Detecting volcanic CO_2 emissions hidden in tropical volcanic forests using fixed-wing sUAS

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ABSTRACT

CO2 emissions are among the earliest indicators of subsurface state change and reactivation of volcanic systems and these deep signals reflect in faint diffuse emissions variations on volcanic flanks. Monitoring vast areas of rainforests covering tropical volcanoes is challenging, and space-borne sensors like OCO-2 are not sensitive enough. Fortunately, trees exposed to mild enhancements of CO2 may experience fertilization and build excess CO2 into excess biomass (Cawse-Nicholson, et al. 2018, Biogeosciences). They also process excess CO2 through photosynthesis, measurable by fluorescence (Bogue et al., 2019, Biogeosciences). Furthermore, spaceborne remote sensing instruments have demonstrated increasing NDVI months to years before eruptions, unexplained by other factors (e.g., Houlie et al. 2006, EPSL; Seiler et al. 2017, PLoS One). By providing a means to map large areas of above-canopy CO2 variations over tropical rainforest on the flanks of actively degassing volcanoes, we enable to interpret the signals plants provide in response to excess CO2 with airborne and spaceborne hyperspectral remote sensing methods, including a possible future Surface Biology and Geology (SBG) NASA satellite mission.As a critical step to mature and test this concept, we deployed small unmanned aerial systems (sUAS) using a fixed-wing sUAS designed for autonomous operations and long endurance in extreme environments, without causing significant disturbance of the sampled air. We integrated an in-situ sensor to record the CO2 enhancement field above the forest canopy. Test flight results on the flanks of Turrialba volcano in Costa Rica above forest canopies covering known moderate gas seeps demonstrate the sUAS-borne detection and mapping capabilities of above-canopy elevated CO2 gradients. The strong detection capabilities and high detector signal stability resulted from key system design elements including RF shielding, mechanical stabilization, and calibration procedures. This highly robust system is readily applied for diffuse volcanic CO2 emission studies on active volcanoes covered by dense vegetation.