Amazon rainforest fires produce secondary ultrafine particles that may affect weather and climate

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The thick smoke seen in vegetation fires in the Amazon rainforest contains millions of ultrafine particles (diameters less than 50 nm), which could seed cloud droplets and intensify heavy rain in the atmosphere. Current understanding is that smoke from burning biomass does not include ultrafine particles although larger particles (>100 nm diameter) are known to be prevalent. Credit: Jason Tomlinson | Pacific Northwest National Laboratory

Particles in wildfire smoke can lower air quality and harm human health. Smoke aerosols can also influence weather and climate by modifying cloud formation and changing how much of the sun's energy is reflected or absorbed by the atmosphere. Compared to larger particles directly emitted from fires, the formation and presence of ultrafine particles (UFPs) have previously been overlooked, as it was thought that they were quickly "scavenged" by the larger particles.

By analyzing aircraft measurements and conducting detailed model simulations, a team of researchers found that ultrafine particles were abundant in smoke from vegetation fires in the Amazon region, and their formation and survival were favored. Furthermore, high-resolution modeling showed that these ultrafine particles may intensify storm clouds and heavy rain. This research deepens our understanding of how vegetation fires produce aerosols that may impact weather and climate change.

Earth system models have not considered secondary UFPs formed by nucleation and growth of atmospheric constituents that are formed by chemical oxidation in smoke from burning biomass, because previous understanding suggested there were large losses of nucleating species to primary smoke particles. Contrary to this understanding, a team of researchers identified efficient nucleation and growth mechanisms for secondary UFPs that produced nucleating species in smoke which could overcome their losses to primary smoke particles and thereby sustain nucleation and the long-term presence of many UFPs in smoke.

This work is expected to fill a major gap in the process understanding of UFPs and opens new research frontiers by highlighting the large potential impacts of UFPs that are formed in smoke from burning biomass on the formation of clouds, development of rain, short-term weather conditions, and longer-term climate conditions which have been previously overlooked. The study is published in the journal *One Earth*.

New particle formation in smoke from vegetation fires is thought to be unlikely due to large condensation and coagulation sinks that scavenge freshly nucleated molecular clusters in smoke. By analyzing the G-1 aircraft measurements of smoke tracer gas acetonitrile and particle size distributions collected over the Amazon rainforest, a multi-institutional team of researchers identified abundant UFPs present in smoke from fresh vegetation fires.

Using detailed regional modeling with the Weather Research and Forecasting Model coupled to chemistry (WRF-Chem), they elucidated key mechanisms that explain the formation of UFPs in biomass smoke. Their analyses suggest that to maintain the observed UFP concentrations and overcome the large losses of nucleating species to primary biomass burning aerosols, the biomass burning emissions of dimethyl amines (DMA) need to be included in the model.

Additionally, the DMA emission rates, along with the chemical production rates of sulfuric acid and the extremely low volatility organic gases in smoke, need to be increased proportionally to the observed particle size distributions in smoke.

To simulate the impacts of UFPs and the larger particles in smoke on clouds and precipitation, the team used the particle size distributions and hygroscopicity profiles simulated by WRF-Chem and provided them to a detailed cloud microphysics model, called WRF with spectral bin cloud microphysics. The fine resolution WRF with spectral bin cloud microphysics simulations showed that UFPs may cause a stronger storm with a larger anvil and heavier rain, while the larger particles directly emitted by fires delay and suppress rain.

More information: Manish Shrivastava et al, Intense formation of secondary ultrafine particles from Amazonian vegetation fires and their invigoration of deep clouds and precipitation, *One Earth* (2024). DOI: 10.1016/j.oneear.2024.05.015

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