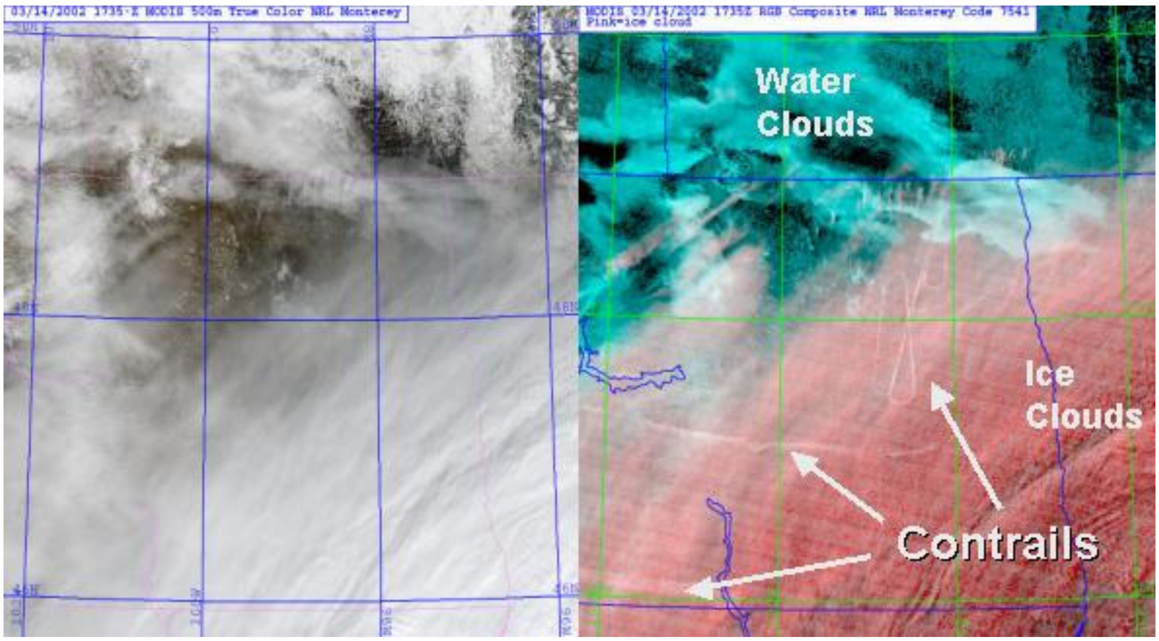
Satellite Product Tutorials:
Aircraft Contrails



Above: The contrail enhancement (right panel) reveals several linear features produced by condensation on jet fuel exhaust high in the atmosphere. These features, called condensation trails (or "contrails," for short), are often indiscernible in the true color satellite imagery (left panel). With the appropriate information and increasing spatial detail, next generation satellites are in an increasingly better position to detect, track and study the behavior of these contrails around the world.

Why We're Interested…

Contrails form when warm, moist jet exhaust mixes with the cold and dry upper troposphere environment. Depending on the amount of moisture at these high altitudes, contrails may either dissipate rapidly or persist and spread over time (forming extensive cirrus shields). In the latter case these cirrus impact the heating and cooling profile of the entire atmosphere by reflecting sunlight and absorbing and re-emitting terrestrial radiation.

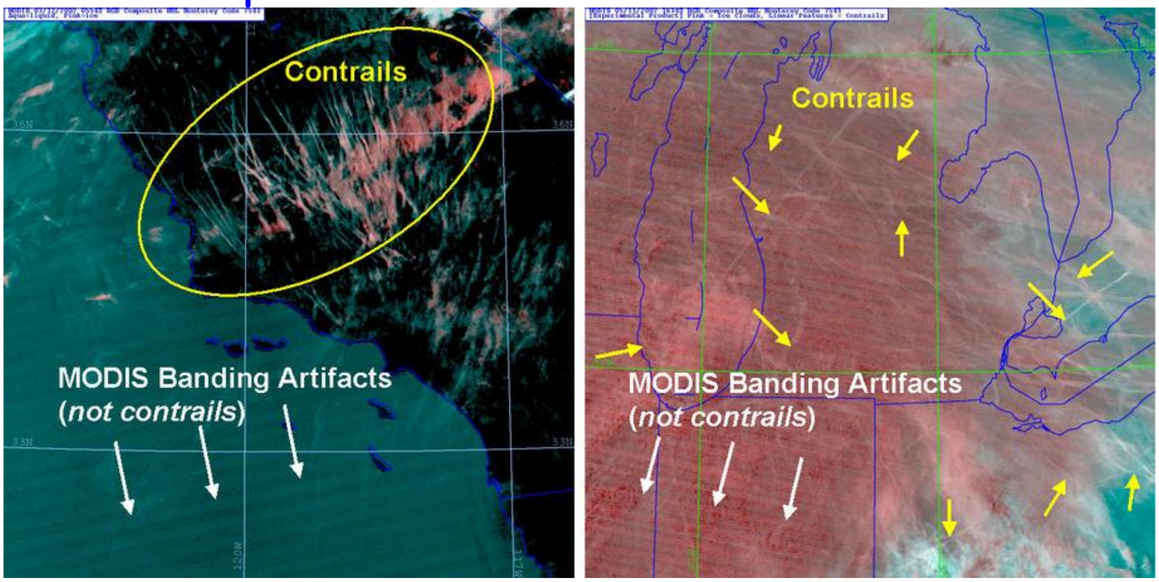
Studies indicate that in this way cirrus effectively reduces the day/night range of surface temperatures (warmer nighttime lows and cooler daytime highs).

How This Product is Created…

Contrails are of interest from the military perspective from the standpoint of air traffic monitoring and operations. Several researches have illustrated technique to detect contrails from space, based on the 11.0 – 12.0 micron "split window" brightness temperature difference. The technique is based on the physics of cirrus, which appear "thicker" at 12.0 micron than they do at 11.0 micron (in other words, less light can pass through them). This results in different measurements being recorded for the two channels. If the measured differences are large enough, we classify the scene as containing thin cirrus clouds. Because contrails form under different circumstances than any naturally occurring cirrus at the same level, we can often differentiate the contrail component based on different "split window" difference values—even in cases where the contrail is embedded within the cirrus layer itself. In addition, contrails in satellite imagery often appear as straight or curved lines that are easy to pick out in the enhanced imagery.

Combining the split-window information from the MODIS 8.5 micron channel, we can separate liquid from ice clouds in the scene. The absorption of both ice and liquid-phase water clouds increases as we progress toward longer wavelengths in the infrared part of the spectrum from 8.5 to 12.0 micron. However, the increase is not constant, and it turns out that ice cloud absorption increases faster in the first part (from 8.5 to 11.0 micron) than it does in the last part (11.0 to 12.0 micron), where as the opposite is true for liquid-phase clouds. As a result, we can examine the difference between measurements of liquid and ice clouds at these three wavelengths and come to some conclusions about which is which. This so-called "tri-spectral" technique is potentially very useful in identifying clouds comprised of supercooled liquid water (liquid-phase cloud droplets occurring at temperatures less than the freezing point, which are found regularly in nature and lead to a dangerous flight hazard known as "aircraft icing"). In this case, we use the tri-spectral information to help improve isolation between the upper level cirrus and contrails from lower level clouds. In the current product,

How to Interpret…



The figure above demonstrates the different ways that contrails appear in the current product. The left panel is an example of primarily stand-alone and easily detected contrails created by commercial aviation in southern California. Here, sufficient upper level moisture is present, allowing the contrails to persist over time. In the example at right, an extensive shield of cirrus blankets the Midwestern states. Yellow arrows point to a subset of the contrails revealed by the enhancement. Due to optical property differences between the naturally occurring cirrus and the contrails, the latter are revealed throughout the scene.

Both examples above also point to an important caveat associated with the way MODIS collects its imagery data. As the satellite orbits the earth, the MODIS sensors scan from left-to-right across the path (this is called "cross-track scanning"). For AVHRR and GOES imagers, there is one detector-per-channel that performs this operation, so that adjacent "scan lines" are based on the same detector. In the case of MODIS, there is a stack of ten detectors, oriented in the direction of the orbit path, such that a single scan of MODIS results in ten "lines" being scanned simultaneously. This allows MODIS to scan at a slower rate, and collect better information over a given area (and over smaller areas). The trade-off is that not all the detectors are exactly alike, and therefore each one responds a little differently to the radiation it senses. These slight differences in how the scene appears to each detector in the ten-detector stack result in subtle "banding" effects that are periodic and oriented in the cross track direction. The left panel shows the bands oriented from lower left to upper right, indicating an ascending (coming up from the southeast and heading toward the northwest) node of the orbit, and the right panel shows the opposite orientation associated with a descending (from northeast to southwest) node. The regular patterns produced by this effect usually make them easy to distinguish from actual contrails, which will vary in shape, brightness, and orientation across the image.

Note: Contrails move along with the environmental winds. If any shear exists in the wind field (changes in speed or direction over space) will result in the distortion of contrail features over time. In general, freshly-formed contrails that form in favorable environments for their sustenance will exhibit sharply-defined linear patterns, while older contrails will appear diffuse and/or distorted. The majority of contrails observed over the continental United States are from commercial airline traffic, although a small subset arises from military aircraft activities.

Looking Toward the NPOESS Era…

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Visible/Infrared Imager/Spectrometer (VIIRS) will provide the same tri-spectral channels demonstrated on MODIS. The high spatial and spectral resolution of VIIRS will provide improved detection capabilities for fine-scale (e.g., recently created) contrails.

Did You Know…?

Based on information taken from twenty-five years worth of satellite data, some researchers have concluded that contrails alone can account for nearly all of the observed global warming over the period.

Want to Learn More?

NASA conducted a field campaign to study contrails, called "SUCCESS"
More NASA Research surrounding contrails…

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