Explorative source models

In order to determine a free geometry rather than a finite geometry for the causative source(s), we performed a non-linear inversion using the inversion package GROWTH 2.0 (Camacho et al. 2011). The inversion is based on a 3-D aggregation of M parallelepiped cells, which are filled, in a growth process, by means of prescribed positive and/or negative density contrasts. This methodology provides, via an automatic approach, a free 3-D geometry of the anomalous body, which matches as much as possible the observed gravity anomaly. A full treatment of the inversion routine is beyond the scope of this paper; the reader is referred to (Camacho et al. 2011) for detailed information. For our model, we partitioned the subsurface volume of Montserrat into approximately 4,750,000 parallelepiped cells with sides of around 130 m. Note, that due to the inability to capture the full wavelength of the anomaly (because of benchmark distribution and on-shore accessibility), the inversion cannot provide a unique solution for the maximum extent of the gravity anomaly at depth. Also, the design of the network with a distance of 1.5 km between neighbouring stations doesn't allow for modelling very shallow sources. Hence, the inversion procedure for the given setting is only sensitive to source depths between 1.5 and 4 km. We further needed to adapt density contrasts (-13 to 13 kg/m^3) lower than are probably realistic. This is because the inversion condition of maximum smoothness, i.e., minimum anomalous mass distribution within the sub-surface, tends to fit small gravity anomalies (as is the case in this study) using compact spheroidal anomalous bodies. Inverting the gravity residuals for the given density contrasts, we obtain models, which show cylindrical to slightly flattened (i.e., dyke-like) structures that are WNW-ESE directed, dipping steeply towards ESE (Fig. S1 and S2). The inferred sources are situated in the western Centre Hills, matching the locations of source centres for the finite source models. The inferred mass loss during the first survey interval is 1.4×10^{10} kg, while the inferred mass gain during the second observation period is 5.5×10^{10} kg. The weighted standard deviation of the inversion residuals is within 16 nm/s^2, representing an excellent quality of fit-to-the-data. Increasing the density contrast by one or two orders of magnitude, however, results in an almost spherical anomalous body, while significantly deteriorating the quality of fit.

The model results support our a priori assumptions on source orientation and location. The results of the explorative approach indicate that the time-lapse gravity anomalies are caused by cylindrical to dyke-like sources. Note, however, that the inversion fails to resolve sources at very shallow depths, i.e., sources with a sill geometry. We therefore cannot unambiguously deduce on dykes as the causative source geometry behind the gravity variations.

Camacho, A.G., González, P.J., Fernández, J. & Berrino, G. 2011. Simultaneous inversion of surface deformation and gravity changes by means of extended bodies with a free geometry. Application to deforming calderas. *Journal of Geophysical Research*, **116**, B10401, doi:10.1029/2010JB008165.

Figure S1: Results of gravity inversion of time-lapse data from the first observation interval (June/July 2006 - Jan/Feb 2007) based on a free geometry approach. The inferred source is a cylindrical to dyke-like structure that is oriented WNW - ESE, dipping steeply towards ESE. Weighted standard deviation of inversion residuals is 16 nm/s^2.

Figure S2: Results of gravity inversion of time-lapse data from the second observation interval (Jan/Feb 2007 - Aug/Sept 2008) based on a free geometry approach. Similar to model results from the first monitoring interval is the inferred source of cylindrical to dyke-like geometry and oriented WNW - ESE, dipping steeply towards ESE. The centre of the anomalic source of the second interval is, however, located about 3 km south of the source location inferred for the first interval. Weighted standard deviation of inversion residuals is 15 nm/s^2.