PHYS.ORG

Pollution alters isolated thunderstorms

December 15 2009

Under certain conditions, pollution can either strengthen or weaken thunderstorm clouds. PNNL researchers have figured out how to factor the effect into climate models. Credit: UCAR/Carlyle Calvin

New climate research reveals how wind shear -- the same atmospheric conditions that cause bumpy airplane rides -- affects how pollution contributes to isolated thunderstorm clouds. Under strong wind shear conditions, pollution hampers thunderhead formation. But with weak wind shear, pollution does the opposite and makes storms stronger.

The work improves climate scientists' understanding of how aerosols -- tiny unseen particles that make up pollution -- contribute to isolated thunderstorms and the climate cycle. How aerosols and clouds interact is one of the least understood aspects of climate, and this work allows researchers to better model clouds and precipitation.

"This finding may provide some guidelines on how man-made aerosols affect the local climate and precipitation, especially for the places where 'afternoon showers' happen frequently and affect the weather system and hydrological cycle," said atmospheric scientist Jiwen Fan of the Department of Energy's Pacific Northwest National Laboratory. "Aerosols in the air change the cloud properties, but the changes vary from case to case. With detailed cloud modeling, we found an important factor regulating how aerosols change storms and precipitation."

Fan will discuss her results Thursday, December 17 at the 2009 American Geophysical Union meeting. Her study uses data from skies over Australia and China.

The results provide insight into how to incorporate these types of clouds and conditions into computational climate models to improve their accuracy.

A Model Sky

Deep convective clouds reflect a lot of the sun's energy back into space and return water that has evaporated back to the surface as rain, making them an important part of the climate cycle. The clouds form as lower air rises upwards in a process called convection. The updrafts carry aerosols that can seed cloud droplets, building a storm.

Previous studies produced conflicting results in how aerosols from pollution affect storm development. For example, in some cases, more pollution leads to stronger storms, while in others, less pollution does. Fan and her colleagues used computer simulations to tease out what was going on. Of concern was a weather phenomenon known as wind shear, where horizontal wind speed and direction vary at different heights. Wind shear can be found near weather fronts and is known to influence storms.

The team ran a computer model with atmospheric data collected in northern Australia and eastern China. They simulated the development of eight deep convective clouds by varying the concentration of aerosols, wind shear, and humidity. Then they examined updraft speed and precipitation.

Storm Forming

In the first simulations, the team found that in scenarios containing strong wind shear, more pollution curbed convection. When wind shear was weak, more pollution produced a stronger storm. But convection also changed depending on humidity, so the team wanted to see which effect -- wind shear or humidity -- was more important.

The team took a closer look at two cloud-forming scenarios: one that ended up with the strongest enhancement in updraft speed and one with the weakest. For each scenario, they created a humid and a dry condition, as well as a strong and weak wind shear condition. The trend in the different conditions indicated that wind shear had a much greater effect on updraft strength than humidity.

When the team measured the expected rainfall, they found that the pattern of rainfall followed the pattern of updraft speed. That is, with strong wind shear, more pollution led to less rainfall. When wind shear was weak, more pollution created stronger storms and more rain -- up to a certain point. Beyond a peak level in weak wind shear conditions, pollution led to decreased storm development.

Additional analyses described the physics underlying these results. Water condensing onto aerosol particles releases heat, which contributes to convection and increases updraft speed. The evaporation of water from the cloud droplets cools the air, which reduces the updrafts. In strong wind shear conditions, the cooling effect is always larger than the heating effect, leading to a reduction in updraft speed.

More information: iwen Fan, "Dominant Role by Vertical Wind Shear in Regulating Aerosol Effects on Deep Convective Clouds" in session A43F, Cloud Properties and Physical Processes, Including Aerosol-Cloud Interactions II on Thursday, December 17, 2009, at 2:10 PM, in Moscone West.

J. Fan, T. Yuan, J. M. Comstock, S. Ghan, A. Khain, L. R. Leung, Z. Li, V. J. Martins, M. Ovchinnikov, Dominant role by vertical wind shear in regulating aerosol effects on deep convective clouds, J. Geophys. Res., 114, D22206, doi:10.1029/2009JD012352

Provided by Pacific Northwest National Laboratory