Real-Time Estimation of Mass Eruption Rate and Ash Dispersion During Explosive Volcanism

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VO52A-1

Why Provide Eruptive Source Parameters?

Icelandic Met Office

During explosive volcanic eruptions it is important to have access to timely and reliable time series of plume height and mass eruption rate to assess the intensity and potential impact of the event

The primary users in our case are

- The Icelandic Civil Protection and Emergency Management
- The Icelandic Aviation Service Provider (Isavia)
- London VAAC (Volcanic Ash Advisory Center)
- The scientific community using our time series as input data for various simulations of the impact on ground, atmosphere, local population and air traffic

Weather Radars
Two fixed position C-band and two mobile X-band


Keflavík SW-Iceland C-band radar.
Photo Þórður Arason 9 August 2011

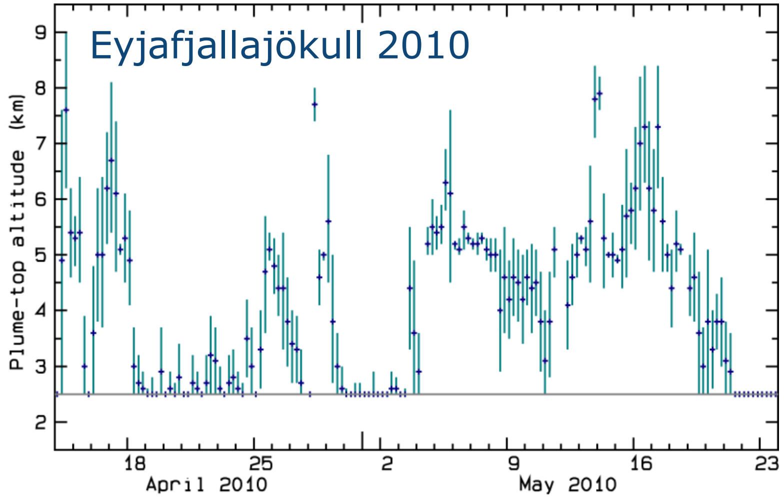
Specially adapted truck to take mobile radar off road.
Photo Geirfinnur S. Sigurðsson 25 September 2012


Fljótsdalsheiði E-Iceland C-band radar.
Photo Geirfinnur S. Sigurðsson 8 October 2012

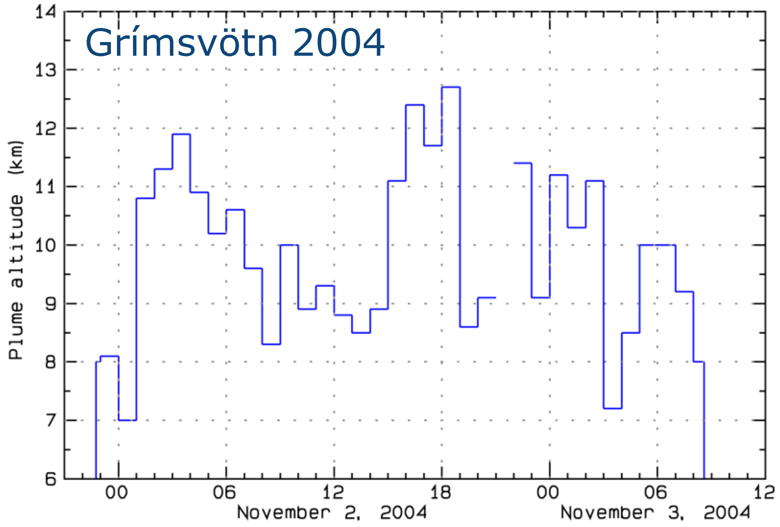

Fljótsdalsheiði
Keflavík
Gunnarsholt
Klaustur
100 km

Plume Height Time Series
Manually estimated from radar images

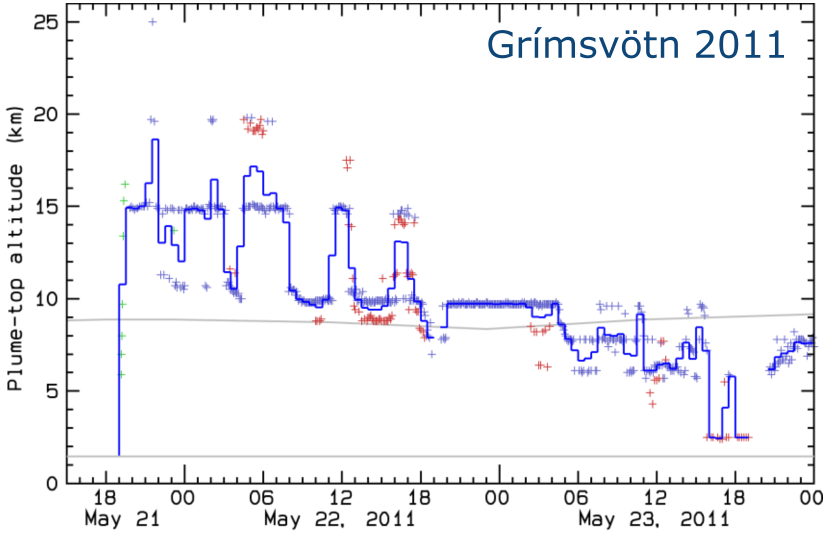
Arason et al. (2011)



Vogfjörd et al. (2005)



Petersen et al. (2012)



The VESPA System

Volcanic Eruptive Source Parameter Assessment

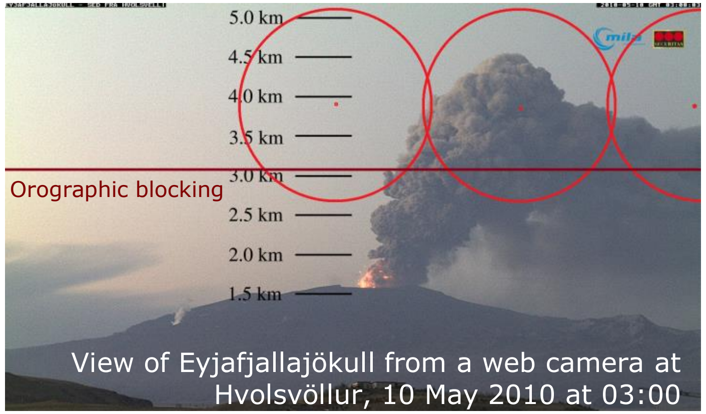
Icelandic Met Office

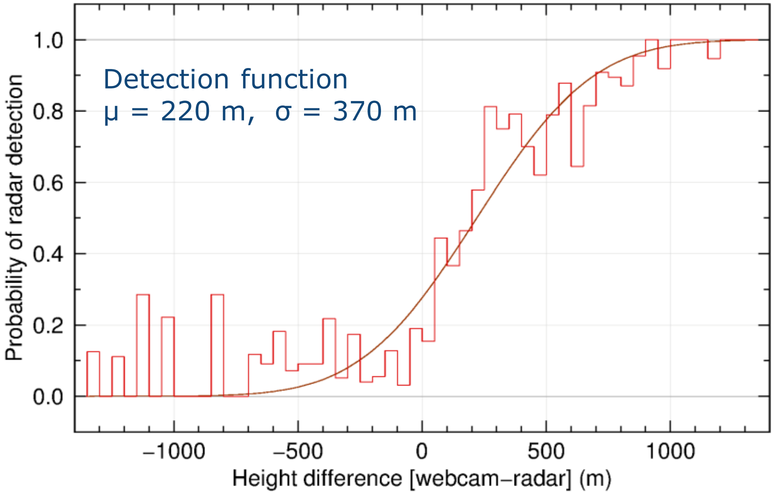
Integrated automatic real-time system

1. **Eruption Onset:** Manually estimated
2. **Plume Height:** Weather radar data are used to estimate plume height over volcano every hour
3. **Source Parameters:** Inversion for source parameters in the 1D DAKOTA PlumeMoM model using the radar plume height and vertical atmospheric profile from the ECMWF numerical weather prediction model
4. **Ash Dispersal:** Initialization of the dispersal models VOL-CALPUFF and NAME with the estimated source parameters and weather data

Plume Height Estimation
Hourly mean plume height and uncertainty

- For each radar scan two heights are determined, H1 the highest point where a significant radar reflection was detected within 10 km distance of the volcano, and H2 the height of the next radar elevation angle above volcano, where plume was not detected
- Single radar scan height is estimated as the mean of H1 and H2, taking into account our detection function and the uncertainty as the standard deviation of a likely distribution between H1 and H2
- Plume height on the hour is estimated as the mean, weighted by uncertainties, for all scans between 30 min before the hour and 30 min after the hour (4-48 scans)

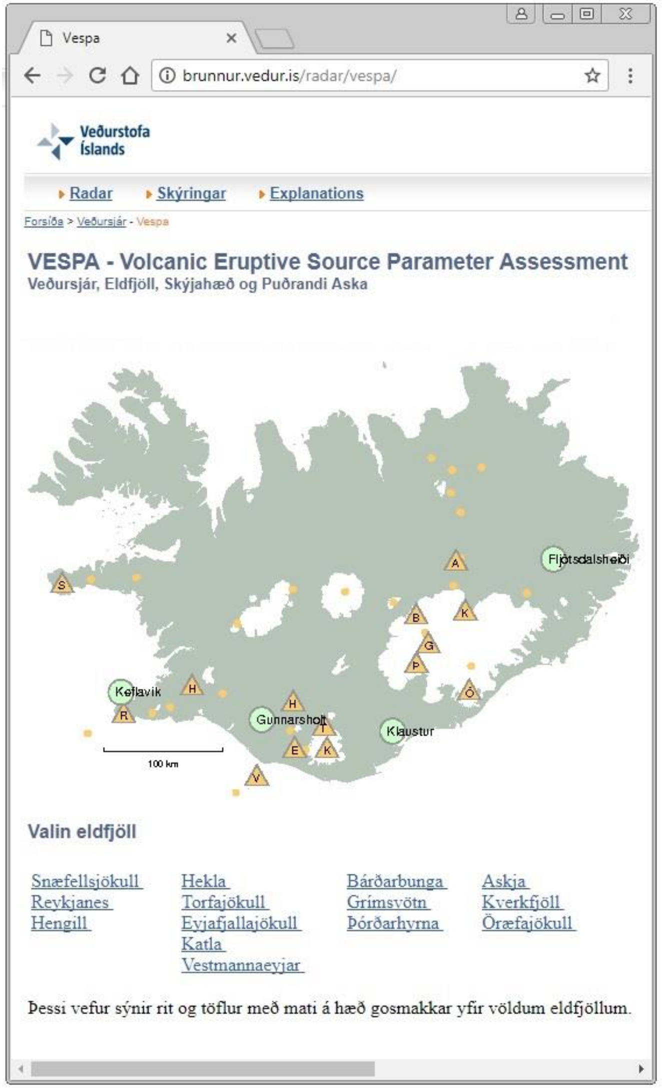


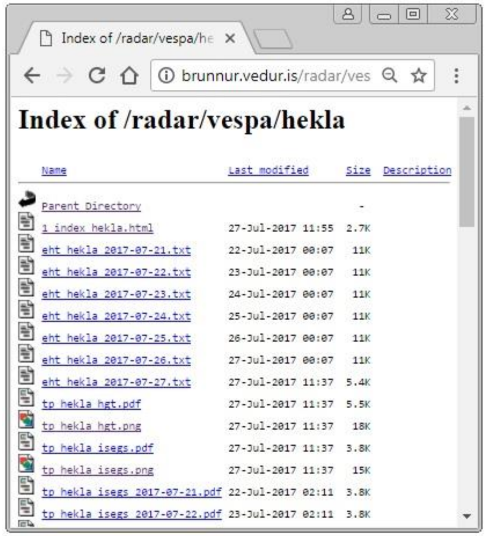


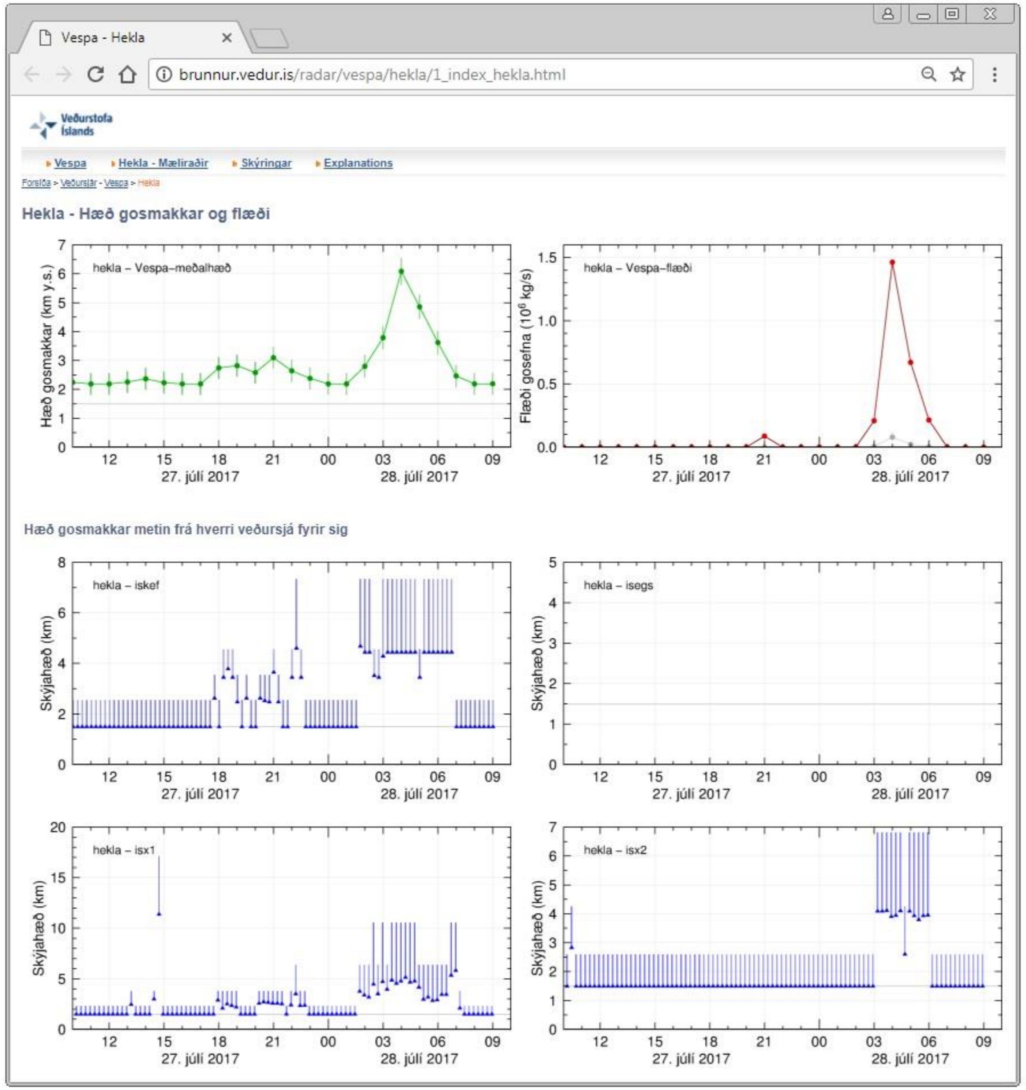
Validation of radar detection at elevation 0.9° during the Eyjafjallajökull eruption using wind corrected plume height of web camera images.

Automatic Plume Height Estimates

http://brunnur.vedur.is/radar/vespa/

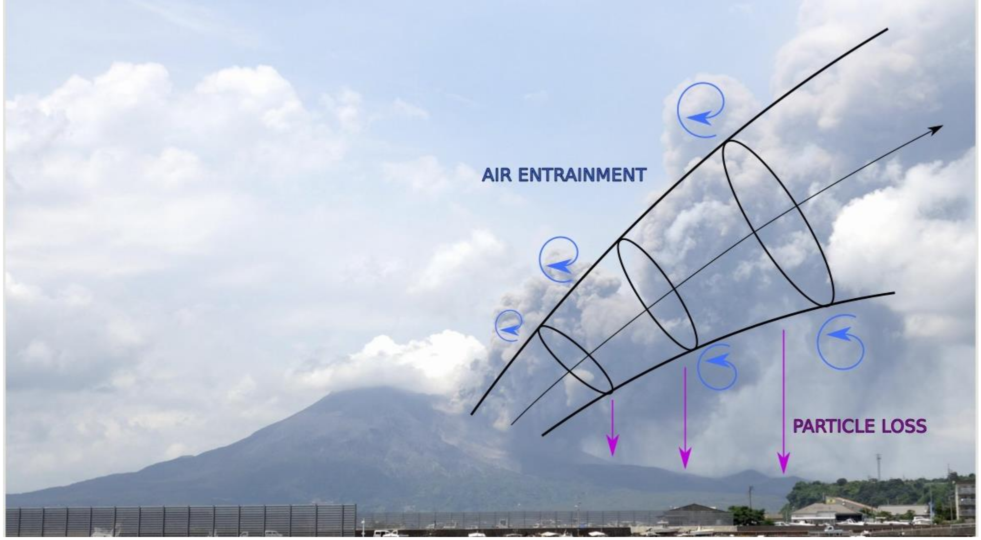


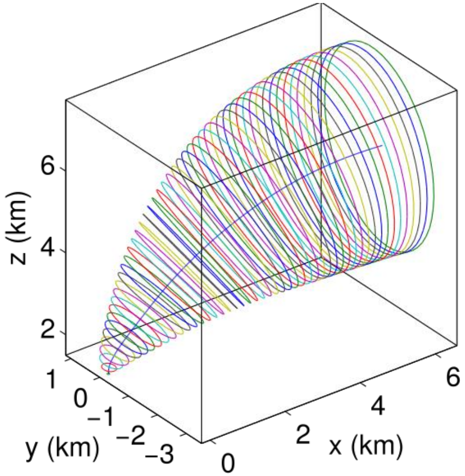


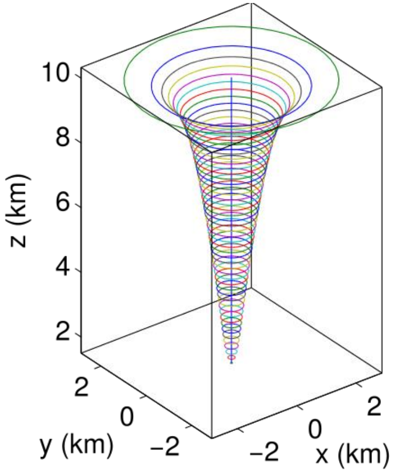


Plume Model – PlumeMoM[1]
Accounts for effects of wind on plume

- Accounts for the effect of wind, which bends the plume trajectory and increases entrainment of ambient air
- Accounts for particle fallout. Radial and crosswind air entrainment are parameterized using two entrainment coefficients
- Solves equations for the conservation of mass, momentum, energy, and the variation of heat capacity and mixture gas constant
- Possible to describe a continuous size distribution of particles through the method of moments
- Vertical profile of wind above volcano is retreived from the latest ECMWF[2] numerical weather prediction model







1 de' Michieli Vitturi et al. (2015; 2016)

2 ECMWF: European Centre for Medium-Range Weather Forecasts is an independent intergovernmental organisation supported by 34 European states. ECMWF is based in Reading UK.

EXERCISE: Eruption of Katla

Started 19 hours ago: 18 August at 02:10 UTC

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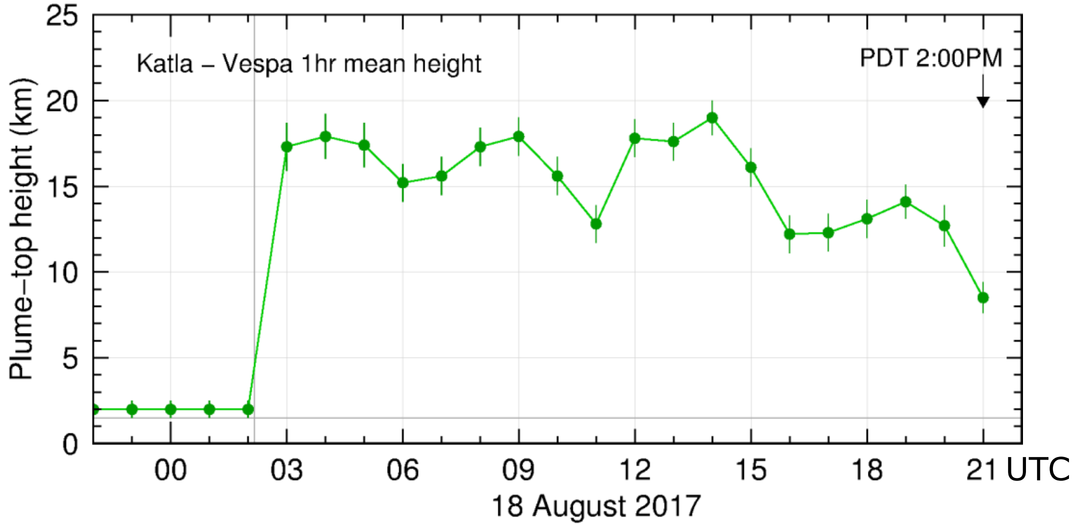
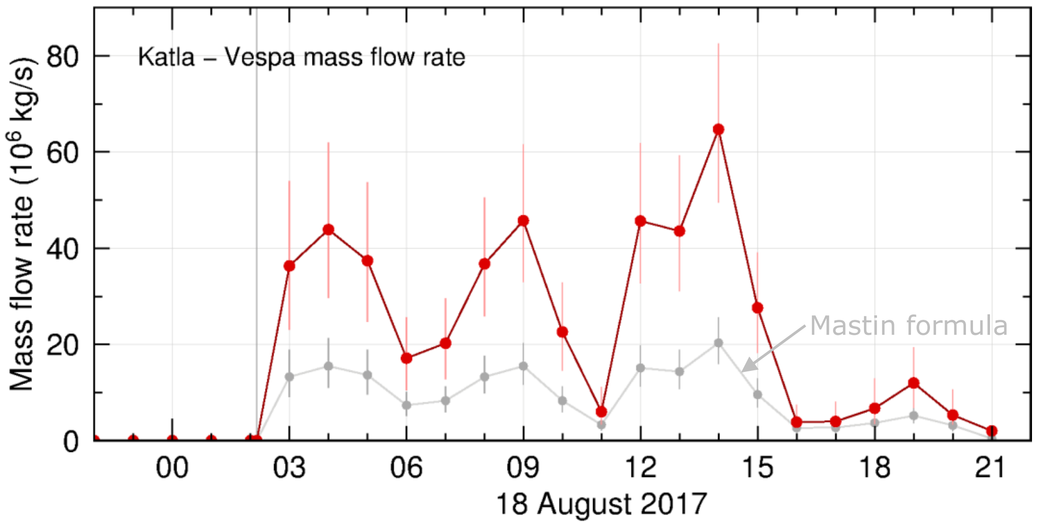
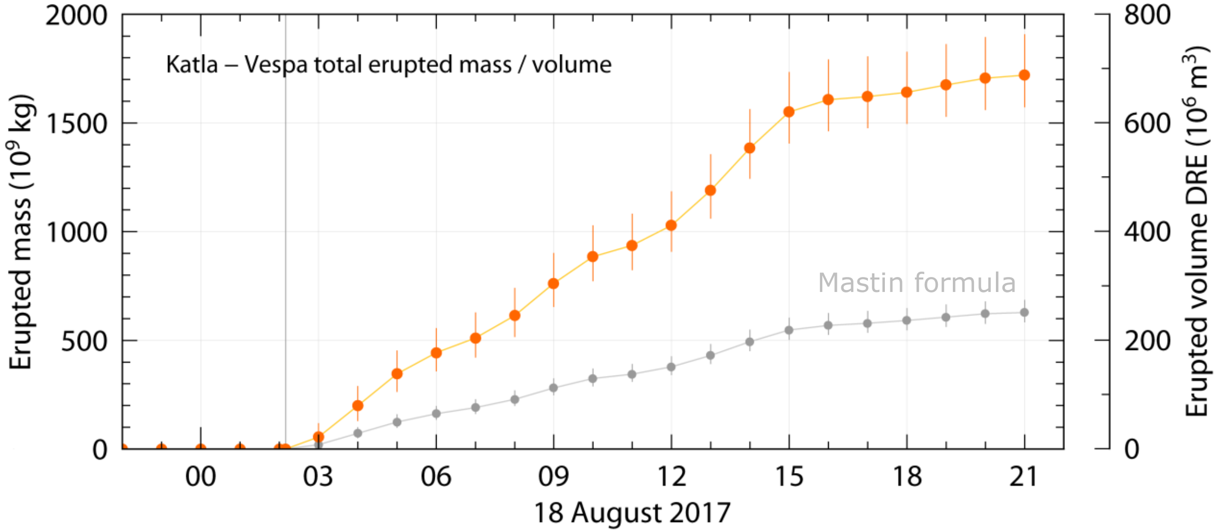






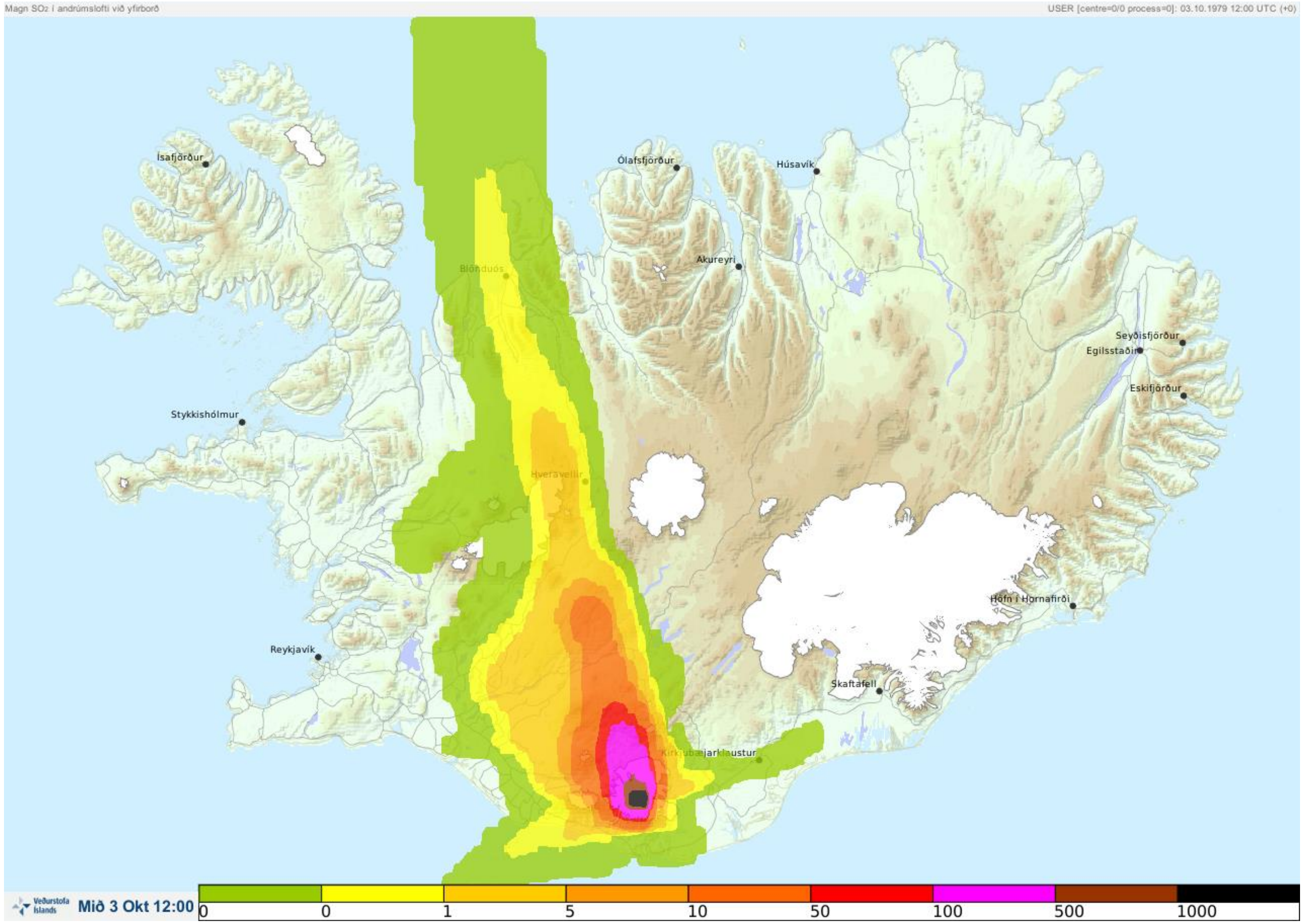
Ash Dispersal Forecast
VOL-CALPUFF* dispersion model

Icelandic Met Office

Dispersion model initialized by

1. Eruption onset
2. Source parameters, e.g. vent radius and exit velocity
3. Grain-size distribution is assumed, based on previous eruption data set
4. ECMWF numerical weather prediction model

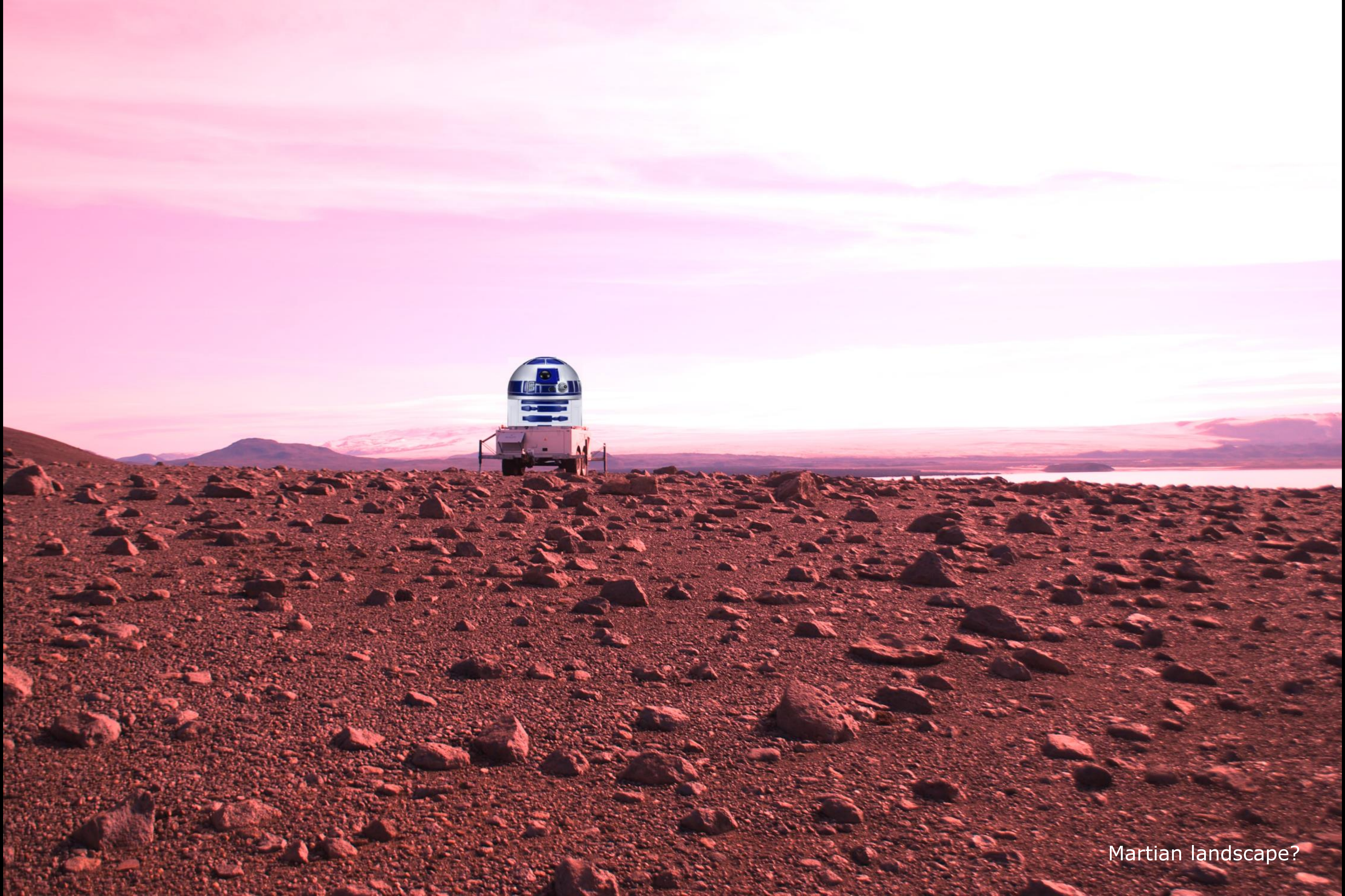
Ash dispersal forecasts are generated for the IMO web in 1 hr timesteps for the next few days



Tephra ground deposits (kg/m^2)

* Barsotti et al. (2008); Barsotti & Neri (2008)

Mobile radar isx1 installed with clear view over Bárðarbunga before the 2014-2015 volcanic eruption.
Photo Þorgils Ingvarsson 22 August 2014



Martian landscape?

Conclusions

Icelandic Met Office

- Real-time output of the Vespa system is currently available for selected volcanoes, and can be turned on in case of unrest or sudden eruption at a new volcano:

  http://brunnur.vedur.is/radar/vespa/

- Current plans include testing the Vespa system rigorously, implementing a PlumeMoM for strongly bent over plumes, adjust some parameters, and applying its calculations to recent eruptions in Iceland

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Abstract

Icelandic Met Office

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IV.4 Volcanic plumes and clouds; from injection to dispersion, Presentation VO52A-1

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The Icelandic Meteorological Office (IMO) is responsible for monitoring over 30 active volcanic systems. For explosive volcanic eruptions, the principal scale parameters are plume height and mass eruption rate. IMO operates two fixed position C-band weather radars and two mobile X-band radars, which are crucial in monitoring plume height, due to their independence of daylight, weather and visibility. During initial phases of an explosive eruption, all available radars will be set to a more detailed scan, optimized to observe the volcanic eruption plume. Radar volume data above the active volcano are automatically analyzed at IMO-headquarters in Reykjavík. These data are available for the natural hazard specialists and meteorologists at IMO‘s 24/7 monitoring room in near real-time, and are communicated to London VAAC to support their ash transport simulations for aviation safety purposes. The newly-developed VESPA software uses the plume height estimates to calculate 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. The model accounts for the effect of wind on the plume dynamics, using atmospheric vertical profiles extracted from the ECMWF numerical weather prediction model. Furthermore, the estimate of mass eruption rate provided by VESPA are used to initialize the VOL-CALPUFF dispersion model to assess the local-scale hazards due to tephra fallout.