Researchers analyze volcanic gases with the help of ultra-lightweight sensor systems

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The observation drone ('little-RAVEN') during a flight test (Photo taken by T. Hoffmann). Credit: *Scientific Reports* (2022). DOI: 10.1038/s41598-022-21935-5

The main gases released by volcanoes are water vapor, carbon dioxide, and sulfur dioxide. Analyzing these gases is one of the best ways of obtaining information on volcanic systems and the magmatic processes that are underway. The ratio of carbon dioxide levels to those of sulfur dioxide can even reveal the likelihood of an impending eruption. Drones are employed to carry the necessary analytical systems to the site of activity. However, because of their size, transporting the drones to their operation sites has to date required significant expense.

A team headed by Professor Thorsten Hoffmann at Johannes Gutenberg University Mainz (JGU) has recently been assessing the potential for using a small, portable observation drone in remote regions. This very compact drone system can even be conveyed on foot to sites that are extremely difficult to access. In addition, it requires only minimal flight and administrative preparations for operation as an aerial observation platform.

Eruptions can be predicted on the basis of volcanic outgassing

Gas discharges from volcanoes mainly consist of water vapor, carbon dioxide, and sulfur dioxide. Released gas emissions are among the few chemical signals that provide evidence of the processes occurring in magmatic systems that are located deep below the surface and are thus otherwise inaccessible. For some time already, researchers have assumed that the analysis of such volatile emissions could play a central role in improving the prediction of volcanic eruptions. A particularly promising parameter when it comes to the surveillance of changes to volcanic activity is the ratio of concentration of carbon dioxide to sulfur dioxide in the released gases. In fact, alterations to this ratio have been observed immediately prior to eruptions of several volcanoes, among which was Etna.

Unfortunately, the practical side of compiling a continuous time series of gas compositions represents a major challenge. Direct manual sampling by means of climbing the volcano is arduous and time-consuming, not to mention the potential dangers should an eruption suddenly occur. On the other hand, stationary monitoring equipment often does not record representative data on gas compositions, mainly due to changing wind directions.

Measurement drones can overcome these problems and have already been used to measure the chemical characteristics of volcanic gases. In particular, the risk to volcanologists of being endangered by sudden changes in volcanic activity is significantly reduced by the greater distances involved. Moreover, drones make it possible to reach emission sources that are otherwise difficult or even impossible to access, such as fumaroles in steep, slippery terrain or older parts of the plume that are typically located in downwind areas and at higher altitudes.

Only larger drones have so far been employed for the monitoring of volcanoes and, of course, this has proved problematic in view of the remoteness of the regions in which most volcanoes are to be found. "It is for this reason that small, easily transportable drones are an essential prerequisite if we want to get to isolated or difficult-to-access volcanic sites and suitably track the activity there," said Niklas Karbach, lead author of the corresponding paper that has recently been published in *Scientific Reports*.

Small drone system that can be carried in a backpack

In collaboration with volcanologist Dr. Nicole Bobrowski of Heidelberg University and the National Institute of Geophysics and Volcanology (INGV) in Catania, the Mainz-based research team has been trialing a tiny commercial drone weighing less than 900 grams equipped with miniaturized, lightweight sensors. This combination that weighs no more

than a bottle of mineral water could be transported easily to the scene in a backpack. But it is not just the weight of the drone that is crucial.

"We need to obtain real-time data on sulfur dioxide levels as this lets us know when we are actually in contact with the volcanic plume, something that readily moves over time in response to atmospheric factors. The localization of a plume by visual means alone from a distance of several kilometers is practically impossible," added Professor Hoffmann, head of the JGU group.

More information: Niklas Karbach et al, Observing volcanoes with drones: studies of volcanic plume chemistry with ultralight sensor systems, *Scientific Reports* (2022). DOI: 10.1038/s41598-022-21935-5

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