Study reveals how particles that seed clouds in the Amazon are produced

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Research shows the role amazon's clouds as transporters of particles between the ground and the upper atmosphere. Credit: Eduardo Cesar

A study published in the journal *Nature* solves a mystery that has puzzled scientists for over a decade: the origin of the atmospheric aerosols that contribute to cloud formation above the Amazon rainforest in the absence of local sources of pollution.

Aerosols are microscopic particles suspended in the atmosphere. They play several essential roles in the climate system. For example, most clouds owe their existence to aerosols, because the water vapor in the atmosphere condenses on them to form cloud droplets that eventually precipitate as rain. These seed-like aerosol particles are called cloud condensation nuclei, the authors explain.

According to the latest findings of the research project, conducted with FAPESP's support as part of the Green Ocean Amazon Experiment (GOAmazon), particles that serve as precursors of cloud condensation nuclei form in the upper atmosphere and are carried down toward the ground by clouds and rain.

"We tried for at least 15 years to measure the formation of new aerosol particles in the Amazon at ground level and the result was always zero. The new nanometric particles simply didn't turn up there. Measurements were made on the surface or in aircraft flying no higher than 3,000 m. We only found the answer when we looked much higher up," said Paulo Artaxo, a professor at the University of São Paulo's Physics Institute (IF-USP) and a co-author of the article.

According to Artaxo, the Amazon rainforest naturally emits gases known as volatile organic compounds (VOCs), including terpene and isoprene. They are swept into the upper atmosphere by cloud convection and can soar as high as 15,000 m, where the temperature is about minus 55 degrees Celsius.

"At these very low temperatures, the VOCs condense and form tiny particles measuring 1-5 nm," Artaxo explained. "These nanoparticles absorb gases and collide with each other, rapidly agglomerating and growing to a size large enough to make them cloud condensation nuclei, typically more than 50-70 nm."

At high altitudes, he added, particle agglomeration is facilitated by low atmospheric pressure, low temperature, and the vast numbers of particles in circulation there.

"Eventually one of these giant convective clouds generates a strong downdraft of air and precipitates as rain, so that the particles plunge down toward the ground," Artaxo said.

Surprising discovery

Some of the measurements presented in the article were made in March 2014 during the Amazon's rainy season by a Grumman Gulfstream-1, a research aircraft capable of flying at 6,000 m, or nearly 20,000 ft, and owned by Pacific Northwest National Laboratory (PNNL) in the US.

Another dataset was obtained between March and May 2014 at the Amazon Tall Tower Observatory (ATTO), which is operated by Brazil's National Institute of Amazon Research (INPA). The ATTO is 320 m high and located in the heart of the rainforest on the Uatumã Biological Reserve, some 160 km northeast of Manaus - beyond the reach of urban pollution.

Supplementary measurements of aerosols were made at the ZF2 towers around 55 km north of Manaus, and in Manacapuru some 100km west of Manaus at the Atmospheric Radiation Measurement (ARM) mobile facility comprising a number of ground-based and airborne devices developed for climate studies and owned by the US Department of Energy.

"Much to our surprise, we found that the amount of particulate matter in the atmosphere increased with altitude. We would have expected higher concentrations nearer to the ground. We found very large amounts of aerosols at around 6,000 m, the highest the Gulfstream-1 can fly," said Luiz Augusto Toledo Machado, a researcher at the National Space Research Institute (INPE) and also a co-author of the article.

The initial observation was confirmed by new measurements captured by the German High Altitude & Long Range Research Aircraft (HALO), which can fly at 16,000 m and is operated by a research consortium that includes the German Aerospace Center (DLR), Max Planck Institute (MPI) and German Research Foundation (DFG).

"We found that in polluted areas there was an extremely high concentration of particulate matter near ground level, which wasn't the case in pollution-free areas. At high altitudes, however, we found large amounts of particles even in the absence of local pollution sources," Machado said. "This latest study shows how these nanoparticles are swept down toward the ground by rain to form new populations of particulate matter that act as cloud condensation nuclei at low altitudes."

According to Artaxo, the observation was surprising because above the planetary boundary layer at 2,500 m there is a temperature inversion that usually inhibits the vertical movement of particules. "But we hadn't taken into account the role of convective clouds as transporters of the gases emitted by the forest," he said.

The studies performed under the aegis of GOAmazon are proving that VOCs from plants are part of a fundamental mechanism for the production of aerosols in continental areas, he went on.

"The combination of forest-emitted VOCs and clouds makes a very specific dynamic that produces huge amounts of particles at high altitudes, where there weren't thought to be any. It's the biology of the forest interacting with clouds to keep the Amazon's ecosystem functioning," Artaxo said.

The VOCs soar into the upper atmosphere where wind speeds are very high, and are redistributed around the planet very efficiently. In the Amazon's case, part goes to the Andes and part to southern Brazil, while some remains in the tropical forest region itself. "At the moment we're modeling all our data to work out more precisely which regions are affected by VOCs from the Amazon that are transported by atmospheric circulation," Artaxo said.

Because it was unknown until now, this aerosol production mechanism is not considered by any of the climate models currently in use. "The knowledge will have to be included," Machado said. "It will help make rainfall simulations more precise."

Provided by FAPESP