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Challenges in forecasting eruptions at open-system volcanoes: A case study at Raung volcano, East Java, Indonesia

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Raung volcano is an open-system, basaltic-andesite volcano in East Java, Indonesia that has been continuously active since the installation of a seismic network in 2011. Significant increases in activity in 2012 and 2015 preceded eruptive episodes. Visual analysis of the monitoring data suggests almost no differences between precursory activity in 2012 and 2015 even though the final outcomes of these eruptions were very different. In both instances, RSAM (Real-Time Seismic Amplitude Measurement) levels increased and seismicity was dominated almost entirely by tremor. Both eruptions led to Strombolian activity and a series of VEI 1-2 explosions that were contained in the summit crater. The 2012 eruption returned to background after several months, whereas the 2015 activity progressed to a VEI 3 eruption that ejected bombs beyond the summit crater walls and produced an ash column that closed multiple regional airports. The only obvious difference between precursory seismicity in 2012 and 2015 was the occurrence of small volcano-tectonic (VT) swarms amidst tremor episodes in 2015. Generally, CVGHM (Indonesia's Center for Volcanology and Geologic Hazard Mitigation) and VDAP (Volcano Disaster Assistance Program) interpret VT swarms as a sign of pressurization and a harbinger for a larger eruption. The swarms at Raung, however, were too small (< 5 events; max M < 2) to confidently forecast increased activity. We use cross correlation techniques on discrete low frequency events to look for changes in event families following the occurrence of VT swarms in 2015. Results show that families of low frequency events changed with time following VT swarms in 2015. These results suggest that the VT swarms at Raung indicated changes in the magmatic system despite their minimal moment release. The results should also inform CVGHM and VDAP about possible precursors to more vigorous activity at open-system volcanoes where monitoring data is limited.