Gretchen Cook-Anderson
Headquarters, Washington
(Phone: 202/358-0836)

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Chris Rink/Julia Cole
Langley Research Center, Hampton, Va.
(Phone: 757/864-6786/4052)

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**Clouds Caused By Aircraft Exhaust May Warm The U.S. Climate**

NASA scientists have found that cirrus clouds, formed by contrails from aircraft engine exhaust, are capable of increasing average surface temperatures enough to account for a warming trend in the United States that occurred between 1975 and 1994.

"This result shows the increased cirrus coverage, attributable to air traffic, could account for nearly all of the warming observed over the United States for nearly 20 years starting in 1975, but it is important to acknowledge contrails would add to and not replace any greenhouse gas effect," said Patrick Minnis, senior research scientist at NASA's Langley Research Center in Hampton, Va. The study was published April 15 in the Journal of Climate. "During the same period, warming occurred in many other areas where cirrus coverage decreased or remained steady," he added.

"This study demonstrates that human activity has a visible and significant impact on cloud cover and, therefore, on climate. It indicates that contrails should be included in climate change scenarios," Minnis said.

Minnis determined the observed one percent per decade increase in cirrus cloud cover over the United States is likely due to air traffic-induced contrails. Using published results from NASA's Goddard Institute for Space Studies (New York) general circulation model, Minnis and his colleagues estimated contrails and their resulting cirrus clouds would increase surface and lower atmospheric temperatures by 0.36 to 0.54 degrees Fahrenheit per decade. Weather service data reveal surface and lower atmospheric temperatures across North America rose by almost 0.5 degree Fahrenheit per decade between 1975 and 1994.

Minnis worked with colleagues Kirk Ayers, Rabi Palinkonda, and Dung Phan from Analytical Services and Materials, Inc., of Hampton, Va. They used 25 years of global surface observations of cirrus clouds, temperature and humidity records from the National Centers for Environmental Prediction (NCEP) reanalysis dataset. They confirmed the cirrus trends with 13 years of satellite data from NASA's International Satellite Cloud Climatology Project.

Both air traffic and cirrus coverage increased during the period of warming despite no changes in the NCEP humidity at jet cruise altitudes over the United States. By contrast, humidity at flight altitudes decreased over other land areas, such as Asia, and was accompanied by less cirrus coverage, except over Western Europe, where air traffic is very heavy.

Cirrus coverage also rose in the North Pacific and North Atlantic flight corridors. The trends in cirrus cover and warming over the United States were greatest during winter and spring, the same seasons when contrails are most frequent. These results, along with findings from earlier studies, led to the conclusion that contrails caused the increase in cirrus clouds.

"This study indicates that contrails already have substantial regional effects where air traffic is heavy, such as over the United States. As air travel continues growing in other areas, the impact could become globally significant," Minnis said.

Humidity is the amount of water vapor in the air and determines how long contrails remain in the atmosphere. Contrails that persist for an extended period of time are most likely to impact the climate.

Contrails form high in the atmosphere when the mixture of water vapor in the aircraft exhaust and the air condenses and freezes. Persisting contrails can spread into extensive cirrus clouds that tend to warm the Earth, because they reflect less sunlight than the amount of heat they trap. The balance between Earth's incoming sunlight and outgoing heat drives climate change.

NASA's Earth Science Enterprise funded this research. NASA's Earth Science Enterprise is dedicated to understanding the Earth as an integrated system and applying Earth System Science to improve prediction of climate, weather, and natural

hazards using the unique vantage point of space.

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