

# How are we prepared for the next explosive eruption in Iceland?

Sara Barsotti, Talfan Barnie, Þórður Arason,  
Melissa A. Pfeffer, Björn S. Einarsson

Icelandic Meteorological Office

sara@vedur.is

**IAVCEI Scientific Assembly**

30 January - 3 February 2023 | Rotorua, New Zealand

[www.iavcei2023.org](http://www.iavcei2023.org)



# Background

- Icelandic volcanoes can feature effusive and explosive eruptions
- The last two explosive eruptions (Eyjafjallajökull in 2010 and Grímsvötn in 2011) generated ash clouds which affected large areas and airspaces
- The last three effusive eruptions (Holuhraun in 2014-2015 and Fagradalsfjall in 2021/2022) were characterized by volcanic SO<sub>2</sub> release and air-quality issues on a national scale

# Objective

The IMO (Volcano Observatory in Iceland) requires a forecasting and observation system for anticipating and monitoring:

Position, Timing and Extension of volcanic clouds in the atmosphere and tephra fallout on the ground.

Such information is provided to the

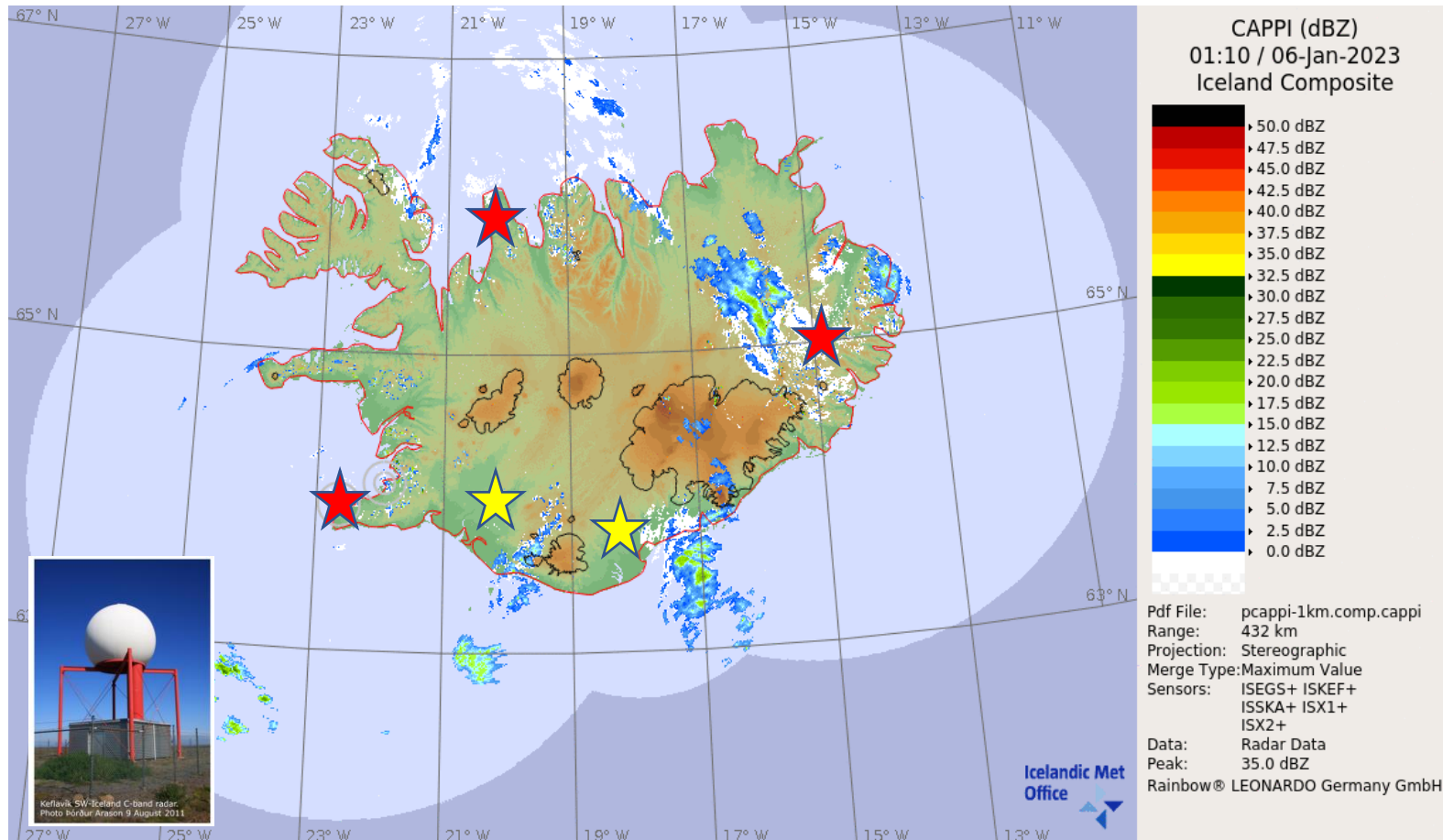
- Civil Protection for decision making and mitigation measures,
- General public for self-assessment and counter measures and
- Aviation stakeholders (which includes airline companies and Air Navigation providers).

# Observation system

It consists of a variety of sensors and instruments:

1. Meteorological radar network
2. Calibrated cameras network
3. Lidar
4. Ceilometer network
5. Satellite products
6. Lightning detector network

# Observing and measuring the plume height: the radar network

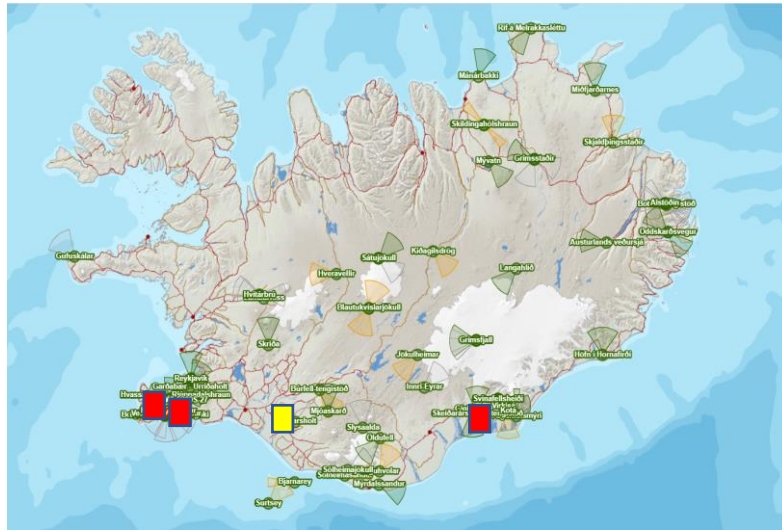


- 5 radars in the country
  - 3 fixed C-band ★
  - 2 mobile X-band ★
- Data streaming each 5 minutes
- Volcanic ash products available



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

# Observing and measuring the plume height: the calibrated cameras network



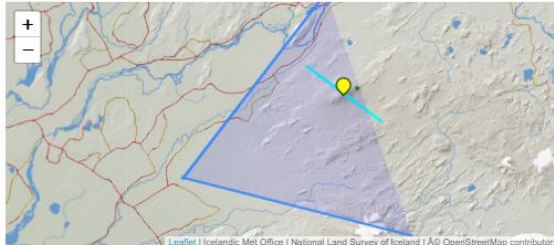
GUIDED TOUR

Vefmyndavél: HEKLA Gunnarsholt

Dagsetning og tími: 2022-09-15 00:10

Veðurlíkan: /ecomwf/hres4calp\_2022091412\_12

Gosstöðvar:



Plume parameters:

63.991884 Lat -19.087340 Lon

Hæð gosmákkar / m y.s. 27714

Wind bearing (clockwise from grid north) 305.3102080902877

Speed 5.087917073433774

Vindátt 0

Fjarlægð undan vindi / m 0

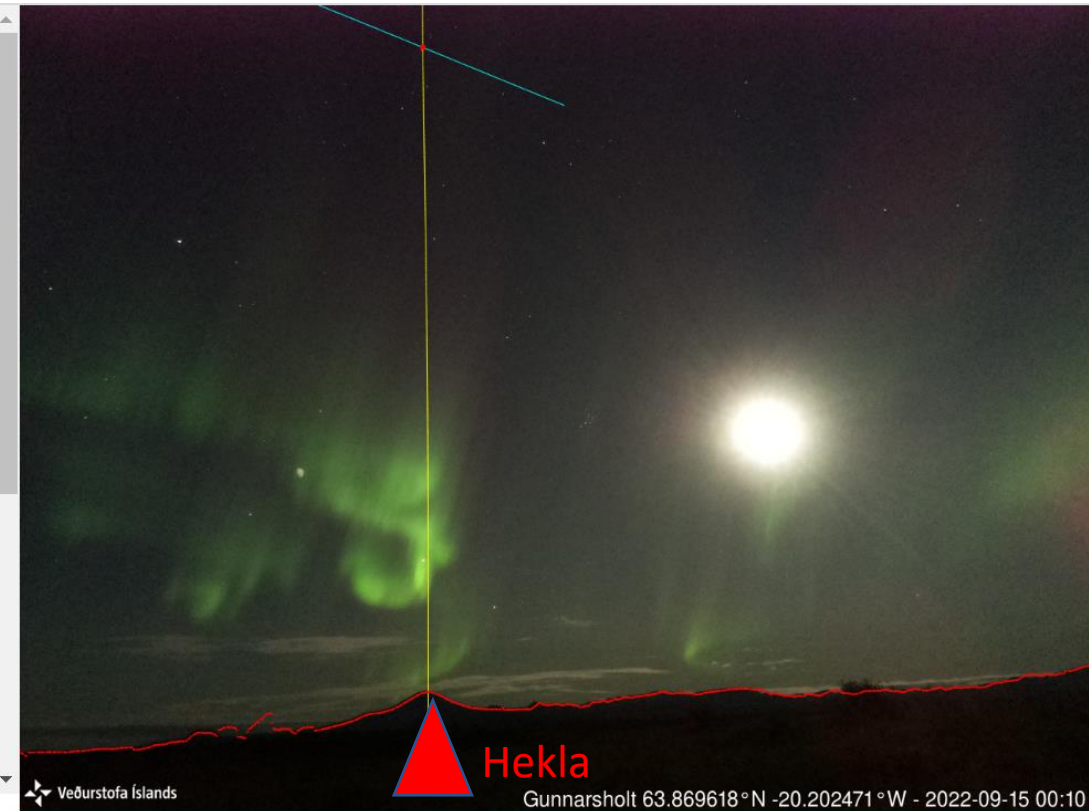
Camera parameters:

Focal Length (Only change for zooming video streams) 1027.44804172584

Yaw 69.41315893880290

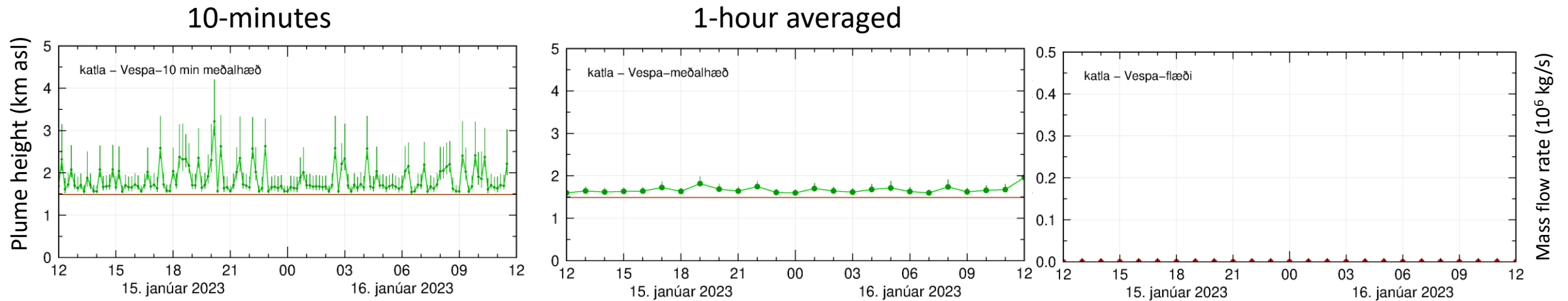
Pitch 21.4578046559451

Roll 3.3231852117687753



- Plume height manually assessed (Barnie et al. 2022, submitted)
- Height corrected based on the wind
- The user can choose between two different met data
- For Hekla, Grímsvötn, Bárðarbunga the view allows to get up to ~30 km

# Estimating the mass flow rate with the VESPA system



- The Mass Flow Rate (MFR) is automatically calculated by inverting the plume model PlumeMoM (de' Michieli Vitturi et al. 2015) as well as Mastin's formula (2009)
- The system ingests by default all radar data available for the target volcano
- Additional plume heights (e.g. from calibrated cameras) can be added for the MFR estimate

# Forecasting volcanic ash and gases transport: implementation of a new system

Two dispersal codes are implemented:

**CALPUFF** code for volcanic gases (Scire, J. et al, 1998)

**NAME** code for tephra and ash (Beckett, F. et al. 2020)

- **Ad – hoc simulations:**

- The IMO operator can initialize any runs any time by accessing the internal web-page, selecting the numerical tool, the target volcano and inserting the ESP needed to execute the codes.

- **Scheduled simulations:**

- It has been fully operational during the last eruption in Fagradalsfjall (2021) when the system has been running constantly (two runs per day) for more than 6 months (Barsotti et al. 2023, Natural Hazards)



# Volcanic ash and gases transport modelling and forecasting

The new forecasting system is accessible by everyone at:

[dispersion.vedur.is](https://dispersion.vedur.is)

(as well as an EPOS VO-TCS service)

Both „hypothetical scenarios“ as well as „real events“ can be available

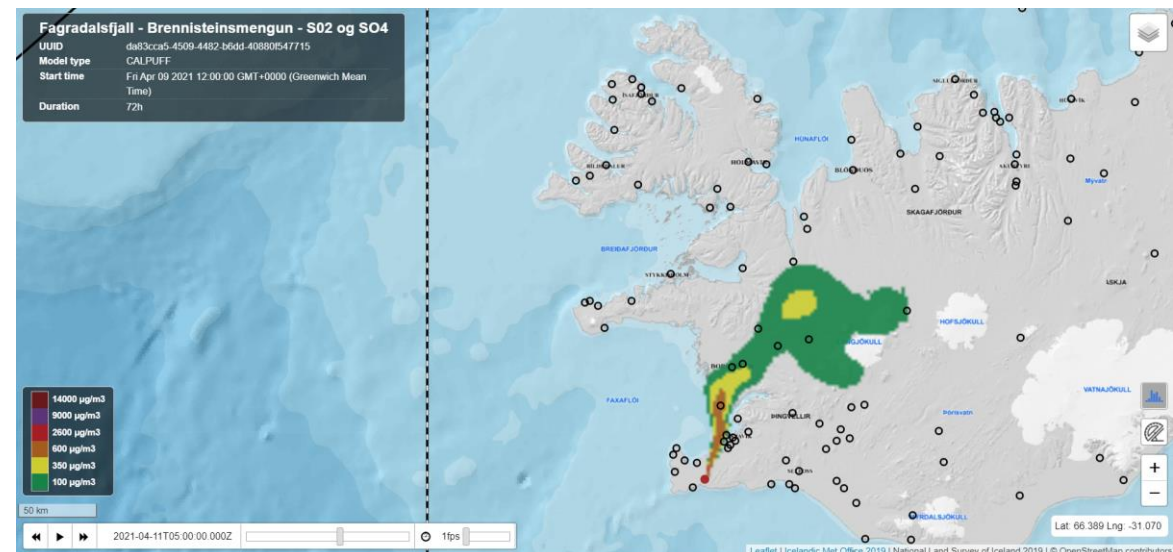
Veðurstofa Íslands Dispersion

Runs

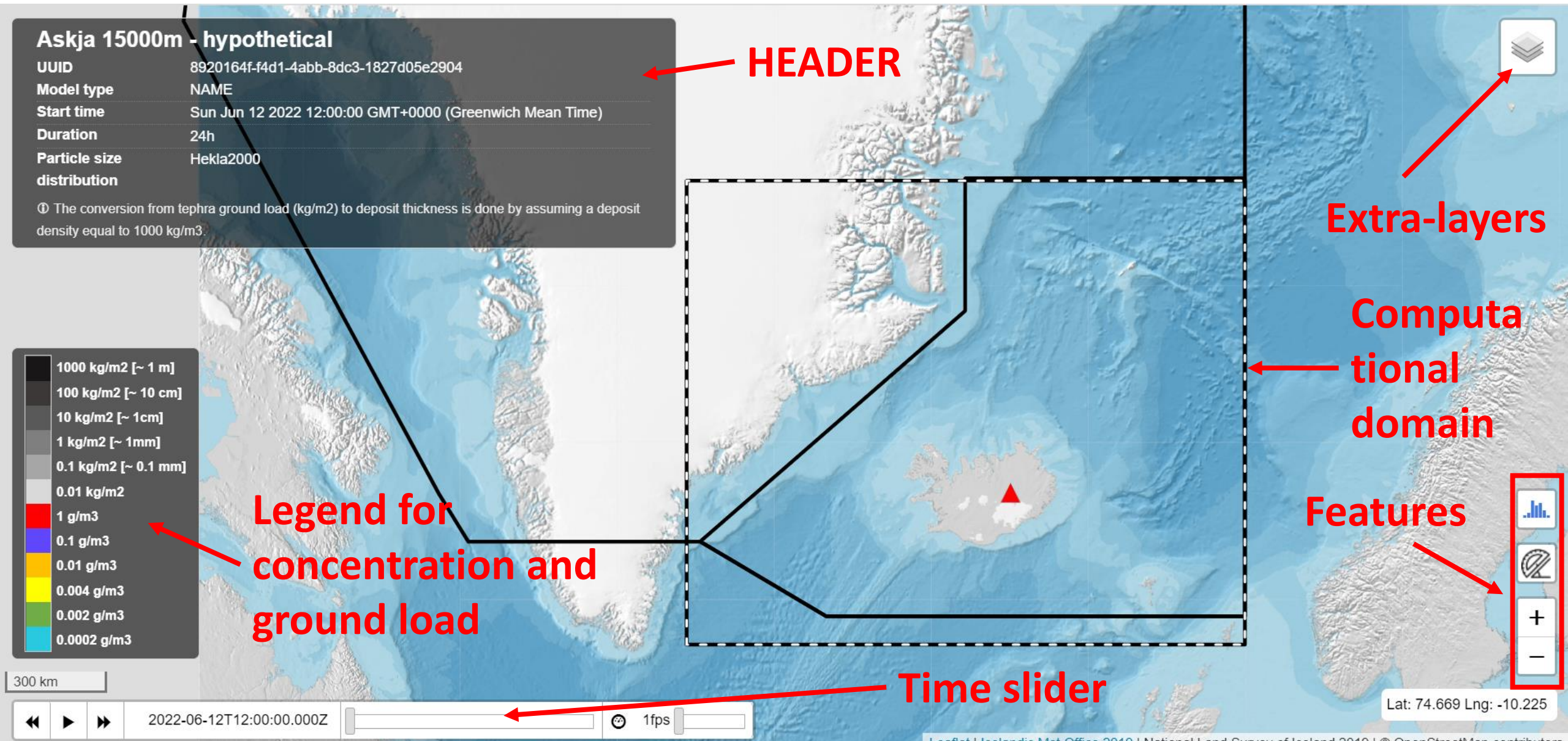
Vefsíðan sýnir niðurstöður spálikans fyrir dreifingu gjósku og gass sem myndast í eldgos. Þegar raunveruleg gos eru ekki í gangi eru imynduð gos hermd. Frekari upplýsingar um líkön, upphaltsforsendur og veðurfræðigögn eru aðgengileg í notendahandbók (undir Hjálparliðanum).

This website shows the results of dispersal forecast simulations of tephra and gas emitted during a volcanic eruption. During not eruptive periods, hypothetical eruptions are modelled for selected volcanoes. Further information on the numerical models, input conditions and meteorological data are available in the User's Guide document (under the Help/Hjálp tab)

Software	Label	Eruption Starting Time	Duration [h]
NAME	Askja 15000m - hypothetical	23/01/12 12:00	24
NAME	Askja 15000m - hypothetical	23/01/12 00:00	24
NAME	Askja 15000m - hypothetical	23/01/11 12:00	24
NAME	Askja 15000m - hypothetical	23/01/11 00:00	24
NAME	Askja 15000m - hypothetical	23/01/10 12:00	24
NAME	Askja 15000m - hypothetical	23/01/10 00:00	24



# Forecasting volcanic ash transport



# Forecasting volcanic ash transport

**Askja 15000m - hypothetical**

UUID: 8920164f-f4d1-4abb-8dc3-1827d05e2904

Model type: NAME

Start time: Sun Jun 12 2022 12:00:00 GMT+0000 (Greenwich Mean Time)

Duration: 24h

Particle size distribution: Hekla2000

ⓘ The conversion from tephra ground load (kg/m<sup>2</sup>) to deposit thickness is done by assuming a deposit density equal to 1000 kg/m<sup>3</sup>.

1000 kg/m<sup>2</sup> [~ 1 m]

100 kg/m<sup>2</sup> [~ 10 cm]

10 kg/m<sup>2</sup> [~ 1cm]

1 kg/m<sup>2</sup> [~ 1mm]

0.1 kg/m<sup>2</sup> [~ 0.1 mm]

0.01 kg/m<sup>2</sup>

1 g/m<sup>3</sup>

0.1 g/m<sup>3</sup>

0.01 g/m<sup>3</sup>

0.004 g/m<sup>3</sup>

0.002 g/m<sup>3</sup>

0.0002 g/m<sup>3</sup>

100 km

2022-06-12T16:00:00.000Z

1fps

Ground deposition

Concentration in air

- Grunnkort

Grunnkort Veðurstofu Íslands (IMO)

-  Dispersion

Source

0m Ash kg/m<sup>2</sup>

5m Ash g/m<sup>3</sup>

1025hPa Ash g/m<sup>3</sup>

950hPa Ash g/m<sup>3</sup>

925hPa Ash g/m<sup>3</sup>

850hPa Ash g/m<sup>3</sup>

700hPa Ash g/m<sup>3</sup>

600hPa Ash g/m<sup>3</sup>

500hPa Ash g/m<sup>3</sup>

400hPa Ash g/m<sup>3</sup>

300hPa Ash g/m<sup>3</sup>

250hPa Ash g/m<sup>3</sup>

200hPa Ash g/m<sup>3</sup>

150hPa Ash g/m<sup>3</sup>

100hPa Ash g/m<sup>3</sup>

+ Þekjur

+ Stillingar

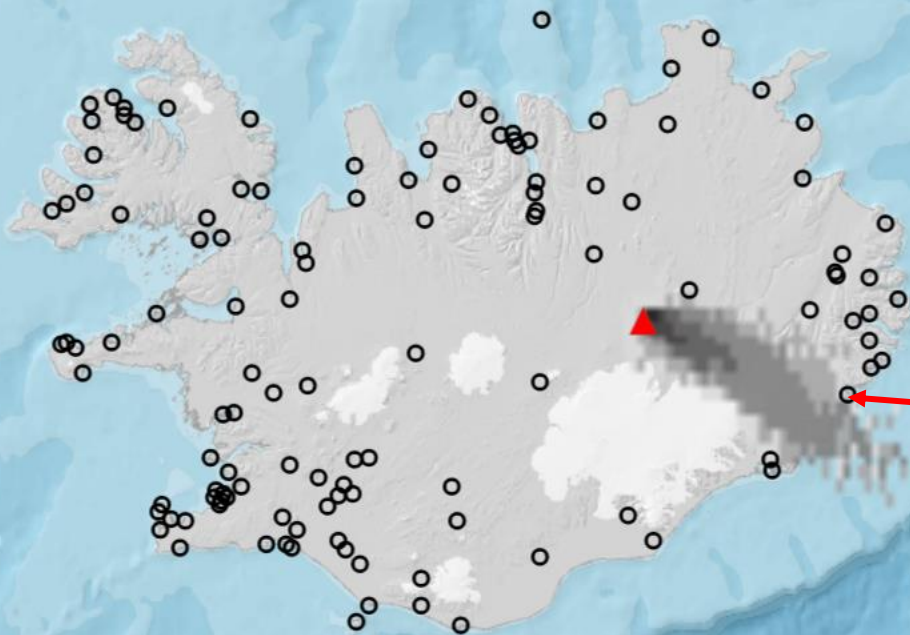
Lat: 70.506 Lng: 9.185

# Forecasting volcanic ash transport

## Askja 15000m - hypothetical

UUID 8920164f-f4d1-4abb-8dc3-1827d05e2904  
Model type NAME  
Start time Sun Jun 12 2022 12:00:00 GMT+0000 (Greenwich Mean Time)  
Duration 24h  
Particle size distribution Hekla2000

ⓘ The conversion from tephra ground load (kg/m<sup>2</sup>) to deposit thickness is done by assuming a deposit density equal to 1000 kg/m<sup>3</sup>.



100 km

2022-06-12T16:00:00.000Z

1fps

Lat: 65.964 Lng: -11.980

# Forecasting volcanic ash

## Askja 15000m - hypothetical

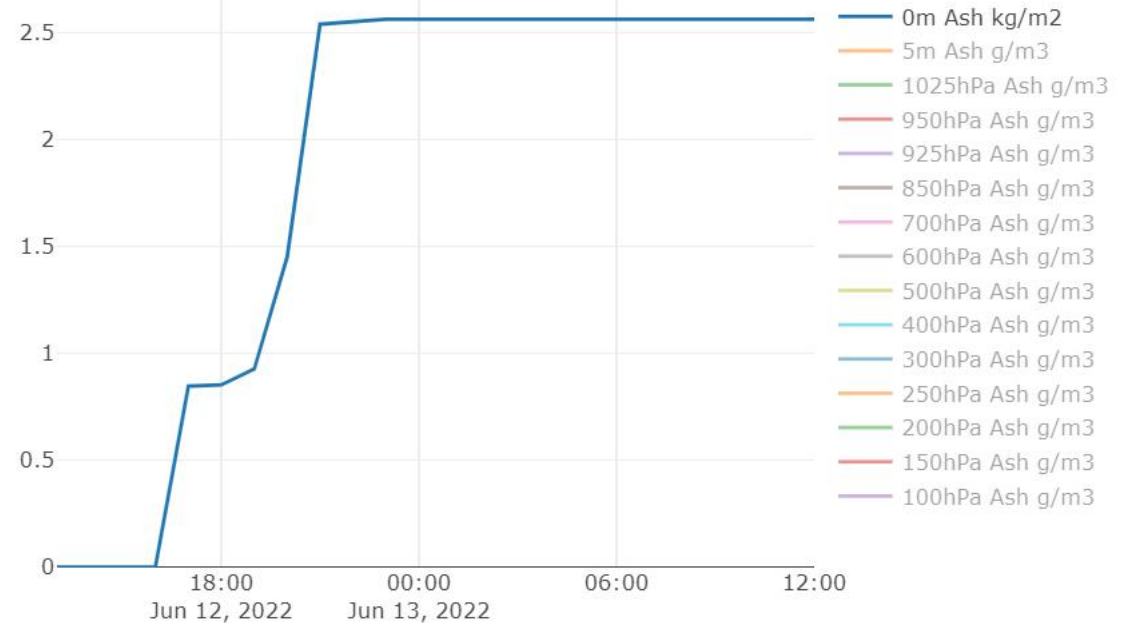
UUID 8920164f-f4d1-4abb-8dc3-1827d05e2904  
 Model type NAME  
 Start time Sun Jun 12 2022 12:00:00 GMT+0000 (Greenwich Mean Time)  
 Duration 24h  
 Particle size distribution Hekla2000

ⓘ The conversion from tephra ground load (kg/m<sup>2</sup>) to deposit thickness is done by assuming a deposit density equal to 1000 kg/m<sup>3</sup>.



## Djúpivogur

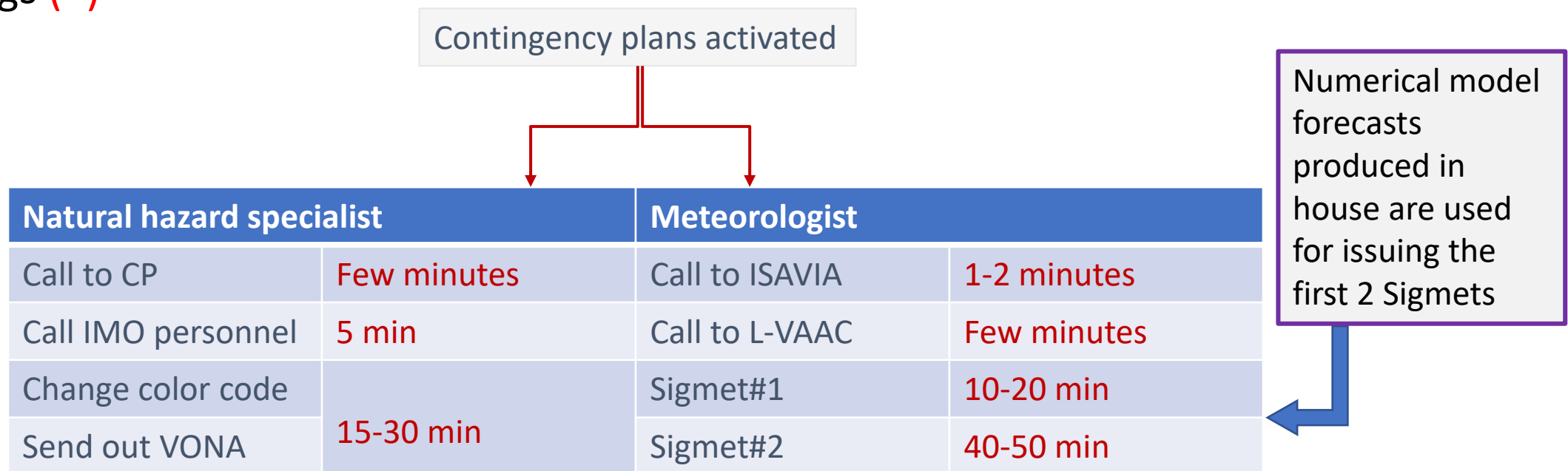
64.6566, -14.2835



Possibility to visualize the time series of the forecasted parameters in a specific (pre-defined) location

# Timeline for the activation and dissemination of information

- IMO practices all the procedures of responding to an imminent explosive volcanic eruption on a monthly basis with London VAAC and ISAVIA (VOLCICE exercises)
- A timeline of actions can be built by reviewing the performances collected during such trainings (\*)



(\*) Assessed by analyzing the time spent for these specific actions during the exercises performed in 2019-2022

# Communication with end-users

- All information is published on IMO's web-page
- VONA are accessible online
- Ash dispersal forecasts will be accessible through the dedicated portal as well as integrated to IMO's website

Home > Earthquakes > Volcanoes > VONA notifications

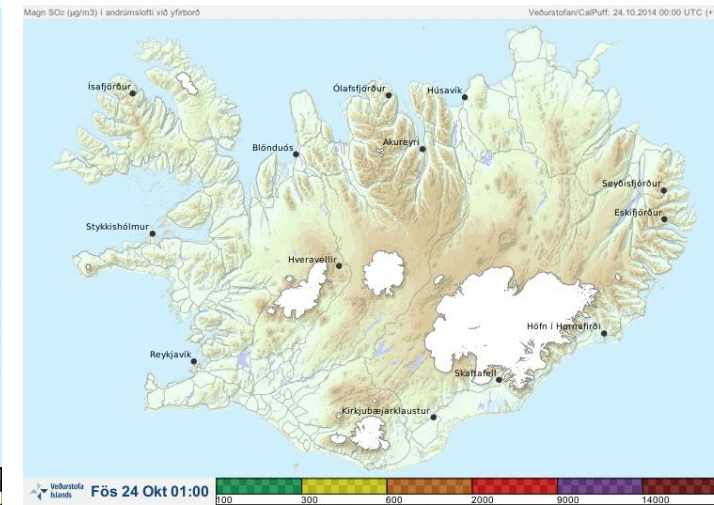
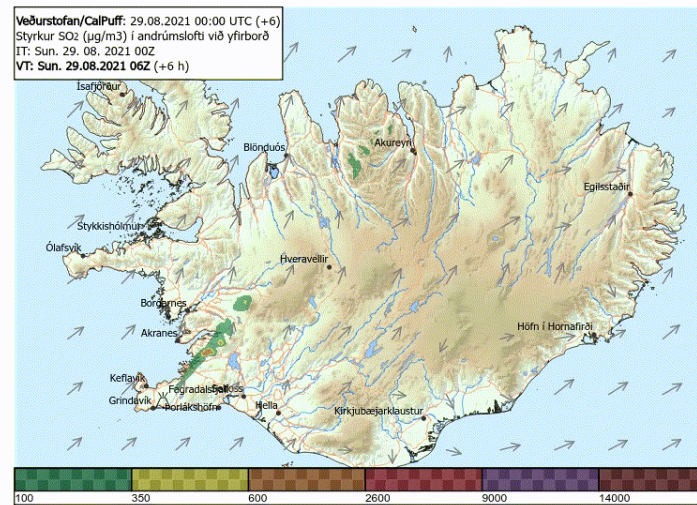
Earthquakes  
Volcanoes  
VONA notifications  
Main Icelandic volcanoes  
Volcanic hazards  
Catalogue of Icelandic Volcanoes  
Tremor measurements  
Strain measurements  
GPS measurements  
Articles  
Reports and publications  
Conferences  
Response to earthquakes  
Other institutions

VONA message

Volcano name	Volcano id	Time	Color code	Previous color code	View
Grímsvötn	373010	2022-11-09 07:57	green	Yellow	<a href="#">View</a>
Askja	373060	2022-11-09 07:54	green	Yellow	<a href="#">View</a>
Grímsvötn	373010	2022-10-16 16:20	Yellow	Yellow	<a href="#">View</a>
Grímsvötn	373010	2022-10-10 15:23	Yellow	Yellow	<a href="#">View</a>
Krýsuvík	371030	2022-09-15 15:29	green	Yellow	<a href="#">View</a>
Fagradalsfjall	371032	2022-09-15 15:27	green	N/A	<a href="#">View</a>
Krýsuvík	371030	2022-08-22 10:52	Yellow	Yellow	<a href="#">View</a>
Grímsvötn	373010	2022-08-09 17:24	green	Yellow	<a href="#">View</a>
Krýsuvík	371030	2022-08-03 15:36	Orange	Yellow	<a href="#">View</a>
Krýsuvík	371030	2022-08-03 13:42	Red	Yellow	<a href="#">View</a>
Grímsvötn	373010	2022-08-02 16:30	Yellow	Yellow	<a href="#">View</a>
Krýsuvík	371030	2022-08-01 09:41	Yellow	Yellow	<a href="#">View</a>
Krýsuvík	371030	2022-07-30 14:04	Yellow	Yellow	<a href="#">View</a>
Krýsuvík	371030	2022-06-22 11:12	green	Yellow	<a href="#">View</a>
Reykjanes	371020	2022-06-02 11:49	green	Yellow	<a href="#">View</a>
Reykjanes	371020	2022-05-16 09:40	Yellow	Yellow	<a href="#">View</a>
Grímsvötn	373010	2022-01-12 12:04	green	Yellow	<a href="#">View</a>
Krýsuvík	371030	2022-01-07 14:36	Yellow	Yellow	<a href="#">View</a>

Related topics

- Instructions on using earthquake pages
- Bárðarbunga and Holuhraun 2014-2015 - overview
- Grímsvötn 2011 - overview
- Eyjafjallajökull 2010 - overview
- Useful links
- FutureVolc
- Global Volcano Model Network (GVM)
- Road conditions
- Earthquake Engineering Research Centre - University of Iceland
- Institute of Earth Sciences
- Incorporated Research Institutions for Seismology
- National Earthquake Information Center
- Preventive response to earthquakes



# In conclusion

- The **technological advancement** in detecting the evolution of a volcanic plume is at the base of an automatic system to rapidly produce reliable forecast
- Regular **practices** are a key element to maintain all these systems in place and guarantee their functionalities in time of crises
- A strong **connection** exists between the key-players and Institutions responsible to respond to a volcanic crises



Thanks!



# Volcanic ash transport modelling and forecasting

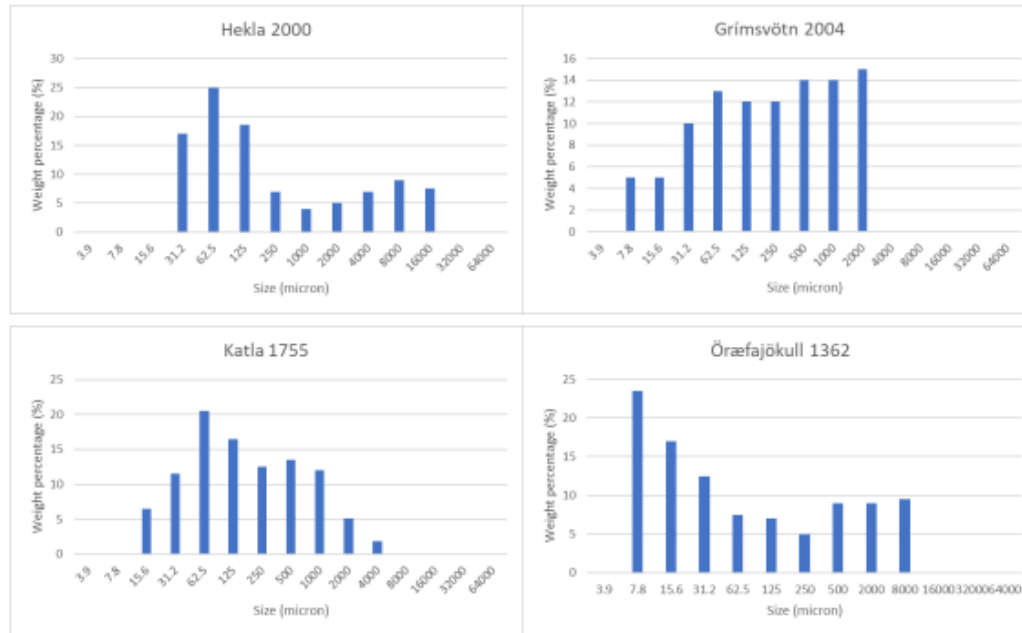


Fig. 5: Four TGSD are available in the current dispersal system. They have been adapted from the ICAO report available at [https://earthice.hi.is/sites/earthice.hi.is/files/Pdf\\_skjol/total\\_grain\\_size\\_distribution\\_in\\_selected\\_icelandic\\_eruptions\\_01.pdf](https://earthice.hi.is/sites/earthice.hi.is/files/Pdf_skjol/total_grain_size_distribution_in_selected_icelandic_eruptions_01.pdf).

Preset varieties of grain size distributions

Icelandic  
Meteorological Office

**Veðurstofa Íslands**

---

## User's Guide for IMO's dispersion system

---

Sara Barsotti  
Davíð Steinar

V2.0

19.02.2020

---

Veðurstofa Íslands +354 522 60 00  
Bústaðavegur 7-9 vedur@vedur.is  
108 Reykjavík