The Contrail Effect

by Peter Tyson

INQUIRY

Are vapor trails from aircraft influencing the climate, and if so, should we worry?

I've always *wanted* to hate contrails, the "condensation trails" streaming out from behind jets. They're man-made. They force lines on nature, which knows no lines. They arise out of pollution, and they generate *visual* pollution—aircraft graffiti that can erase blue from the sky and light from the sun. All good reasons to despise these artificial clouds.

But I don't. I've always been drawn to them. When I see one above, I like to run my eye along its length until I find the plane, a tiny silver toy. I like to wonder at the blank space between the plane and the start of the contrail—emptiness full of potential—and then to see the churning new cloud as it forms, a tumbling cascade. When the roiling slows and the newborn cloud settles into a contrail proper, I admire its perfection: a straight white line sharply etched against the blue. Even when numerous contrails made fat by the wind crisscross the sky, I don't mind.

Well, I might now. After a lifetime of enjoying contrails, it came as a surprise to me to learn recently that something so ephemeral may not be a harmless by-product of the jet age but may in fact impact the climate. This is of particular concern in well-traveled air corridors, where contrails by the hundreds can spread into man-made cirrus clouds that can both block sunlight from reaching the Earth and trap radiated heat from escaping to space.

Whether contrails cause a net cooling or a net warming, even whether their effect is something to worry about, remains unclear. But with air traffic expected to double or even triple by 2050, leading contrail researchers say the influence of these artificial clouds cannot be ignored.

Contrails, the man-made clouds left in the wake of jet aircraft, may actually alter climate, though to what degree remains unclear.

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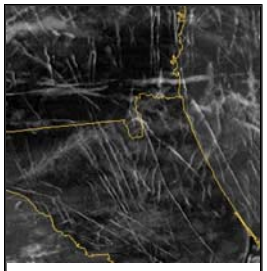
OUT OF THE BLUE

A contrail will form behind a jet if, as exhaust gases cool and mix with surrounding air, the humidity is high enough and the temperature low enough for liquid water to condense. The air needs to be supersaturated and the temperature generally below -40°F, something that typically occurs only in the upper troposphere, the atmospheric layer several miles up where airliners cruise. Under those conditions, water vapor from the jet's exhaust and secondarily from the atmosphere condenses into water droplets. Within a few tens of feet behind the aircraft, these droplets freeze into the snow-white particles that bring the contrail to life.

How long a newly formed condensation trail sticks around depends on the ambient humidity. If humidity is low, contrails will rapidly dissipate, looking like a comet's tail. The ice particles sublimate—meaning go straight from ice to vapor—and you're back to blue sky. If humidity is high, however, contrails can persist—and those are the ones that trouble climatologists.



The sheer number of contrails generated on a typical day in busy air corridors can come as a shock. A NASA satellite took this enhanced infrared image of the southeastern U.S. on January 29, 2004.

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A LINGERING CONCERN

If conditions are right, newly formed contrails will begin feeding off surrounding water vapor. Like vaporous cancers, they start growing and spreading. In time, they can expand horizontally to such an extent that they become indistinguishable from cirrus clouds, those thin, diaphanous sheets often seen way up high. These artificial cirrus clouds can last for many hours, and the amount of sky they end up covering can be astonishing: one study showed that contrails from just six aircraft expanded to shroud some 7,700 square miles.

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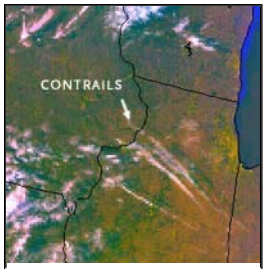

What consequence might these jet-triggered clouds have? Well, most clouds fall into one of two categories. High, thin cirrus clouds are normally warming clouds: they let sunlight through but are good at trapping heat radiating back upwards from the Earth. Low, thick stratus clouds, on the other hand, are typically cooling clouds, because they tend to be more efficient at blocking and reflecting sunlight than they are at trapping radiated heat.

Contrails are initially thick, bright, highly reflective clouds, but over time they morph into wispy cirrus clouds. Are they then warming or cooling clouds?

For a long time, scientists didn't even have a baseline from which to begin to answer that question. Studying contrails has always been difficult: they're high in the sky and either so fleeting that they're gone in minutes or so persistent that dozens or even hundreds can crisscross one another, making the study of individual contrails to get a baseline all but impossible.

In skies normally crosshatched with condensation trails, the only contrails seen in this image from September 12, 2001, were left by the plane returning President Bush to Washington from Nebraska and several escort fighters.

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CONTRAIL HIATUS

At least that was the case until September 11, 2001. For the first time since the jet age began, virtually all aircraft were grounded over the United States for three days. Even as they tried like the rest of us to absorb the enormity of the terrorist attacks, climatologists realized they had an unprecedented opportunity to scrutinize individual contrails, and several studies were quickly launched.

One study looked at the aforementioned contrails that grew to cover 7,700 square miles. Those condensation trails arose in the wake of six military aircraft flying between Virginia and Pennsylvania on September 12, 2001. From those isolated contrails, unmixed as they were with the usual dozens of others, Patrick Minnis, a senior research scientist at NASA's Langely Research Center, and his colleagues were able to gain valuable insight into how a single contrail forms. Those once-in-a-lifetime data sets are so useful that Minnis is about to analyze them again in an expanded study.

In this true-color satellite image shot above northwestern Europe, the contrast between skies with contrails and those without offers a striking sense of the influence these pseudo clouds might have on regional climate.

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Another study that took advantage of the grounding gave striking evidence of what contrails can do. David Travis of the University of Wisconsin-Whitewater and two colleagues measured the difference, over those three contrail-free days, between the highest daytime temperature and the lowest nighttime temperature across the continental U.S. They compared those data with the average range in day-night temperatures for the period 1971-2000, again across the contiguous 48 states. Travis's team discovered that from roughly midday September 11 to midday September 14, the days had become warmer and the nights cooler, with the overall range greater by about two degrees Fahrenheit.

These results suggest that contrails can suppress both daytime highs (by reflecting sunlight back to space) and nighttime lows (by trapping radiated heat). That is, they can be both cooling and warming clouds. But what is the net effect? Do they cool more than they warm, or vice versa? "Well, the assumption is a net warming," Travis says, "but there is a lot of argument still going on about how much of a warming effect they produce."

ONGOING DEBATE

In a study published in 2004, for example, Minnis and colleagues reported that contrails are capable of increasing average surface temperatures sufficiently to account for a warming trend in the U.S. between 1975 and 1994. But some climatologists believe Minnis and his colleagues may have overestimated the contrail warming effect.

Even if Minnis's estimates are correct, other climate experts feel that any warming from contrails is not something to fret about. In a study published in 2005, James Hansen of NASA's Goddard Institute for Space Studies in New York, and colleagues ran models that increased the contrail coverage in Minnis's study by a factor of five. Even with this significant increase, Hansen's team found that global mean temperature change was in the neighborhood of 0.03°C (0.05°F)—a minute amount.

> I too will be looking at contrails with a new eye, a jaundiced one.

"Aircraft are likely to be a significant factor in future climate, but probably not via their contrails," Hansen told me. "I think our main concern about aircraft will be their CO_2 emissions, not contrails, which are a pretty small climate forcing."

Minnis counters that Hansen's model, while on target on the global front, doesn't account as accurately for regional temperature changes. "In zones of greatest air traffic, like between 30° and 50° North, there's a large bulge in the actual increase in temperature that's not reflected in the models," he says. "Until they model that bulge, that thing's still up in the air." For his part, Minnis intends to keep his eye on condensation trails and their aftereffects.

TAKING ACTION

So does Travis, who feels the fact that we can measure a change of *any* sort should be cause for concern. Even a slight alteration of the daily temperature range, for instance, can have repercussions, he says. "To you and I, that may seem like a nice comfortable-sounding scenario—the days are not as hot, the nights are not as cold—but for natural ecosystems, this could be a real problem. For one thing, you need to have extreme

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temperatures to weed out the weaker species—it's classic Darwinism."

For this reason, Travis believes we shouldn't sit by and wait to see what happens with contrails. "Anytime we can see an effect from something artificial like that, I think we want to try to do something about it," he says. The British government, for one, may be about to. It's considering requiring planes to fly at lower altitudes over Great Britain in hopes of promoting fewer contrails.

I too will be looking at contrails with a new eye, a jaundiced one—though I'll admit if they were black as soot, it would be a lot easier. ■

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Peter Tyson is editor in chief of NOVA online.

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