Contrails: a Double Sided Sword?

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Contrails today / Louis Nguyen, NASA Langley Research Center

How contrails form

Contrails are clouds that form in the wake of aircraft. Contrails have been noticed in skies since the 1920s when aircraft first began reaching altitudes cold enough for contrail formation. Although contrails can form under a variety of conditions, nearly all contrails that are seen in the sky are the result of the mixing of the hot, moist exhaust gases of jet aircraft with the cold ambient air. (Like contrails, the cloud that forms on your breath during a cold day is a mixing cloud.)

One remarkable characteristic about mixing clouds is that neither the cold environmental air nor the warm air from the exhaust must be saturated to make a cloud. Thus, contrails can occur in otherwise clear skies. This property has made contrails of interest both to scientists and the military. During World War II, formation flying sometimes produced banks of contrails. Not only did the contrails allow the enemy to spot aircraft easily, reports exist of planes being unable to see targets, and even colliding with other aircraft because of contrails.

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How long they stay

Even though many contrails are short-lived, when the atmosphere is moist enough, the contrails will continue to grow and become persistent contrails. Scientists are most interested in persistent contrails because they form long-lasting and sometimes extensive clouds that would not normally have formed in the atmosphere. Persistent contrails can last for several hours and spread over thousands of square kilometres, becoming indistinguishable from naturally occurring cirrus clouds.

Contribution to climate chance

Clouds are the largest variable controlling Earth's atmospheric temperature and climate. Any change in global cloud cover may contribute to long-term changes in Earth's climate. Contrails, like all clouds and unlike greenhouse gases, affect the radiative balance in the atmosphere both positively and negatively. They reflect some sunlight and can cool the surface slightly during the day, and they also emit thermal infrared radiation that can warm the surface. Overall, for contrails the thermal infrared effect dominates and line-shaped contrails add slightly (a bit less than 1%) to the total man-made radiative heating. Because predicted increases in air-traffic could result in a continued increase in cloud cover, knowledge of when and where contrails form is important for determining their contribution to cirrus cloud cover and their effect on climate.

Besides contrails, global aviation is expected to produce other effects on climate. Aircraft produce a number of radiatively important gases when they burn fuel, including carbon dioxide (CO_2) and nitrogen oxides (NOx).

At present, global aviation accounts for approximately 2% of the man-made CO_2 emissions (and thus approximately 2% of the man-made CO_2 radiative warming). The NOx interact chemically with other gases in the atmosphere to produce ozone (adding to the warming) and to remove some methane (decreasing the radiative warming). Aircraft also emit other gases such as sulphates and water vapour, but their effect on the radiative balance is expected to be much smaller than CO_2.

Radiative effects

Adding all of the factors together (including contrails), the total radiative forcing from global aviation is expected to be on the order of 3% of the total radiative forcing derived from all anthropogenic-based sources. The uncertainty in present estimates is large, and thus aviation forcing may range from 2 to 8 percent of man-made forcing. Also, as global air travel increases, these radiative effects should increase as well. These estimates are based on observations of the direct climatic effect of the line-shaped contrails we can see in satellite imagery. Additional uncertainties arise when we try to estimate the coverage of cirrus clouds that are produced or modified by persistent contrails under certain atmospheric conditions. Another potentially important unknown is the impact of aircraft-produced soot particles that could act as ice nuclei in the air traffic corridors. Ice nuclei are often uncommon at these altitudes, so that soot particles could have a large impact on the coverage and nature of cirrus clouds.

Photo credit: Wikipedia

Propeller contrails during World War II

Solutions?

In principle, it may be possible to selectively minimize the creation of late afternoon contrail-induced cloudiness that will persist during the night, when they would have a net warming effect, while intentionally increasing the formation of contrails early in the day, generating a daytime cooling. Current research is focused on accurately predicting the times and locations at which contrails are likely to persist for long periods of time and spread over wide areas as contrail-induced cirrus. Such information could help mitigate the negative effects of aviation on regional and global climate by incorporating it into operational air traffic control and routing systems.

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