Geophysical Research Abstracts
Vol. 20, EGU2018-15993, 2018
EGU General Assembly 2018

UAV based detection and measurement of volcanic plumes at Volcán de Fuego, Guatemala

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Many active volcanoes still lack regular, quantitative monitoring due to the hazards inherent in undertaking direct measurements that require in-plume or vent proximal measurements. Volcán de Fuego, Guatemala, is one of Central America's most active volcanic systems, and has more than one hundred thousand people living within ten kilometres of the summit, many of them in profound poverty. Frequent ash-rich explosive activity and steep topography present significant access challenges with unacceptably high risk, therefore eliminating some traditional ground based measurements, and manned aircraft flights. A research team comprising engineers and scientists from the Universities of Bristol, Cambridge, and Birmingham, supported by sensor developers and the local monitoring institute (INSIVUMEH), have been developing and deploying a variety of Unmanned Aerial Vehicle (UAV) systems to study Volcán de Fuego. Crucially, UAVs offer the opportunity to observe, map, and quantify gas and tephra emissions, lava extrusion rates and heat flux, and model dynamic topography from a safe distance. However, the closest operators can approach to the volcano is approximately 2.5 km from the summit of a neighbouring peak, necessitating the use of systems capable of beyond visual line of sight (BVLOS) flight.

During 2017, three UAV-based field expeditions were conducted making use of both fixed-wing and rotary-wing type vehicles. The team have observed and quantified changes in the summit morphology immediately prior to a paroxysmal eruption, mapped the key drainage systems after a large eruption on 5 May 2017 deposited large volumes of pyroclastic material, and performed in-plume sampling of tephra and gases (CO_2, SO_2, H_2S, HCl) using a range of onboard instruments.

A particular engineering focus has been to completely automate the operation of a fixed-wing vehicle capable of flying from the local INSIVUMEH observatory into both the distal and proximal volcanic plume. This flight path required achieving a maximum range of 8km and altitudes of 4100m above sea level. Catapults were used to automate the take-off process, significantly increasing the reliability and reproducibility of take-off in hot high conditions with little or no headwind. Pre-programed waypoint missions then allowed the vehicle to automatically fly to the summit region, intercept the plume, and return for landing. An analysis of the sensor data and the autopilot log files revealed that there are clear indications when the UAV enters a plume; for example, a reduced throttle command due to rising air, and increased vibrations and turbulence detected by accelerometers. The next stages of this research campaign research will focus on the further automation of BVLOS flights, including automatically searching for, and loitering in, the plume based on real-time on-board processing and interpretation of sensor data.

Details of the UAV systems and their operation will be presented alongside an overview of the scientific outcomes.