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Developing and testing a low cost method for high resolution measurements of volcanic water vapour emissions at Vulcano and Mt. Etna

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The most voluminous of emissions from volcanoes are from water vapour (H_2O) (Carroll and Holloway, 1994), however, measurements of this species receive little focus due to the difficulty of independent measurement, largely a result of high atmospheric background concentrations which often undergo rapid fluctuations. A feasible method of measuring H_2O emissions at high temporal and spatial resolutions would therefore be highly valuable. We describe a new and low-cost method combining modified web cameras (i.e. with infrared filters removed) with measurements of temperature and relative humidity to produce high resolution measurements ($\approx$ 0.25 Hz) of H_2O emissions. The cameras are affixed with near-infrared filters at points where water vapour absorbs (940 nm) and doesn't absorb (850 nm) incident light. Absorption of H_2O is then determined by using Lambert-Beer's law on a pixel by pixel basis, producing a high spatial resolution image. The system is then calibrated by placing a Multi-GAS unit within the gas source and camera field-of-view, which measures; SO_2, CO_2, H2S and relative humidity. By combining the point measurements of the Multi-GAS unit with pixel values for absorption, first correcting for the width of the gas source (generally a Gaussian distribution), a calibration curve is produced which allows the conversion of absorption values to mass of water within a pixel. In combination with relative humidity measurements made outside of the plume it is then possible to subtract the non-volcanic background H_2O concentration to produce a high resolution calibrated volcanic H_2O flux. This technique is demonstrated in detail at the active fumarolic system on Vulcano (Aeolian Islands, Italy). Data processing and image acquisition was completed in Matlab® using a purpose built code. The technique is also demonstrated for the plume of the North-East Crater of Mt. Etna (Sicily, Italy). Here, contemporaneously acquired measurements of SO_2 using a UV camera, combined with gas ratios in the plume, allow for the first comparison between CO_2, SO_2 and H_2O emissions at high resolution, however, calibration and conversion to real H_2O values in this instance is more complex and problematic. Although, non-calibrated measurements still prove useful by providing a basis for comparing periodicity with other gas species. Indeed, in tandem with recent observations of CO_2 and SO_2 flux at Mt. Etna (e.g. Tamburello et al. 2013; Pering et al. 2014), H_2O emissions also demonstrate periodicity over similar periods to those previously observed.