Spatial and temporal tilt maxima of an ascending Mogi source

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Joint seismological and deformation analyses are of great importance for studying the dynamics of magmatic processes at active volcanoes. While InSAR only provides informations about the present state of deformation and longterm variations at volcanic systems, high resolution GPS and especially tilt measurements can deliver valuable insights into ongoing short term magma accumulation processes and magma movements.

This study analyses temporal variations of tilt maxima, measured at the Columbo submarine volcano, north of Santorini (Aegean Sea, Greece), during an earthquake swarm in July 2006. Microearthquakes of the swarm have been relatively relocated using the data of an amphibian network of land- and ocean bottom seismometers. By investigating event densities over time, an ascent of the main seimic cluster with velocities of around 15 cm/s has been observed. Simultaneous, ocean bottom tiltmeters deployed on a profile over the volcano were showing increasing tilt radial to the earthquake cluster, i.e. uplift of the epicentral region. For larger epicentral distances, the maximum of the tilt signal was reached at an earlier point than on tiltmeters closer to the source, before retreating rapidly. This time shift can not be described by a volume source at a fixed location, but rather reflects the dependency of the wavelength of the deformation signal on the varying depth of the source.

Using the simplified model of an upwards migrating Mogi source, time shift and amplitude changes between the observed maxima could be reproduced numerically and analytically. The timing of the observed tilt maximum at a certain epicentral distance is depending on the initial depth and ascent velocity of the source. This temporal maximum differs from the spatial maximum of the whole tilt field due to the exponential increase of the amplitude for decreasing source depths, i.e. the tilt amplitude temporarily increases further although the spatial maximum has already passed the tiltmeter. The temporal maximum can be calculated as the envelope of tilt functions by deviating the Mogi equations with respect to depth and epicentral distance. Subsequently, the ascent velocity of the source can be determined by using the time shift between the temporal maxima on tiltmeters at varying distances. For our observations at Columbo, the obtained results are in good agreement with the vertical migration velocity of the seismic cluster.