

# CONTRAILS FACT SHEET

## Summary

This fact sheet describes the formation, occurrence, and effects of condensation trails or “contrails.” It was developed by scientific and regulatory experts at the Environmental Protection Agency (EPA), the Federal Aviation Administration (FAA), and the National Oceanic and Atmospheric Administration (NOAA) in response to public inquiries regarding aircraft contrails.

Contrails are line-shaped clouds that sometimes form behind jet airplanes at cruise altitudes. Contrails tend to be most common and persistent in the sky during periods when there is high moisture content in the atmosphere. Contrails are composed primarily of water (in the form of ice crystals) and do not pose direct health risks to humans. They do, however, affect the cloudiness of the Earth’s atmosphere. The basic processes of contrail formation described in this fact sheet apply to any jet airplane.



[epa.gov/contrails](https://epa.gov/contrails)

[faa.gov/contrails](https://faa.gov/contrails)

## What are Contrails?

Contrails, short for condensation trails, are line-shaped clouds produced by an airplane’s hot engine exhaust interacting with cold humid air several miles above the Earth’s surface. Depending on the temperature and the amount of moisture in the air, contrails may evaporate within minutes (if the humidity is low) or persist for hours (if the humidity is high). Persistent contrails are of interest to scientists because they increase the cloudiness of the atmosphere and if around long enough, can form aviation-induced cirrus clouds.



# How do Contrails Form?

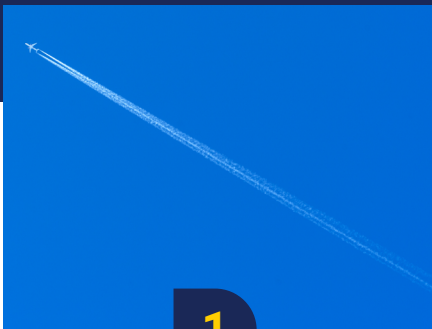
Contrails form when hot, humid air from an airplane exhaust mixes with low temperature air in the upper atmosphere. If the atmosphere is cold and humid enough, the engine exhaust will cause the water vapor to condense onto fine particles, forming water droplets. These water droplets quickly freeze into ice crystals, creating a visible contrail. Since air temperatures at these high atmospheric levels are very cold (as cold as  $-70^{\circ}\text{F}$ ), only a small amount of humidity is necessary for condensation to occur. Water and particles are byproducts of combustion, which mix with the already present particles and water vapor in the upper atmosphere to create a visible trail of ice crystals.

Just as, how you can sometimes see your breath on a cold day, contrail visibility and persistence depend upon the temperature and humidity of the air at altitude. Some contrails develop into longer-lasting, persistent contrails and diffuse into contrail cirrus clouds. Contrail cirrus persistence depends on atmospheric conditions and the airplane's engine exhaust composition, which is impacted by engine combustion technology and fuel chemistry. In the United States, contrails can form at any time throughout the year; however, they are most likely to form and persist when the atmosphere is cold and humid. Contrails will not form if the air at the airplane's altitude is too warm or too dry. Note that the humidity at ground can differ greatly in comparison with humidity in the upper atmosphere.

Contrails can be generally classified into three types<sup>1</sup>:

1

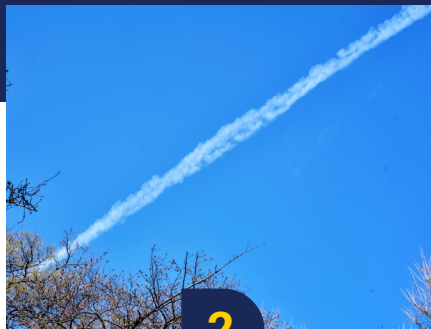
## Short-Lived Contrails



**Short-lived contrails**, as their name implies, disappear within seconds-to-minutes of their formation under low humidity conditions. Newly formed ice particles will quickly evaporate as exhaust gases are completely mixed into the surrounding atmosphere.

2

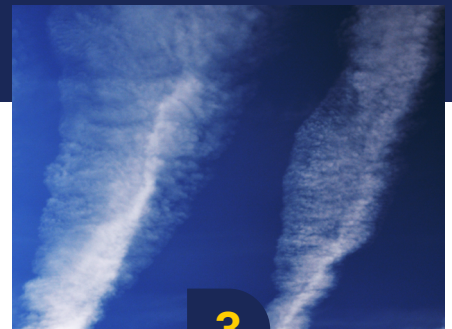
## Persistent Non-Spreading Contrail



A **persistent non-spreading contrail** forms when the air is extremely humid and will stay in the sky long after the airplane has flown out of sight. It can last for a few minutes or longer than a day. If a contrail is formed in a region of the atmosphere with low windshear, it can maintain its shape of a thin line for many hours.

3

## Persistent Spreading Contrail Cirrus<sup>2</sup>



**Persistent contrails** form in extremely humid regions of the atmosphere and can last for hours-to-days. Newly formed ice particles will continue to grow by taking water from the surrounding atmosphere. The resulting line-shaped contrail extends behind an airplane. If contrails persist for a long enough time in a region of the atmosphere with high windshear, they can spread across the sky due to the prevailing winds at the level at which they formed.

<sup>1</sup> <https://scied.ucar.edu/image/three-types-contrails>

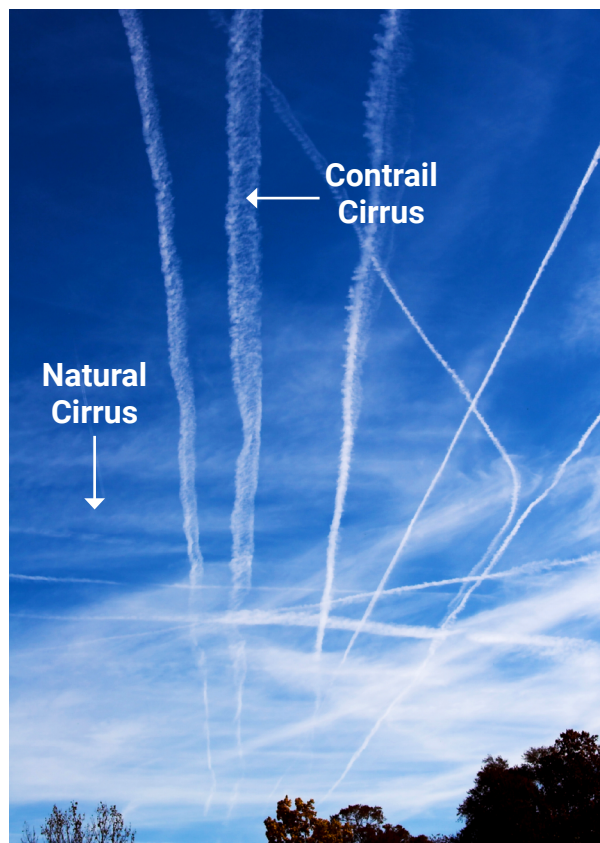
<sup>2</sup> <https://www.weather.gov/fgz/CloudsContrails>



# Persistent Contrails

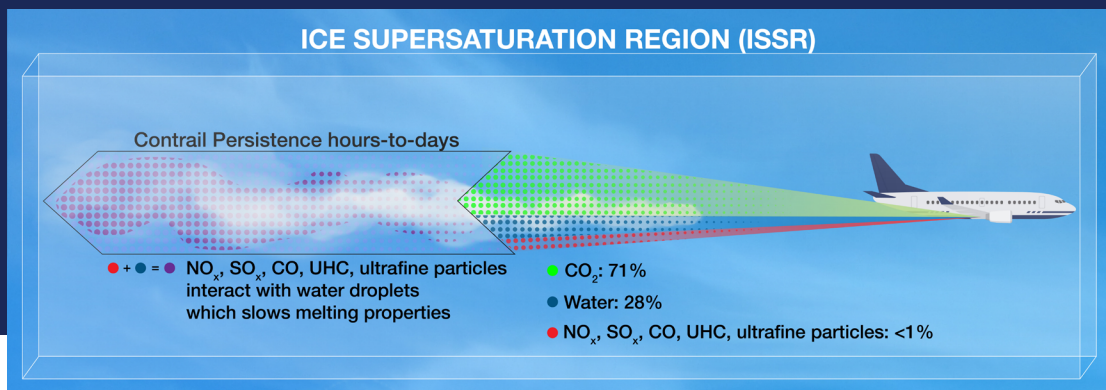
Recently formed persistent contrails can be easily identified from the ground and satellites as being formed from aviation activity. However, if contrails persist long enough to widen and spread, it becomes difficult to distinguish them from naturally occurring cirrus clouds. This also means that sometimes natural cirrus clouds can be mistaken for contrails when viewed from the ground or from satellite imagery when they have formed patterns such as parallel lines.

Atmospheric temperature and humidity at any given location undergo natural daily and seasonal variations. This means that conditions at a specific location in the atmosphere are not always suitable for the formation of contrails. As an airplane flies in and out of areas conducive to contrail formation (known as ice supersaturation regions or ISSR), the contrail can appear to start or stop abruptly. This is entirely due to changes in the natural atmospheric state and not to changes in the aircraft exhaust.



## How are Airplane Engine Emissions Linked to Contrail Formation and Persistence?

Airplane engines produce similar combustion-related emissions as cars and trucks. Airplane engine exhaust is composed of 71% carbon dioxide and 28% water vapor. The exhaust also contains less than 1% of other combustion products such as sulfur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), unburned hydrocarbons (HCs), and particulate matter (PM – aka soot particles). As the hot exhaust plume cools, water vapor released in the engine exhaust condenses onto fine particles (either existing in the atmosphere or from the engine exhaust) which grow and freeze to form the ice crystals visible as contrails. Because naturally occurring fine particles are found throughout the atmosphere, only the addition of water vapor in the engine exhaust is required to form a contrail. Additionally, the presence of SO<sub>x</sub> and unburned hydrocarbons in engine exhaust can slow the melting of the ice crystals and contribute to contrail persistence.



Note, at ground level, engine exhaust pollutants like SO<sub>x</sub>, NO<sub>x</sub>, CO, UHC, and soot particles can pose human health concerns. This is why EPA, FAA, and other Federal agencies collaborate on research and standards development to protect the health of our communities.

# Why are Persistent Contrails of Interest to Scientists?

It has been estimated that in certain flight corridors, cloud cover has increased by as much as 20 percent.<sup>3</sup> Additional research is needed to improve scientific understanding of contrail formation and persistence. This research will help determine ways to avoid or mitigate persistent contrail formation. Advanced airplane engine technologies, new aviation fuel formulations, and operational re-routing may aid in contrail mitigation. More research is needed to find the best ways to strategically deploy these capabilities across the aviation sector in the near-, mid-, and long-term.

The FAA, along with other Government agencies, have complementary ongoing research programs to improve our understanding of how combustion of jet fuel contributes to persistent contrails in the atmosphere. The U.S. government, in partnership with industry, recognizes the need to improve the combustion efficiency of airplane engines, as well as to assess the contribution of fuels to particle emissions. Advanced engine designs and alternative fuel composition may help to reduce engine particle emissions that contribute to contrail formation.

## Are Persistent Contrails Harmful to the Public?

Although persistent contrails visible in the sky for hours may cause public concern, they do not indicate an airplane had dispersed harmful chemicals. The U.S. Government is not conducting weather modification nor releasing harmful agents into the atmosphere. The EPA and FAA will take appropriate actions to address any substantiated claims of unauthorized spraying of chemicals.

Jet fuel does not contain metal-based compounds. Any dissolved metals in jet fuel would affect engine stability, causing a major safety concern.

## Additional Resources

More information on contrails formation and impacts can be found at:

- <https://www.weather.gov/fgz/CloudsContrails>
- <https://www.aerosociety.com/news/chemtrails-debunked/>
- <https://scied.ucar.edu/image/multiple-contrails>
- <https://www.icao.int/environmental-protection/Pages/non-CO2-emissions.aspx>
- [Aircraft contrails - GOV.UK](#)
- [Contrail Gallery - Clouds Protocol - GLOBE.gov](#)
- <https://www.nasa.gov/stem-content/contrails/>
- [Boeing Contrails-Fact-Sheet.pdf](#)

<sup>3</sup> <https://www.weather.gov/fgz/CloudsContrails>

