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Analytical approach on the link between the Earth tidal potential and volcanic degassing

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The tidal forces periodically deform the Earth's surface and interior. The predominant periodicities of this deformation are semi-diurnal or diurnal, depending on the latitude. The magnitudes of these variations are modified within the spring-neap tide cycle with a periodicity of about 14.8 days. Evidence for tidal impacts on volcanism has been reported since the 1960s from different proxies such as the coinciding timing of Earth tidal extrema and volcanic eruptions or seismic events, and correlations between tidal patterns and volcanic deformation or degassing patterns.

We aim to understand the about biweekly periodic pattern observed in the gas emissions of several volcanoes in the recent decade. The tidal stresses may influence the volcanic degassing on several ways such as a widening of tectonic structures, a periodic decompression of the host rock, a self-sealing of hydrothermal fractures, and a mechanical excitation of the uppermost magmatic gas phase. Additionally, the tide-induced local gravity variations may cause a periodical vertical magma displacement. While debated for long, no quantitative model of a causal link from the tidal potential to variations in the volcanic degassing has yet been proposed.

We model the response of a simplified magmatic system on the gravity variations by an analytical approach and discuss the resulting consequences. We derive for simplified model versions of the Villarrica and Cotopaxi volcanoes vertical magma displacements with an amplitude of only 0.1-1 m, depending on geometry and physical state of the magmatic system. Vertical magma displacements of such a small amplitude have presumably no significant direct effect on the volatile solubility. But we show that the inhomogeneous magma flow profile across the radial conduit caused by the vertical magma displacement may result in a significant increase of the bubble coalescence rate by up to several ten percent in a depth of several kilometres. The bubble coalescence rate is often a major driver of the volcanic volatile degassing rate. We argue that - if the degassing is governed by the bubble coalescence rate - the derived tidal variation may propagate to a manifestation of varying volcanic degassing behaviour.