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Studying clouds can provide deeper insight into climate change

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The measuring station at the top of the mountain. Credit: 2021 LAPI/EPFL

An international team of scientists conducted CALISHTO, a large-scale air measurement campaign in Greece last fall, with the goal of surveying, counting and characterizing the tiny particles and their impact on cloud formation. The goal is to incorporate this information in climate models for improved predictions of clouds, precipitation and climate.

The Earth's climate works like a huge puzzle, and being able to understand all the different mechanisms involved requires piecing together massive amounts of data. Developing reliable climate models requires understanding the exact role that clouds play, and is currently missing. To fill this gap, an international team of scientists—including researchers from EPFL's Laboratory of Atmospheric Processes and their Impacts (LAPI) and Environmental Remote Sensing Laboratory (LTE)—carried out air measurements recently on an unprecedented scale.

The research project is called CALISHTO, which is short for Cloud-AerosoL InteractionS in the Helmos background TropOsphere. The measurements were taken on Mount Helmos at the heart of the Peloponnese throughout the fall of 2021. The scientists spent months meticulously surveying, counting and characterizing the different types of particles in the air at different times of day. These microscopic particles, also known as aerosols, are important because they serve as "seeds" for clouds.

"Without aerosols, there would be hardly any clouds in the sky," says Athanasios Nenes, the head of LAPI and one of the organizers of CALISHTO. "Water vapor condenses on these particles, forming droplets and ice crystals that we see as clouds. And the type of cloud formed can vary significantly depending on the number of aerosols, their size and their chemical characteristics. Particles of sand from the Sahara Desert, for example, will have a very different effect on clouds from those produced by forest-fires. That's what we wanted to study with this measurement campaign."

Understanding the process of cloud formation is especially important given the essential role that clouds play in the climate system, and therefore in climate change. Clouds form a veil over the Earth, reflecting large amounts of incoming solar radiation back into space through what's known as the albedo effect. They also trap some of the longer-wavelength radiation (infrared radiation) that's emitted from the Earth's surface, keeping some of the heat in the atmosphere. What's more, clouds are involved in regulating and distributing precipitation and the hydrologic cycle in general, meaning they have a direct influence on freshwater supplies for many ecosystems and for agriculture.

A critical factor

Despite this essential role that clouds play, there's still a lot of uncertainty in how they should be factored into climate models—particularly when you take into account the many different interactions and chemical and physical processes involved, all taking place at the micro scale, much smaller than any climate model can resolve.

What makes Mount Helmos particularly interesting for cloud and climate research is that it sits at the crossroads of many different air streams. Situated in the center-north part of the Peloponnese peninsula in Greece, it provides an ideal site for collecting and measuring an array of particles from continental Europe, from nearby areas as well as the marine particles from the Mediterranean Sea and Dust from the Sahara. The site is often in the level of cloud formation, so it provides a unique opportunity to directly observe how cloud properties change with the particles that are present in the air.

Kostas Eleftheriadis, a research director at the NCSR Demokritos, co-organizers of the campaign and initiator of the Mount Helmos site: "Our measuring station is the only one of its kind. We were able to watch the atmospheric processes that determine what happens to anthropogenic and natural emissions of particles and greenhouse gases across the broader eastern Mediterranean region. These data will help us understand the overall effect that human activity is having on the environment, both in our region and elsewhere."

"Our measuring station is located at an altitude of 2,300 meters and lets us observe how two distinct layers of air interact—a lower one, where all the anthropogenic pollution accumulates, and an upper one, where the air is much cleaner, with clouds in the region" says Ghislain Motos, a scientist at LAPI. Observing this huge diversity of cloud formation conditions for extended periods of time allows for an understanding of the processes that occur for clouds all over the world.

Nearly three dozen instruments

The scientists installed almost three dozen state-of-the-art research instruments at Mount Helmos and the surrounding region. Some collected data on atmospheric factors like air temperature, humidity, wind speed, sunlight, while others measured gases like ammonia and aerosol characteristics, such as size, number, hygroscopicity, chemical composition, density, optical properties, even biological content. The ability of aerosol to form cloud droplets and ice crystals was directly measured with a Cloud Condensation Nuclei counter co-developed by Nenes and a new ice nuclei counter that only few groups possess worldwide.

At the end of the campaign, the station was in real winter conditions. Credit: NCSR Demokritos

The research team also employed remote sensing systems that provide key pieces of information completing the measurements collected at the mountaintop. "We use systems called LIDARS, that sent light from lasers into the atmosphere to obtain information on the vertical distribution of particles from near ground up to 10 to 15 km height. This allows the characterization of air masses arriving over the Helmos station and helps determine where particles come from," says Alexandros Papayannis, the head of the Laser Remote Sensing Unit at the National Technical University of Athens, affiliate of LAPI and co-organizer of CALISHTO.

So far, the scientists have seen that dust particles from Sahara can considerably enhance the concentration of ice in clouds, which strongly promotes their ability to rain and snow. Interestingly, the concentration of biological particles is also increasing alongside with dust. Given that biological particles can act as superb ice nucleators, and help facilitate ice multiplication processes—does this mean that aerosols can make clouds rain and snow even more intensely than thought? The final analysis will tell in a few months.

Provided by Ecole Polytechnique Federale de Lausanne

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