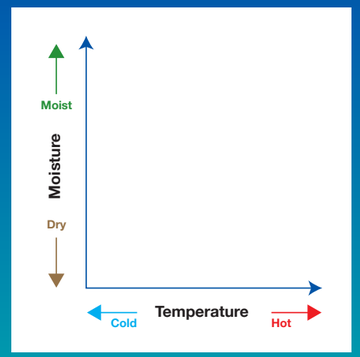
National Aeronautics and Space Administration

www.nasa.gov

Contrail Identification Chart and Formation Guide

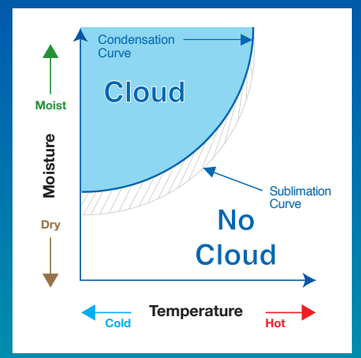
Contrails are clouds formed when water vapor condenses and freezes around small particles (aerosols) that exist in aircraft exhaust. Some of that water vapor comes from the air around the plane, and some is added by the exhaust of the aircraft. Clouds are the largest variable controlling Earth's atmospheric temperature and climate. Any change in global cloud cover may contribute to long-term changes in Earth's climate. Contrails, especially persistent contrails, represent a human-caused increase in the Earth's cloudiness, and are likely to be affecting climate and ultimately our natural resources. Scientists today are trying to learn more about the longevity of persistent contrails and how much they may affect the climate in the future.

1 Setting up Contrail Conditions Graph



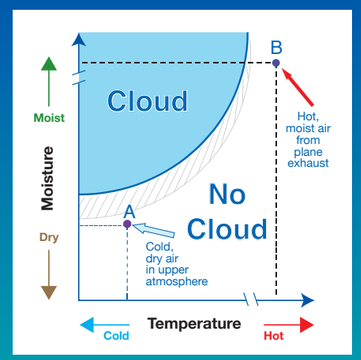
The X-axis *(horizontal axis)* represents the temperature and the Y-axis *(vertical axis)* represents the amount of moisture in the atmosphere.

2 Where Water Changes State



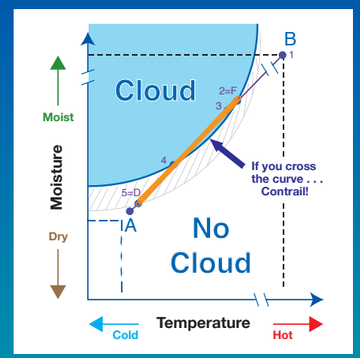
The shaded area shows where condensation (gas to liquid) occurs. Because it is cold where airplanes fly, any water drops freeze into ice crystals (liquid to solid). The hatched area shows where ice will persist. In the white area, ice will sublimate (solid to gas). The reverse process (gas to solid) does not occur in the atmosphere.

3 Typical Starting Points, A and B



The cloudless atmosphere at high altitude is generally cold and dry (point A). Aircraft exhaust is hot and moist (point B).

4 The Mixing Process Starts at B and Moves Toward A

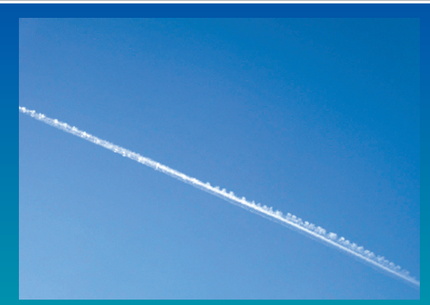


1. Hot, moist gas from plane.
2(=F Formation of contrail). As it mixes with the air, the exhaust cools to the condensation curve.
3. Water drops freeze to ice crystals.
4. Water drops would evaporate, but ice persists.
5(=D Dissipation of contrail). Ice sublimates, and the contrail dissipates.

5 Short-lived

A contrail that forms and disappears as the plane moves along. Although its length remains about constant it may be very short, or it may span a large fraction of the sky. Generally it is very thin.

6 Persistent

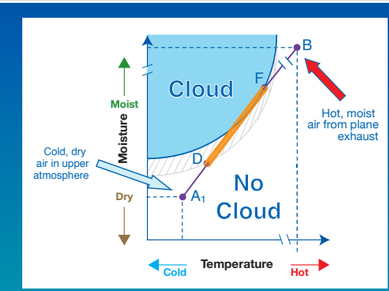


A thin contrail that remains in the sky after the plane has disappeared. These contrails are not much wider than the short-lived contrails and are thinner than 1 finger held at arm's length.

7 Persistent Spreading

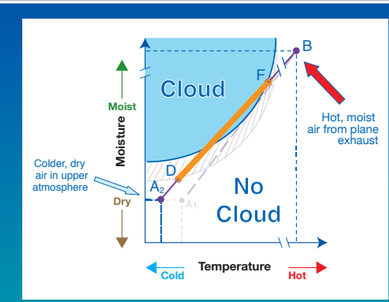
A thick contrail that remains in the sky after the plane has disappeared. These are wider than 1 finger held at arm's length. These contrails can grow to resemble natural cirrus clouds.

Contrails in Dry Air → Short-Lived Contrails



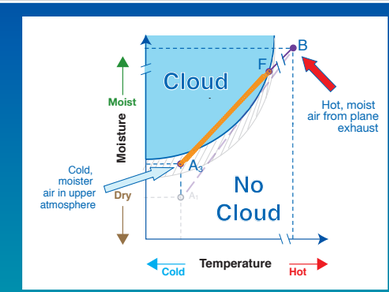
The exhaust from the airplane mixes with the air from the atmosphere, along the straight line between points B and A_1. A contrail forms at point F and persists to point D. When the straight line between points A_1 and B barely crosses into the condensation curve, a short-lived contrail is formed.

Contrails in Colder Air → Persistent Contrails



When point A_2 is such that the straight line between points B and A_2 crosses further into the condensation area, and A_2 is closer to the sublimation curve, a longer lasting, or persistent, contrail forms between points F and D.

Contrails in Moister Air → Persistent Spreading Contrails



When point A_3 is in the hatched area(moister air), the addition of warm, moist airplane exhaust leads to a persistent, possibly spreading, contrail since the ice particles created at point F will not sublimate at point A_3.

Contrail Education Website: http://asd-www.larc.nasa.gov/GLOBE/

Contrail Prediction Website: http://asd-www.larc.nasa.gov/GLOBE/resources/activities