Airborne Measurements of Volcanic Emissions

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Background: Rainforests absorb huge amounts of carbon dioxide (CO_2) from the atmosphere, but increasing oversaturation makes their future capacity to do so highly uncertain. Fortuitously, active, non-erupting volcanoes persistently seep out excess CO_2 into these tropical ecosystems, providing a window into predicted global conditions. The forested flanks of active volcanoes function as natural laboratories, offering insights into how future higher atmospheric CO_2 levels affect tropical forests.

ARC led a UAS (Uncrewed Aircraft System) science flight mission called Costa Rica Airborne research on foresT Ecosystem Response to volcanic emissions (CRATER) to the Rincón de la Vieja volcano in Costa Rica to examine these effects. CRATER deployed the fixed-wing Black Swift Technologies S2 UAS (a NASA SBIR product) to collect airborne imagery and gas concentrations (CO_2 and H_2O) along with SO_2 plume cross-sections on the south-southeastern flank of the volcano. The team completed several days of successful test and science sorties from May 11 - 22, 2025.

Main Findings: The S2 UAS trace gas payload demonstrated robust stability and in-flight reliability, validating the gas sensor integration and the aircraft's sampling performance under dynamic conditions. Preliminary results reveal coherent CO_2 plume gradients and enhancements. High resolution visible imagery identified vegetation stress and gas plume features, enabling precise flight planning. The system's sensitivity and accuracy in detecting subtle CO_2 enhancements, mapping vegetation stress, and resolving detailed tree canopy structure, endorse its application in future missions for quantifying the emissions, fate, and vegetation effects of volcanic CO_2 in complex and remote terrains.

Impact: CRATER advances UAS concept-of-operations and deployment logistics, enabling NASA to conduct routine and ad-hoc airborne investigations in hazardous, remote terrain. The mission investigates how persistent volcanic emissions affect tropical ecosystems by tracking volcanic gas transport above the canopy. CRATER will improve an understanding of volcano-atmosphere-biosphere interactions, as well as contribute to the development of UAS-borne sensing tools for Earth system science.

NASA ARC Black SwiftTM S2 UAS take-off. The catapult-launched, electric-powered fixed-wing S2 UAS carries a 5-pound science payload for over 60 minutes and can reach targets more than 20 miles away. Its capability for stand-off launches and recovery enables operations in complex, remote terrain without requiring an airfield. The modular platform with field-swappable payload cones supports sorties in agile succession.

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CRATER is a collaboration between ARC's Earth Science Division, Black Swift Technologies, and the University of Costa Rica's GasLAB.