Mass Eruption Rate Estimates Made During the January 2016 FutureVolc Exercise

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Introduction

Many FutureVolc partners participated in a three-day exercise to practice their responses to precursory signals followed by an eruption in Iceland. Precursory activity included a glacial outburst flood from beneath Mýrdalsjökull, the glacier capping Katla volcano, an increase in the smell of gasses, a significant increase in seismicity, and a steam explosion. Participants reacted by holding scientific advisory board meetings to discuss visual observations, hydrological data, seismic data, infrasound detections, and satellite images. A volcano observatory notice for aviation (VONA) was issued and the aviation color code of Katla was elevated. After the eruption started on the second day of the exercise, observations and measurements of the eruption cloud and the volcanic system were provided by radar-determined plume heights, SEVIRI images, ash size distributions, simulations of tephra ground loading, and the same networks used for the precursory monitoring.

The Mass Eruption Rate was defined by the initiators of the exercise, who used the MER to simulate the eruption plume height (Fig. 1). The simulated plume heights were then used, in conjunction with the geographical relationship between Katla and the nearest radar and its scanning algorithm, to ascertain the plume heights that would be measured by the radar for these "real" plume heights (Fig. 1). Mass Eruption Rates were estimated with REFIR (Fig. 2), PlumeRise (Fig. 3) and Infrasound (Fig. 4).

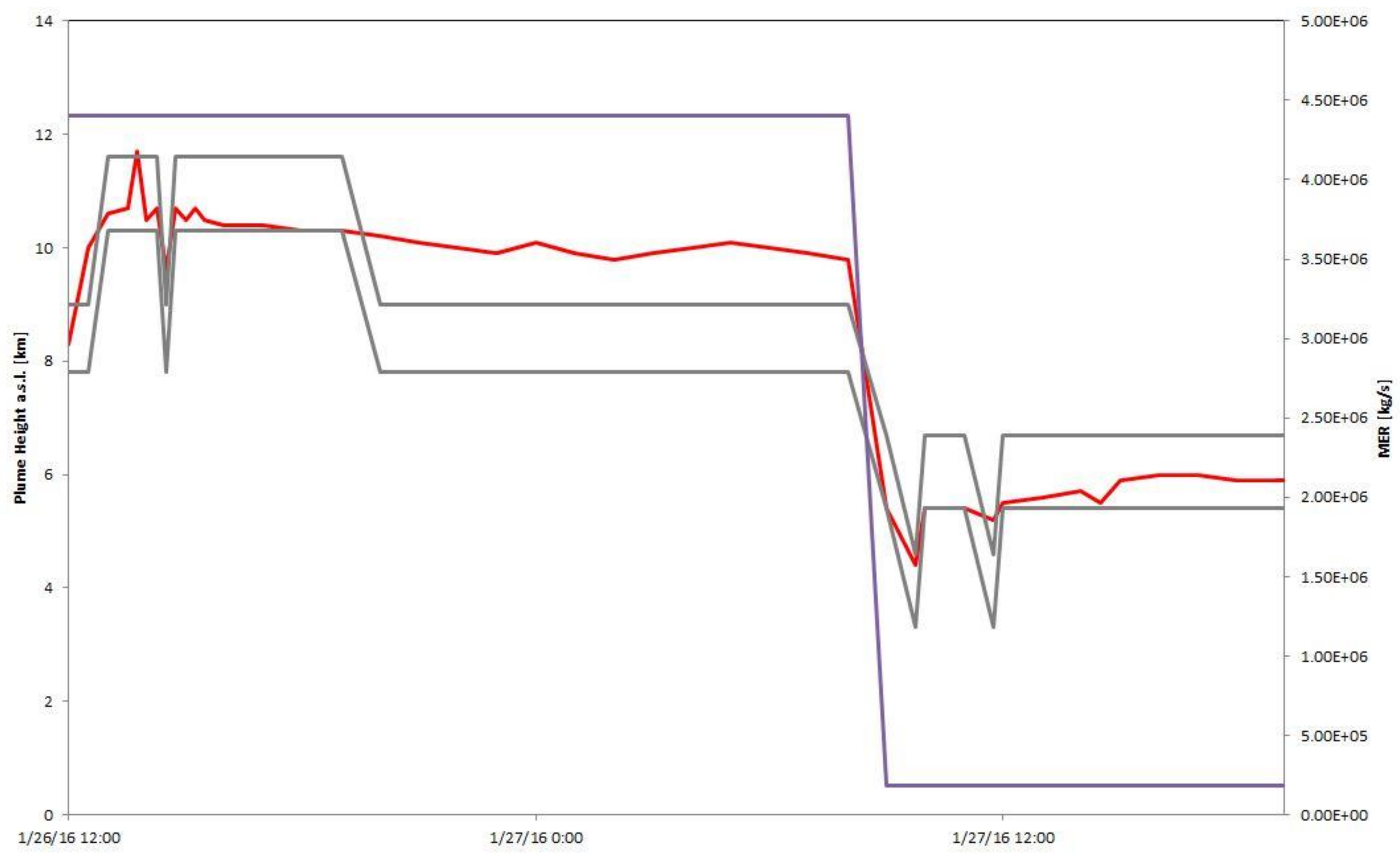

Figure 1: MER defined by the initiators of the exercise (purple). This remained constant, with only one stepwise decrease during the second day of the eruption. The variations in the "real" plume height (red) within the constant MER times was due to changing meteorological conditions. The plume height measured by the radar (grey) has maximum and minimums due to the beam width. The radar-derived plume heights are discretized because the radar scans at set elevation angles.

REFIR

The Real-time Eruption source parameters Futurevolc Information and Reconnaissance system (REFIR) is a multi-parameter system which can receive and combine incoming streaming data from radars and height tracking systems based on visual, UV or IR cameras. The observations of plume height are the primary input parameter which are integrated with a suite of plume models to provide a range of possible MERs (Dürig et al. 2016).

PlumeRise

PlumeRise is an integral model of wind-blown volcanic plumes. The atmospheric conditions are specified using radiosonde soundings. An automated system using PlumeRise has been developed for Icelandic volcanoes, with atmospheric soundings made at Keflavík relayed from IMO. The arrival of new sounding data triggers a suite of PlumeRise model calculations that vary across uncertain parameters (vent size, exit velocity, magmatic temperature and solids fraction), producing a set of MERs with corresponding plume heights (Woodhouse et al. 2013).

Infrasound

Infrasonic waves produced by volcanic activity can be related to the intensity of an eruption. An infrasonic array signal processing algorithm discriminates signals from noise in terms of wave propogation back-azimuth (direction of the signal relative to the array), apparent velocity (information on source elevation) and time residual (signal/noise indicator). This data is processed in order to calculate the plume exit velocity, which is in turn used to estimate the mass flow rate across uncertain parameters (vent diameter and mixture density; Ripepe et al. 2013).

Calculated Mass Eruption Rates

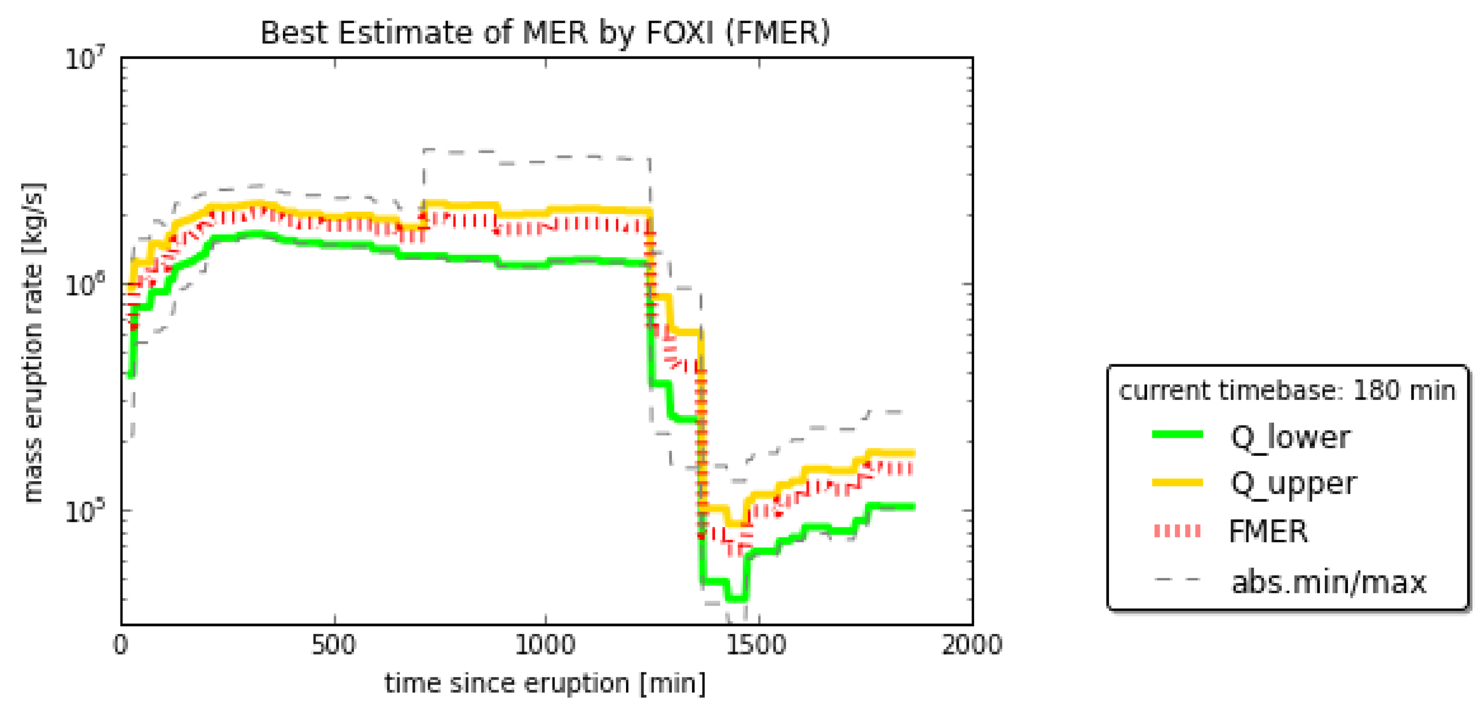

Figure 2: MER calculated using REFIR for the full eruption.

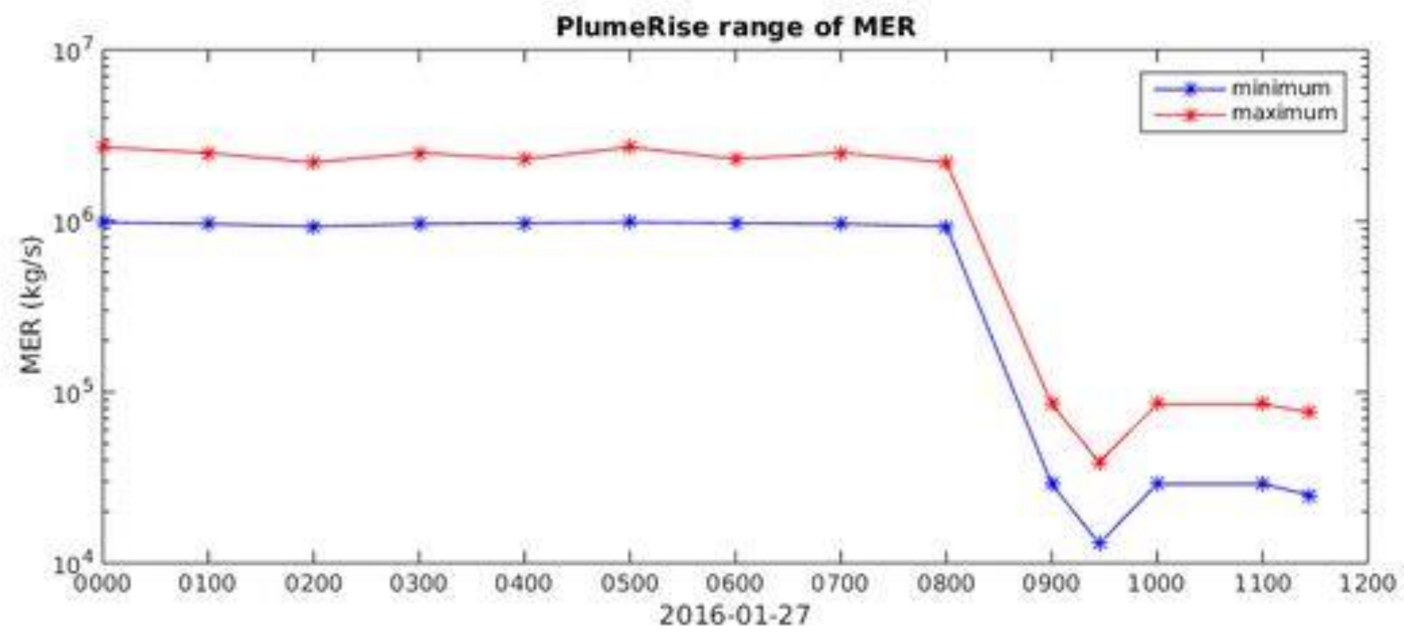

Figure 3: MER calculated using PlumeRise for the second day of the eruption.

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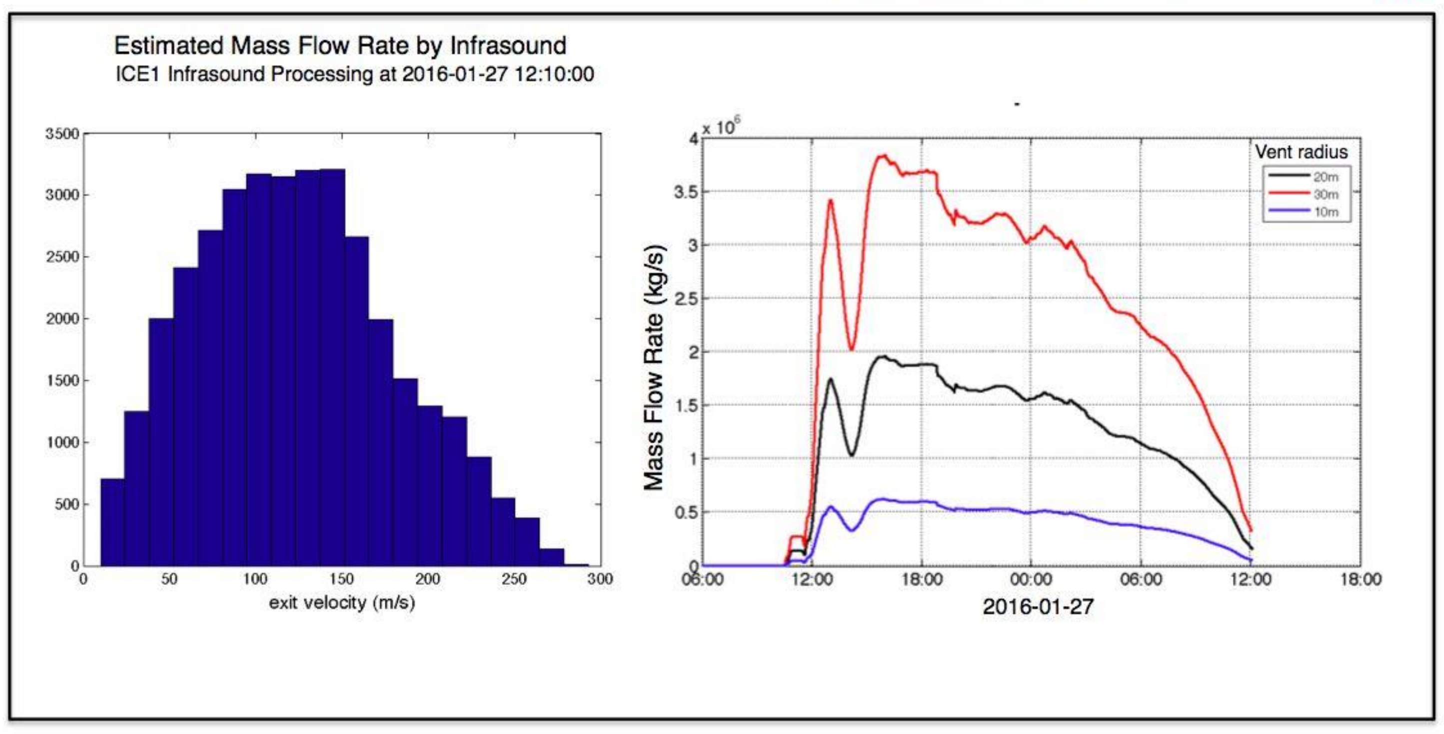

Figure 4: MER calculated using Infrasound for the full eruption.

Conclusions

All three approaches calculated MERs that agreed with the "truth" within each approach´s individual uncertainty. REFIR and PlumeRise MER determinations are both reliant on plume height observations, with all of the associated uncertainties, and on a calculated relationship between plume height and mass eruption rate, with its own set of uncertainties. The Infrasound approach is independent of these factors, however with its own assumptions and uncertainties. This ensemble-like approach of merging the results of independent methods to provide an envelope of reasonable solutions is bringing us ever closer to a quickly derived, robust solution for this important eruption parameter.

During the exercise, several questions arose.

- Is the reported plume height the plume top or the plume centerline?
- Is the plume height above vent or above sea level?
- What is the uncertaintly of the plume height measurement?
- How are we constraining the other uncertain variables, such as vent diameter, exit velocity, gas fraction in the magma, and magma temperature?
- Can providing an envelope of solutions be less useful/more confusing than providing a best-guess solution?

It is very important that as we communicate results from observations to model input and subsequently from model results to downstream users, we are explicit about what we are communicating and that it is communicated in the way that is easiest to understand and utilize.

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Dürig et al. 2016: REFIR – The operational FutureVolc multi-parameter system providing a best estimate of mass eruption rate during ongoing eruptions in near real-time. Geophysical Research Abstracts Vol. 18, EGU2016-13437-1, 2016 EGU General Assembly 2016.
Woodhouse et al. 2013: Interaction between volcanic plumes and wind during the 2010 Eyjafjallajökull eruption, Iceland, Journal of Geophysical Research: Solid Earth 118, 92–109.
Ripepe et al. 2013: Ash-plume dynamics and eruption source parameters by infrasound and thermal imagery: The 2010 Eyjafjallaj-kull eruption, Earth and Planetary Science Letters, v366, 112-121.