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Modelling of thermal contraction of emplaced lava flows at Hekla volcano

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During and after the emplacement of magma the flow cools down and undergoes thermal contraction. This latter process leads to subsidence of the emplaced lava relative to its surrounding area, and thus masking the overall current crustal movement due to magma pressure changes in the volcanic system. Other effects such as void space compaction and the bending of the underlying elastic crust due to the weight of the lava accompany the emplacement and lead to further complications regarding the studies of thermal contraction. Interferometric synthetic aperture radar (InSAR) provides good possibilities for the detection and resolution of vertical movements around a volcano because of high spatial resolution and good accuracy during favorable conditions. Comparisons of the interferograms with the outline of lava flows at e.g. Hekla volcano or Mount Etna agree well with areas of higher subsidence or minor uplift, respectively, being taken as an eclipsing of the above-mentioned effects. Interferograms from 1993 to 2012 give evidence that the lava fields of the Hekla eruptions in 1991 and 2000 are continuously subsiding. Even there are several publications dealing with such observations, models taking into account a physical basis for thermal contraction are currently spare.

Nevertheless, several theoretical approaches state the time-dependent temperature distribution within a lava flow taking into account heat-flow processes. On the basis of these calculations, we have developed a one-dimensional numerical model that shows the subsidence and subsidence rate after a certain time after emplacement. The model takes into account the conduction of heat away from the fluid magma towards the magma-air interface and the magma-rock interface. Furthermore, contraction at the transition boundary between the liquid phase of magma and the solidified gabbro are considered to be in the range of volume change of 9% according to density measurements. After full solidification the temperature distribution is calculated using the heat diffusion equation, with boundary conditions that take into account the heat loss to the air. The subsidence decreases after the solidification time to less than 0.5% per year. The model is to be extended in dimensions and the resulting annual subsidence rate compared with crustal deformation measurements at Hekla volcano in Iceland based on interferometric SAR data.