Automatic real-time estimation of plume height and mass eruption rate using radar data during explosive volcanism

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Plume height and mass eruption rate are the principal scale parameters of explosive volcanic eruptions. Weather radars are important instruments in estimating plume height, due to their independence of daylight, weather and visibility.

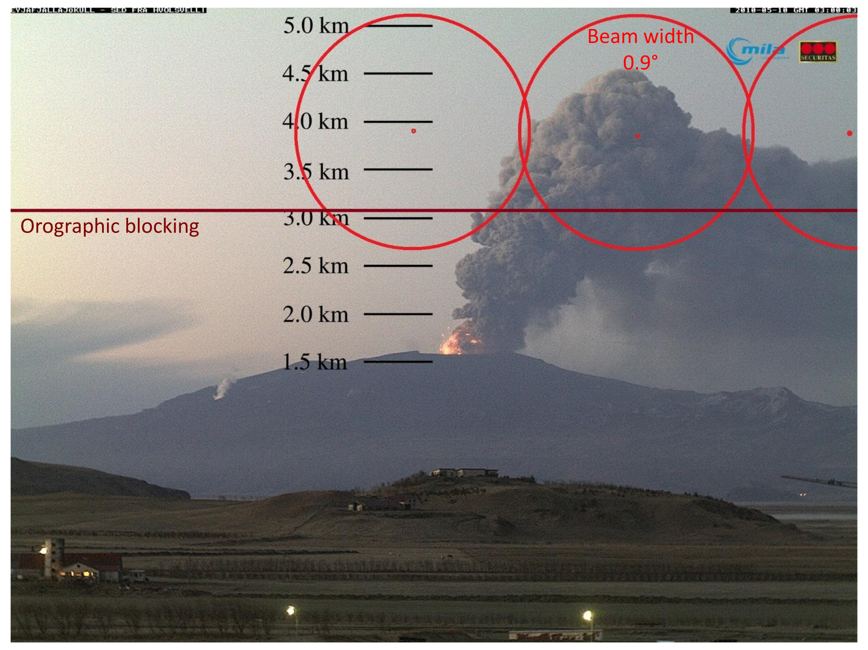

Figure 1. Radar Beam Width at 150 km. View of Eyjafjallajökull from a web camera at Hvolsvöllur, 10 May 2010 at 03:00.

Validation of Radar Height Estimates

Web camera images from Hvolsvöllur during the Eyjafjallajökull 2010 eruption were used to estimate plume height (Arason et al., 2011). This time series has now been wind corrected and compared to the automatic determination of radar heights.

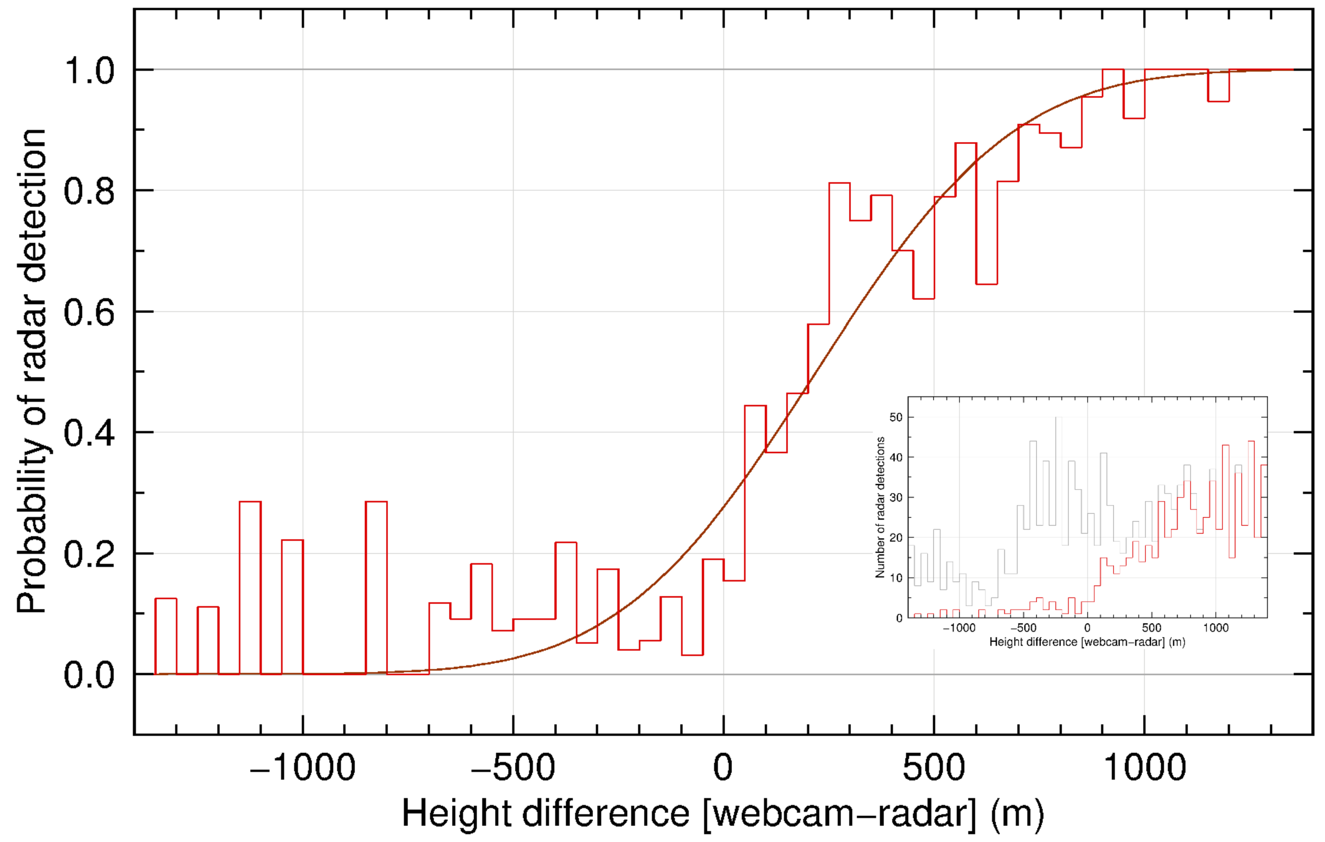

Figure 2. Radar – Web Camera Validation. Comparison of the wind corrected plume height of web camera images and the radar detection at elevation 0.9° (about 4 km) during the Eyjafjallajökull eruption. The webcam-height usually needs to be slightly higher than the center-beam radar-height. For comparison we plot the erf-function (integral of the normal distribution) for $\mu = 220$ m, $\sigma = 370$ m.

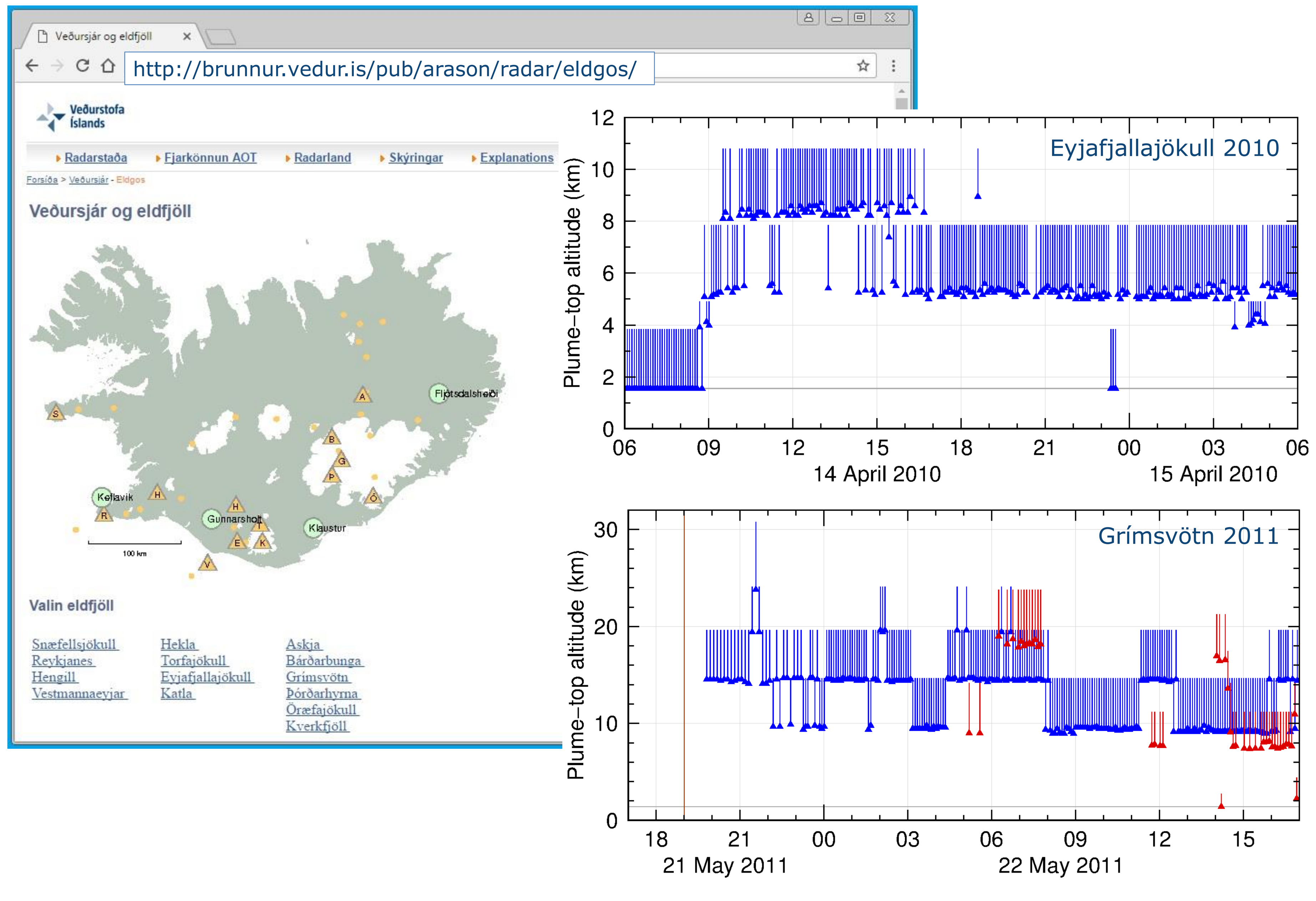

Figure 3. Automatic System to Estimate Plume Heights. Graphs showing plume-top altitude estimates during the first 24 hours of Eyjafjallajökull 2010 and Grímsvötn 2011.

Automatic Determination of Plume Height

The Icelandic Meteorological Office (IMO) operates two fixed position C-band weather radars and two mobile X-band radars. All volcanoes in Iceland can be monitored by IMO's radar network, and during initial phases of an eruption all available radars will be set to a more detailed volcano scan.

When the radar volume data is retrived at IMO-headquarters in Reykjavík, an automatic analysis is performed on the radar data above the proximity of the volcano. The plume height is automatically estimated taking into account the radar scanning strategy and beam width. This analysis provides a distribution of the likely plume height.

Figure 4. Icelandic Radar System. (a) The Keflavík C-band weather radar, (b) Huginn mobile X-band radar, (c) Radar reflectivity during the Grímsvötn 2011 eruption measured by a mobile radar. Photos Þórður Arason and Geirfinnur S. Sigurðsson.

Inversion for Source Parameters

The automatically determined plume height estimates from the radar data are used as input to a numerical suite that calculates the eruptive source parameters through an inversion algorithm. This is done by using the coupled system DAKOTA-PlumeMoM which solves the 1D plume model equations iteratively by varying the input values of vent radius and vertical velocity (de' Michieli Vitturi et al., 2015). The model accounts for the effect of wind on the plume dynamics, using atmospheric vertical profiles extracted from the ECMWF numerical weather prediction model.

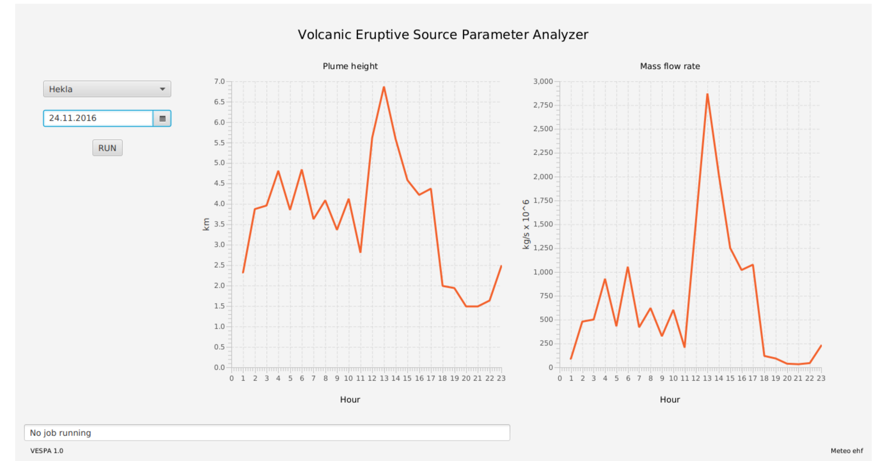

Figure 5. Volcanic Eruptive Source Parameter Analyzer. Interface for the inversion algorithm used to retrieve source parameters that fit the observed plume height.

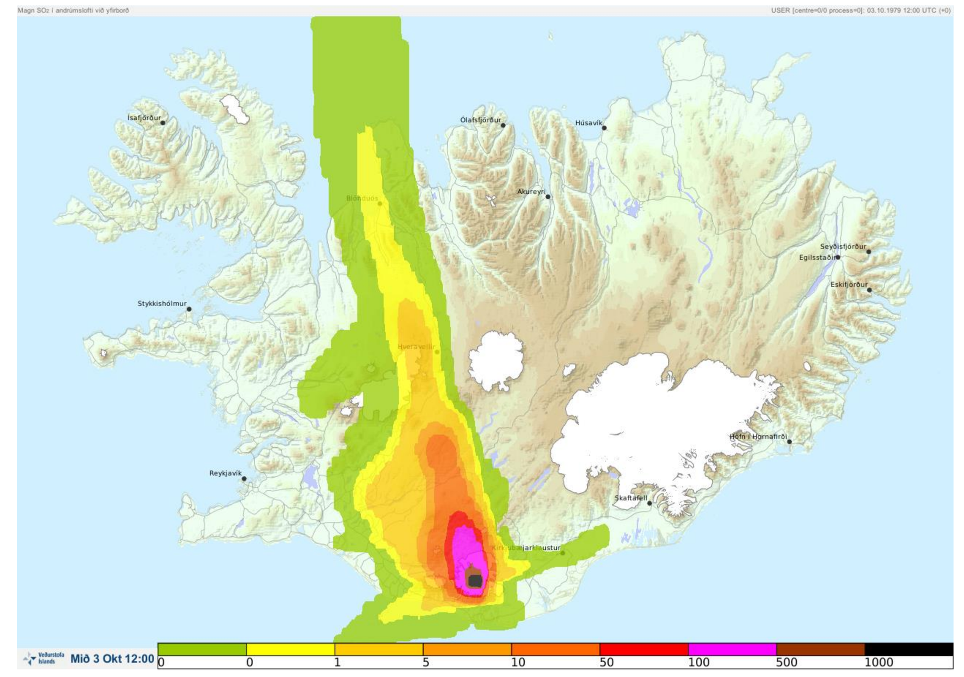

Figure 6. Results of the Ash Dispersal Model. Scenario-based VOL-CALPUFF simulations for Katla 1918 tephra loading computation. Ground deposition (kg/m²) after 20 hours.

Ash Dispersal

The resulting estimates of mass eruption rate are used to initialize the dispersal model VOL-CALPUFF to assess hazard due to tephra fallout (Barsotti et al., 2008), and communicated to London VAAC to support their modelling activity for aviation safety purposes.

Arason, P., G. N. Petersen & H. Bjornsson (2011), Observations of the altitude of the volcanic plume during the eruption of Eyjafjallajökull, April-May 2010, *Earth System Science Data*, **3**, 9-17, doi:10.5194/essd-3-9-2011.
Barsotti, S., A. Neri & J. S. Scire (2008), The VOL-CALPUFF model for atmospheric ash dispersal: 1. Approach and physical formulation, *J. Geophys. Res.*, **113**, B03208, doi: 10.1029/2006JB004623.
de' Michieli Vitturi, M., A. Neri & S. Barsotti (2015), PLUME-MoM 1.0: A new integral model of volcanic plumes based on the method of moments, *Geosci. Model Dev.*, **8**, 2447-2463, doi:10.5194/gmd-8-2447-2015.

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