Aircraft emissions could influence climate change through cloud formation

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Airplane exhaust could affect the ice crystals that form cirrus clouds, thus affecting radiant heat and contributing to climate change.

(PhysOrg.com) -- Aircraft emissions can affect the properties of cirrus clouds, contributing to climate change. This was a key finding from PNNL scientist Dr. Xiaohong Liu and his colleagues from a recent study. The team concluded that black carbon and/or metallic material from airplane exhaust could affect radiant heat and climate by acting as efficient sources for making ice crystals, thus affecting the creation of cirrus clouds.

The team also found that when particles from fossil fuel and burning biomass are emitted from the Earth's surface, they can travel at least 5 miles higher. At that altitude, these tiny bits of sulfate and black carbon create more ice-crystal-forming cirrus clouds.

The effect aerosol particles have on clouds remains the largest uncertainty in assessing future climate change. Aerosols can influence the Earth's radiant heat balance by scattering incoming radiation back to space or by affecting the properties of clouds. In addition, how ice particles are formed from ice nucleation on aerosols and how they are distributed in clouds can influence precipitation, which affects the distribution of heat.

This study was one of the first to model the effect of human-caused aerosols on cirrus clouds and to quantify the amount of energy that cirrus clouds reflect into space and absorb. Many previous studies have shown how aerosols change warm clouds—those with temperatures greater than 0°C—but few on cirrus clouds, which are more difficult to measure because they float at least 8 km, or 5 miles, from the Earth's surface. Cirrus clouds cover about 30 percent of the Earth's surface.

Some of the improvements to date about ice microphysics parameterization have now been incorporated into the National Center for Atmospheric Research Community Atmospheric Model Version 3 (CAM3) climate model that will be released for future users.

The team used a computer model to examine the effects on cirrus clouds of two sources of human-caused aerosols—tiny particles of sulfate and black carbon from fossil fuel and burning biomass.

Scientists used the CAM3. They used an ice microphysics treatment that predicts ice water and the number of ice crystals, coupled to a global aerosol model known as the Lawrence Livermore National Laboratory Chemical Transport Model. They found that the relative humidity in the upper troposphere plays a key role in determining how ice crystals are formed. Researchers modified the CAM large-scale cloud condensation and evaporation parameters to allow ice supersaturation in the upper troposphere. They then combined the CAM3 with ice crystal number

prediction together with an aerosol model to study the impacts of human-caused aerosols on climate through changing ice cloud properties, such as cloud radiation and microphysics. Model simulations were conducted with both present-day and pre-industrial emissions.

Researchers analyzed the changes in ice water content, ice crystal number concentration, temperature, humidity, and cloud cover between the experiments for present-day and pre-industrial aerosols to identify the effects of human-caused ice formation particles (sulfate or black carbon) on the cirrus clouds and hydrological cycle. In addition, researchers calculated the changes in the shortwave and longwave and net radiation between the pre-industrial simulation and the present-day simulations to estimate the radiative forcing resulting from the aerosol effects on cirrus clouds. Then they analyzed the different present-day simulations to compare the relative importance of heterogeneous ice crystal formation versus homogeneous ice freezing to identify the contribution from aircraft-emitted soot as compared to that from the Earth's surface sources.

Future studies will focus on improving ice microphysics formulations in the climate model and evaluating the model simulations using data from Atmospheric Radiation Measurement (ARM) Climate Research Facility sites and field campaigns. Researchers will use both old and new ARM data. For example, they will use data from the ARM field campaign SPARTICUS (Small Particles in Cirrus) between November 2009 and March 2010, which will focus specifically on measuring properties of cirrus clouds.

More information:

Liu, X., J. E. Penner, and M. Wang. 2009. "Influence of Anthropogenic Sulfate and Black Carbon on Upper Tropospheric Clouds Using CAM3 Coupled with an Aerosol Model." *Journal of Geophysical Research*, 114,

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