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Researchers using drones to better understand environmental phenomena

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A version of the X8 aircraft designed and flown by the Earth Signals and Systems (ESS) group. Credit: Sai Ravela

In the thick, dry grass of the Paso de Cortés mountain pass in Mexico, MIT's Earth Signals and Systems (ESS) group struggled to launch a small aircraft high up into the volcanic plume rising steadily from Popocatépetl. It was a windy day, and nothing was going right. Then the volcano began to erupt. "It sounded like a big engine going off, a loud boom," says Sai Ravela, principal research scientist in the MIT Department of Earth, Atmospheres, and Planetary Science. Their escort from CENAPRED, Mexico's federal disaster prevention agency, told them to drop everything and leave.

Fortunately, that day last autumn was the only time Popocatépetl has derailed the group's mission to gather the first data set of its kind: the chemical composition and dispersion of a volcanic plume. They have developed a novel application of technology, termed a cooperative autonomous observing system (CAOS) to capture dynamic maps of a natural hazard as it billows into the atmosphere, or to "follow the plumes and puffs."

This kind of targeted, real-time measurement of volcanic emissions could provide, for example, a far more detailed understanding of the role of aerosols in climate change. More practically, remote monitoring downstream of eruptions could help airports gauge the extent of air traffic snarls, such as the delays due to Iceland's Eyjafjallajökull surprise in 2010.

The electric unmanned aircraft, with up to a 3-meter wingspan and tail propeller, can stay in the air for two hours. Its reinforced foam body carries a hefty payload, including lithium batteries, a camera, GPS, particle counters, chemical probes, and wind-speed and inertial sensors. The vehicle can follow flight instructions from a handheld remote control or operate in autonomous mode. At MIT, the EES group tweaks the design everyday to make the aircraft a more power-efficient sampling instrument, and a more graceful flying machine.

"The confluence of the small scale at which these problems are of interest and the small size of the aerial vehicle that can match these scales is really what enables the environmental application," Ravela says. "Their abilities range from flying a lawnmower pattern to grab data to actually tracking and mapping the whole structure."

The ESS group, arguably the most diverse in EAPS in terms of science and engineering backgrounds, aim beyond improved methods of data collection. They interpret localized atmospheric phenomena—including small ones, such as volcanic plumes or factory smokestack emissions—in computer models to better quantify risk. And that means reinventing the relationship between data and models.

The CAOS method is called "targeted observation" and involves successive rounds of intelligent data sampling. In this envisioned scheme, one aircraft flies to the plume and monitors its characteristics using an imaging sensor. On the ground, a computer program transforms the data points into a simple model—"a moving stick figure" of the plume. This initial sampling serves as a plan for a second aircraft to fly in for supplementary measurements. The model, constantly updating in response to new information, gets closer and closer to a good representation of the plume's evolution in reality.

Ravela estimates a quick, easy, and inexpensive application of this complex data science, calling for just "two guys in a pick-up truck, a couple of drones, and a small laptop computer." He says this scenario could play out by the end of the year.

The motivation behind CAOS—to address real-world environmental problems—sets the project apart from those in other earth science, robotics, and aerospace engineering programs at MIT. "The difference being," Ravela says, "is that we don't do methodology for the sake of methodology. On the earth science side, we are gathering data not just to constrain models, but are turning that paradigm on its head by using models to gather data more effectively. On the robotics side, instead of building abstract machine learning algorithms, we build ones that assist technology in effective data-driven science."

Eventually, the ESS group will set their sights on low-lying clouds. Cloud processes are currently the biggest uncertainty in climate models, partly because researchers do not have reliable measurements of these evolving small-scale structures. But cloud-monitoring unmanned aerial vehicles could change that. Ravela imagines the possibility of dense space-time maps of clouds from specific locations. A database of different types of clouds could serve as a reference guide for any modeler.

For now, CAOS researchers are processing the data from the initial experiments at Popocatépetl and waiting to see if the measurements reveal any of the plume's secrets. And they are not the only ones. The excitement is palpable in the hallways of MIT. Because hiking up volcanoes or flying piloted jets into toxic clouds of smoke are not options, people just want to see and touch the data from inside the volcanic plume. It's not uncommon for Earle Williams, principal research engineer in the MIT Department of Civil and Environmental Engineering, who studies how water released in volcanic eruptions can trigger lightning, to pop his head into Ravela's office: "Do you have them yet?"

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