a natural question to ask whether these are having an environmental impact," says Friedl.

Fueling this investigation are several sketchy studies hinting that ground temperatures have shifted in the last few decades in regions beneath well-traveled jet routes. "There is some concern that aircraft may play a role in some of the changes that have been seen," notes Friedl.

Although commercial jets have been sailing through the skies since the 1950s, scientists have only just started wondering about their widespread effects on the atmosphere. NASA launched its environmental investigation of subsonic aircraft 2 years ago and plans to continue the $140 million program through 2001. European researchers began similar studies in 1992 and are running a project parallel to the NASA work.

Anderson may have lost his snack during the recent experiment in Kansas, but he can count himself fortunate. So many scientists on board another of NASA's research planes lost their lunch when their DC-8 entered the wake of a Boeing 757 that they ran out of air-sickness bags. Yet all but one of the 40 investigators climbed back on board for the next flight.

Like an airborne bloodhound, the DC-8 tracked the chemical scent left by the 757, enabling investigators to measure exhaust plumes at distances of up to 10 miles. The nimble Saberliner could approach planes much closer, at times tagging only 150 feet behind the larger jets to sample fresh emissions immediately after they had left the engines. From above, a high-flying ER-2 plane surveyed the scene and measured the optical properties of the exhaust.

In flights over the central United States, the Rocky Mountains, and the Pacific Ocean, the NASA team measured emissions of sulfur and soot, with the aim of understanding how these affect high-altitude clouds. The scientists also analyzed the makeup of condensation trails, or contrails, those long, straight clouds often created by jets. NASA, ever eager for a catchy acronym, labeled the mission SUCCESS, for Subsonic Aircraft: Contrail and Cloud Effects Special Study.

Contrails develop when hot, humid fumes from a jet engine meet the cool air of the upper troposphere. Water vapor in the exhaust and atmosphere freezes to create tiny cloud particles, much like the mist that forms when a person exhales on a cold winter day. As turbulence in the upper atmosphere tears contrails apart, they can spread into wispy sheets essentially identical to natural cirrus clouds.

Engines can also stimulate cloud growth indirectly, by way of tiny aerosol particles within the exhaust. These aerosols—droplets of sulfuric acid and specks of soot—serve as seeds. They provide surfaces upon which water molecules can condense or freeze to create cloud particles, explains Eric J. Jensen, a participant in SUCCESS and a researcher at NASA's Ames Research Center in Mountain View, Calif.

Scientists do not know the fate of the aerosols once they leave the back end of a jet engine and start mixing with the ambient air. The specks and droplets may be among the ingredients necessary for creating contrails. They may also thicken natural cirrus clouds, rendering them more opaque to sunlight and making them last longer.

In fact, so little is known about the clouds produced by aircraft exhaust that researchers cannot say whether, on balance, they cool or warm the climate.

The uncertainty exists because high-altitude clouds have numerous and contrary effects. Contrails and cirrus help cool the globe by reflecting sunlight that would otherwise hit Earth's surface. At the same time, they exert a warming influence because they absorb infrared radiation emitted by the ground, thus trapping energy and heating the atmosphere.

By studying what happens to engine exhaust immediately after it leaves the plane, SUCCESS aims to reveal how sulfuric acid and soot alter clouds. Although participants in the project are only now beginning to sift through the data, the sulfuric acid measurements have already shown some surprises.

Previous engine tests conducted on the ground had suggested that most of the sulfur emitted by jets comes out as gaseous sulfur dioxide, with less than 1 percent in the form of sulfuric acid. But SUCCESS observations made at cruising altitude indicate that at least 10 percent of the sulfur in the exhaust appears as sulfuric acid droplets, making jet pollution an efficient producer of clouds. These results confirm observations from 1994, when 15 minutes after the supersonic Concorde passed, the ER-2 flew through its wake (SN: 10/7/95, p. 229).

The recent SUCCESS measurements made right behind jet engines reveal that the sulfuric acid forms either within the engine or immediately after it is ejected, says Anderson.

S. Changnon

Multiple contrails high over the Midwest.

What this observation means for clouds and climate remains unclear. Yet many meteorologists think that increasing jet traffic in the last several decades has altered weather in noticeable ways.

In 1981, climatologist Stanley A. Changnon of the Illinois State Water Survey in Champaign reported that the Midwest had grown significantly cloudier during the 1960s and 1970s, with the greatest changes seen in areas of high jet traffic. He also noted a narrowing of the gap between high and low temperatures, possibly attributable to the increase in clouds.

More recently, Kuo-Nan Liou, an atmospheric physicist at the University of Utah in Salt Lake City, examined changes in high clouds. He found a 5 to 10 percent increase in cirrus cover over Salt Lake City, Denver, Chicago, St. Louis, and several other cities between 1948 and 1984. "Statistically, the high-level clouds appear to be increasing. So we speculate that there might be some potential relationship between aircraft activities and these high-level cloud increases," says Liou.

According to David J. Travis, a climatologist at the University of Wisconsin-Whitewater, who studies contrails, "there is a lot of circumstantial evidence that contrails are probably having an effect."

Travis and Changnon are collaborating in an attempt to document how contrails tweak climate. Because the artificial clouds trap heat predominantly at night, when they do not reflect sunlight, the researchers posit that contrails could be responsible for a trend toward reduced differences between daytime and nighttime temperatures, observed in the United States and elsewhere.

European researchers have also detected signs of the influence of aircraft, says Ulrich Schumann of the DLR Institute in Oberpfaffenhofen, Germany. "There are certainly obvious indications that aircraft cause additional cloudiness regionally, say over mid-Europe and some parts of the United States. There is no doubt about that," says Schumann. "But whether this is just a minor change or whether it is an essential change is absolutely an open question."

Because so many factors influence weather, scientists have had a difficult time determining what effect—if any—aircraft have actually had on conditions at Earth's surface. "People have looked for changes in sunshine duration and for changes in temperature. Some of these results are suggestive, but none are conclusive. There are too many other possibilities to explain the same observations," Schumann cautions.

While European and U.S. researchers are just starting to tackle the cloud question, they have a longer history of addressing how aviation affects the chemistry of Earth's atmosphere.

Like anything that burns fossil fuel, airplanes emit carbon dioxide gas and thereby contribute to global greenhouse warming. Currently, planes account for only about 3 percent of the carbon dioxide produced by humans, far behind other emitters, such as automobiles. Surging air travel and transport are pushing fuel consumption steeply upward, however, and airplanes may outpace other carbon dioxide sources, especially if countries make good on their promises to limit greenhouse gas emissions.

Planes can also contribute to global warming through emissions of nitrogen oxides, which stimulate ozone formation in the lower level of the atmosphere, called the troposphere.

Ozone is best known for the protective role it plays higher up in the stratosphere, where it blocks out harmful ultraviolet radiation coming from the sun. Close to the ground, ozone is a pollutant that endangers the health of humans and plants; for that reason, the International Civil Aviation Organization sets standards for nitrogen oxide emissions during takeoff and landing.

Yet aircraft spend most of their time and release most of their nitrogen oxides at the top of the troposphere. The ozone produced there is too high to threaten health directly. Instead, its most important effect is as a greenhouse gas that traps thermal energy and may contribute to global warming.

In the future, fleets of supersonic aircraft would have a different influence because they would emit nitrogen oxides and sulfuric acid in the stratosphere, where they trigger chemical reactions that destroy, rather than produce, ozone.

Recent measurements and calculations by European and U.S. researchers indicate that current aircraft are responsible for about half the nitrogen oxides present in the Northern Hemisphere's midlatitudes at an altitude of 26,000 to 40,000 feet, says Schumann.

Studies using computer models suggest that these nitrogen emissions could have boosted tropospheric ozone concentrations by several percent, especially over the heavily traveled North Atlantic. But a 1994 report by the World Meteorological Organization warned that "little confidence should be put in these quantitative model results of subsonic aircraft effects on the atmosphere."

Scientists point to many uncertainties that undermine the reliability of model results. Current models include only some chemical reactions and may be missing important ones. In addition, researchers do not know what quantity of nitrogen oxides comes from other sources, such as lightning. Estimates of lightning's input could be off by several hundred percent, warns Howard L. Wesoky, of NASA headquarters in Washington, D.C.

"We simply don't know quantitatively how significant the effects of aircraft are," says Wesoky.

Driven by this question, researchers plan to head once again into the skies next summer for a NASA-sponsored mission over the North Atlantic. This time, however, they will stock a more generous supply of air-sickness bags. □