EGU2020-12683
https://doi.org/10.5194/egusphere-egu2020-12683
EGU General Assembly 2020

Pre-eruptive diffuse heating of volcanoes

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Identifying the observables that warn of volcanic unrest and impending eruptions is one of the greatest challenges in the management of natural disasters. An important but scarcely explored observable is diffuse heating, that is, the heat released passively through the ground. Diffuse heating represents one of the major energy sources in active volcanoes during inter-eruptive periods, and can dominate over the elastic energy released during seismic and deformation events. However, many questions remain open: Is there a direct correlation between diffuse heating and the subsurface processes that precede volcanic eruptions? To what extent are volcanic eruptions preceded by an enhancement of the diffuse emissions of heat? We address these questions by analyzing 16.5 years of long-wavelength (10.780 – 11.280 μm) thermal infrared radiance data recorded over nine volcanoes by the moderate-resolution imaging spectroradiometers (MODIS instruments) aboard NASA's Terra and Aqua satellites; this amounts to >35 TB of data and >210,000 MODIS scenes. Our statistical analysis reveals that volcanic edifices get warm for several years before magmatic, phreatic and hydrothermal eruptions. This pre-eruptive warming has been observed at Ontake (Japan), Ruapehu (New Zealand), Domuyo (Argentina), Calbuco (Chile), Redoubt and Okmok (Alaska), Pico do Fogo (Cape Verde), El Hierro (Spain), and Agung (Indonesia) volcanoes. In particular, we found pre-eruptive increases of up to ~1.5 K in the median temperature of the volcanic edifices; this, based on an energy balance, reflects increases of heat flux of up to 10 W/m^2. We theorize that the pre-eruptive surface warming of volcanoes is the surface manifestation of shallow hydrothermal activity. Our retrospective analysis is especially relevant, since several of the eruptions analyzed did occur with little or no warning (e.g., the 2014 phreatic eruption of Ontake and the 2015 magmatic eruption of Calbuco). The possibility of tracking temporal changes of diffuse heating using satellite data opens new horizons to study the thermal reactivation of magma reservoirs and improve the forecasting of volcanic eruptions.