Meteorological interactions with volcanic plumes in the moist tropics: implications for volcanic plume monitoring

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The development of the International Airways Volcano Watch in the early 1990s created an operational requirement for real time global monitoring for volcanic ash at all observable concentrations (more recently formalised as visible or discernable ash through the work of the International Volcanic Ash Task Force). One of the more interesting areas of the world to do that has been the moist tropics, with many active volcanoes, relatively poor seismic monitoring, and a highly active atmosphere dominated by deep convection.

The frequency of showers and thunderstorms (particularly around volcanoes and other mountains), poor observing conditions on the ground, satellite obscuration by long-lasting cirrus anvils, and challenges in funding and maintaining ground based infrastructure such as radar and lidar together mean that the occurrence and heights of volcanic plumes have certainly been under observed in the moist tropics. Volcanic Ash Advisory Centre data also demonstrates a strong observational bias towards the drier seasons. As a result, even large eruption plumes such as from the 2010 eruptions of Merapi in Indonesia can be very difficult to monitor.

In addition, within a moist tropical environment there is an active interplay between active volcanoes and the meteorological environment. In an unstable or potentially unstable environment, tropical convection to high altitudes (17+ km) is frequently triggered by very subtle influences such as low level sea breezes or differential heating. Modelling suggests and observations demonstrate that active volcanoes, with a range of influences extending to the very unsubtle, can act as triggers to produce volcanic cumulonimbus such as those observed at Pinatubo, or volcanic plumes that have been very significantly increased in height and in ice content through moist convective processes. Eruption heights tend to cluster near the height of the tropical tropopause; relatively weak volcanic eruptions can trigger deep tropospheric convection that transports volcanic material to the tropopause or above. Because of the role of hydrometeors in enhancing particle aggregation and removal, the smaller modelled eruptions also produce a relatively small proportion of fine ash in the umbrella cloud compared to eruptions in a dry atmosphere.

It is therefore difficult to reliably infer the strength of a tropospheric or lower stratospheric volcanic plume in the moist tropics using its reported height alone. Additional volcanological and meteorological observations, including seismic, visual, lidar and radar observations, and geostationary remote sensing can be added to satellite height observations to assist in rapidly assessing eruption magnitude and the real-time response required. Close collaboration between the volcanological and meteorological science communities will help to attain these additional observations on a routine, operational basis.