German
Aerospace Center

To what extent do thunderstorms influence the formation of ozone?

31 May 2012

Measurement flights by DLR, NCAR and NASA

Thunderstorms have a significant effect on the formation of ozone. Nitrogen oxide is produced as a result of lightning; this in turn yields ozone at altitudes of 10 kilometres. Strong updraughts in thunderstorms also transport emissions from the ground into the upper atmosphere. But how significant is this effect – compared to aviation, for example? Researchers at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR), in collaboration with the US National Center for Atmospheric Research (NCAR), NASA and other partners, are studying such questions. To this end, they will be conducting measurement flights in the United States until mid-June. The researchers are looking to increase the existing body of data and gain a better understanding of the processes that take place in thunderstorms.

"Thunderstorms are like vacuum cleaners," explains Heidi Huntrieser from the DLR Institute of Atmospheric Physics. The DLR project leader is supervising the measurement flights in the United States. "Thunderstorms suck air up from the ground, sometimes at speeds surpassing 100 kilometres per hour, and carry it to an altitude of about 10 kilometres, to what is known as the 'anvil region'. This is the mushroom-shaped layer high above the storm, where the air can only flow horizontally and hardly upwards at all." If polluted air, such as that from vehicle emissions on the ground, is transported to this region, the chemistry of these emissions is altered by the low temperatures, differing humidity and more intense solar radiation there; they take much longer to break down, and the production of ozone is increased. "At these altitudes, nitrogen oxide can produce up to 10 times as much ozone as on the ground," says Huntrieser.

Huntrieser and her project partners intend to use the measurements to increase the existing data pool. "Previous measurements lead to the conclusion that global aviation produces about one teragram of nitrogen oxide per year, but thunderstorms are responsible for about five times as much. All nitrogen oxide sources jointly contribute about 50 teragrams of nitrogen oxide to the atmosphere each year, so thunderstorms are responsible for about 10 percent," explains Huntrieser. A teragram is 10 to the power of 12. New model simulations show that thunderstorms exert a great influence on ozone. "These were somewhat surprising results," says Huntrieser. “Now we need more measurement data to confirm this."

Use of three research aircraft

Three research aircraft are being used for the mission: the DLR Falcon research aircraft will take measurements at an altitude of 10 kilometres, while the American HIAPER research aircraft will take measurements at up to 15 kilometres. A DC-8, a much larger aircraft, will mainly operate at lower altitudes. "Our ambitious goal is for all the aircraft to operate simultaneously at different altitudes in the vicinity of thunderstorms. It would be a first," says Huntrieser.

Influence exerted by different types of lightning

Besides the transportation processes from the ground to the upper atmosphere, the studies will focus on the influence exerted by different types of lightning. There are relatively short lightning bolts a few kilometres long, and some that stretch horizontally over a distance of 100 kilometres or more. The formation of lightning also depends on the type of storm; previous measurements over Europe indicate that storms with large amounts of hail and frozen rain that occur at mid-latitudes can contain relatively more and sometimes longer lightning bolts. By comparison, measurements in tropical storms in Brazil indicate fewer ice particles, more cloud droplets and many – but shorter – lightning bolts. Previous measurements also indicate that less nitrogen oxide per lightning bolt is produced in storms with shorter lightning bolts than in those with longer lightning bolts. Due to the varied climatic conditions in the United States, the researchers can investigate both types of storms. Over Alabama there are storms with less ice, and over Colorado there are those with more frozen rain and hail. Oklahoma is known for its violent storms, also known as supercells, which can also trigger tornadoes.

The research flights are very challenging, but not dangerous for the occupants: "We are not flying directly into the storms. That would be much too dangerous because of the strong turbulence, risk of ice formation, lightning strike and the high wind speeds. Our measurements are being taken in the calmer anvil region," explains Huntrieser. The robust Falcon is ideal for this. The DLR pilots have already carried out numerous similar measurements with the research aircraft over Europe, Brazil, Australia and Africa.

The researchers are also breaking some new ground with their measurement flights. Between 12 and 48 hours after the storm has dissipated, the scientists are planning to carry out measurement flights inside the storm's residual air mass and determine, for example, how much ozone has been produced and how the chemical composition has changed as a result of the storm.

The partners

Besides DLR, partners involved in the measurements include the US space agency NASA, the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA) and the University of Innsbruck. The mission is sponsored by the US National Science Foundation (NSF).

About DLR

DLR, the German Aerospace Center, is Germany's national research centre for aeronautics and space. Its extensive research and development work in aeronautics, space, energy, transport, defence and security is integrated into national and international cooperative ventures. As Germany's Space Agency, DLR is tasked with the planning and implementation of Germany's space programme.

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View from the cockpit of the Falcon during a measurement flight

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The DLR Falcon and the DC-8

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