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

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ICELANDIC MET OFFICE
1920-2020

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 airpaces
- The last three effusive eruptions (Holuhraun in 2014-2015 and Fagradalsfjall in 2021/2022) were characterized by volcanic SO_2 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

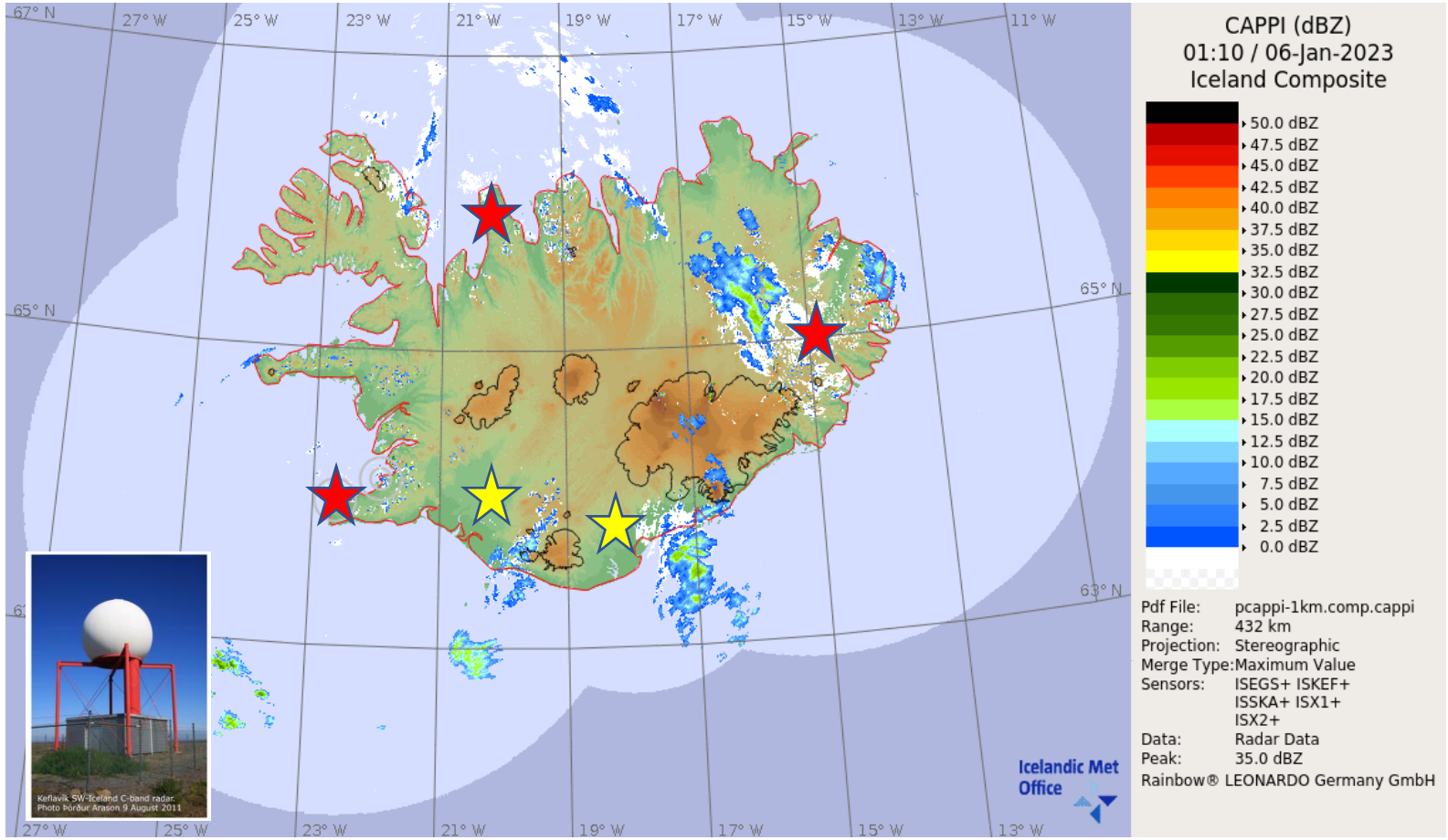
- Civil Protection for decision making and mitigation measures,
- General public for self-assessment and counter measures and
- Aviation stakeholders (which includes airline companies and Air Navigation providers).

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

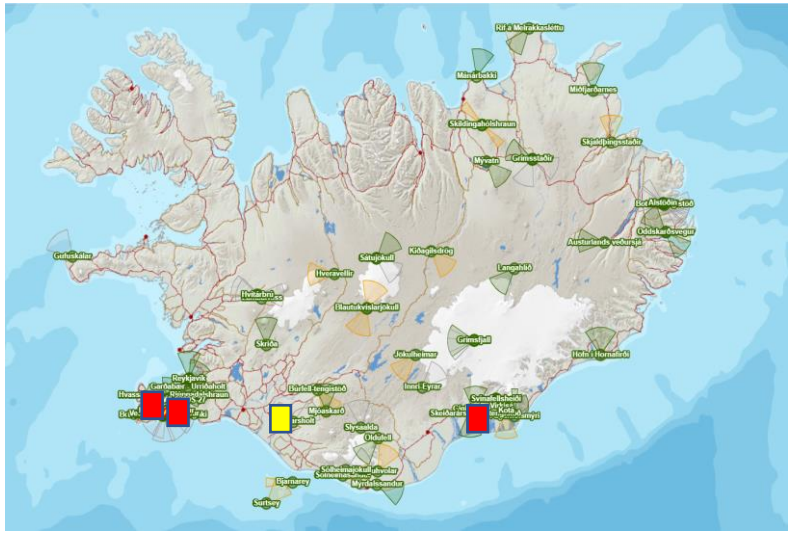
Observing and measuring the plume height: the radar network

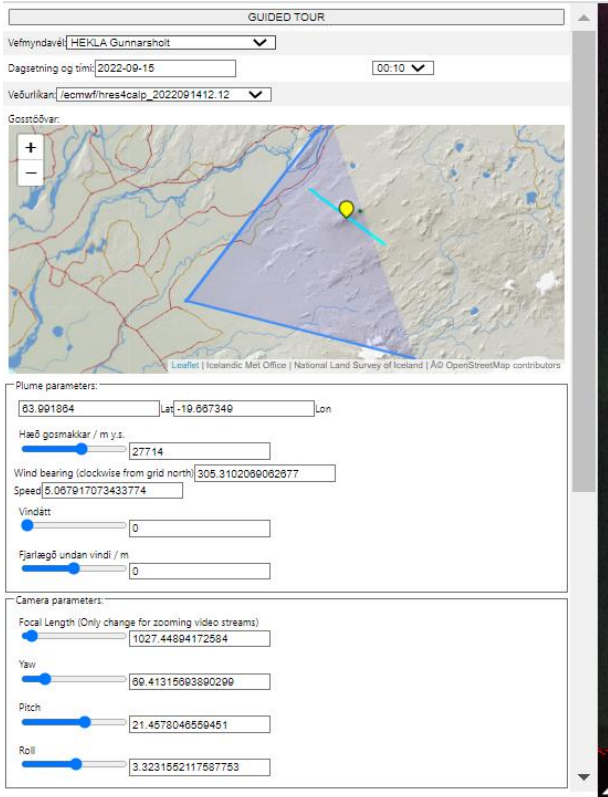


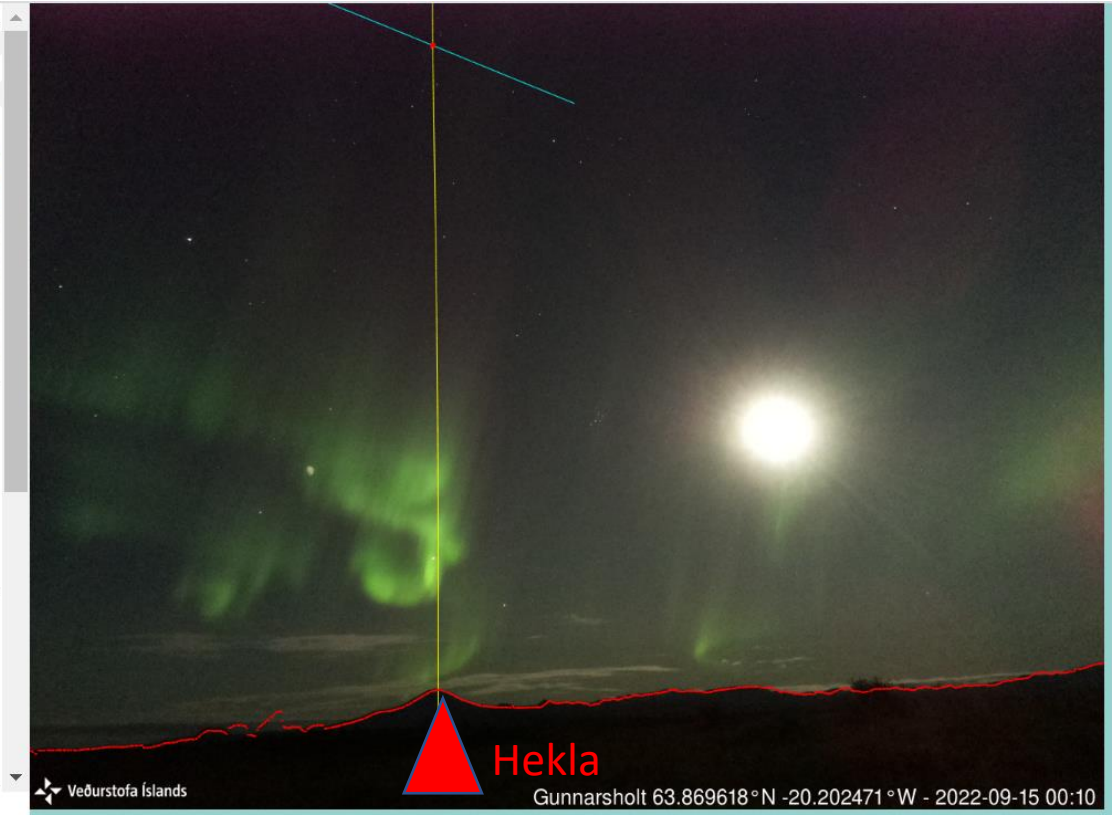
- 5 radars in the country
  - 3 fixed C-band
  - 2 mobile X-band
- Data streaming each 5 minutes
- Volcanic ash products available


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



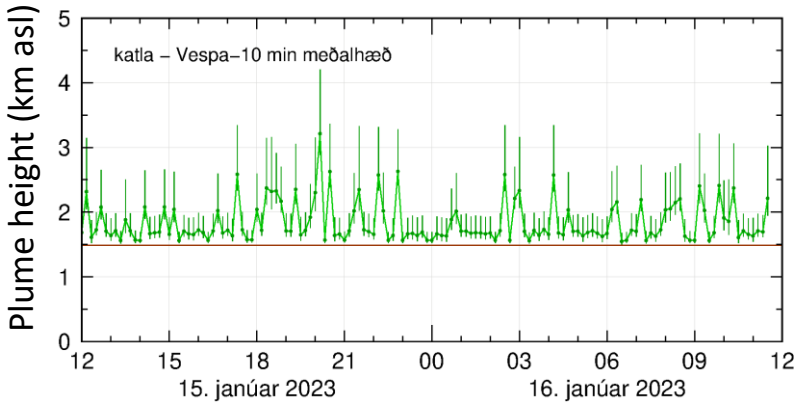




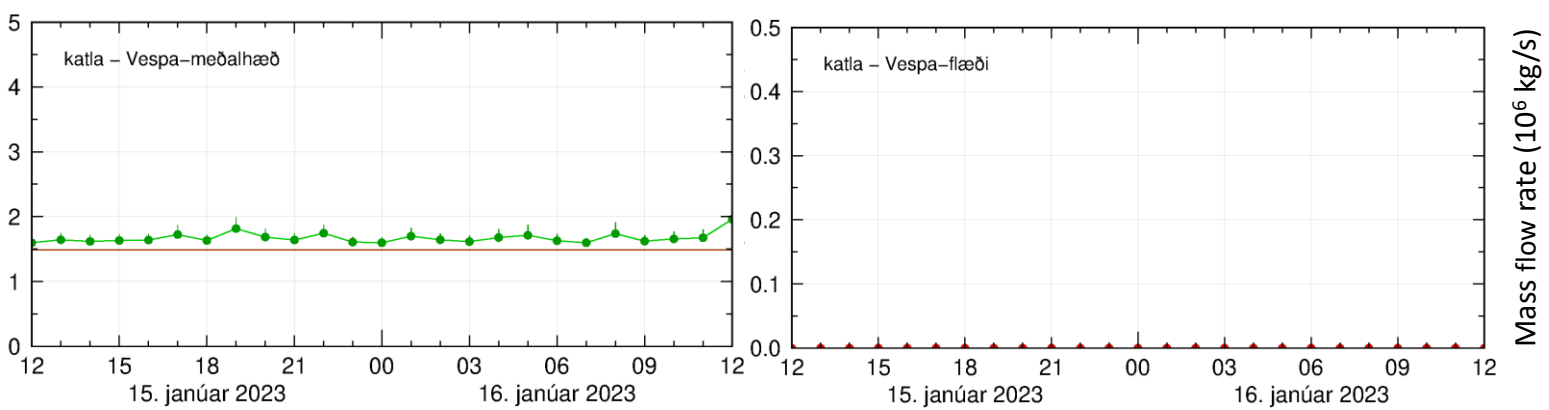
- Plume height manually assessed (Barnie et al. 2022, submitted)
- Height corrected based on the wind
- The user can choose between two different met data
- For Hekla, Grímsvötn, Bárðarbunga the view allows to get up to ~30 km

Estimating the mass flow rate with the VESPA system

10-minutes



1-hour averaged



- 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

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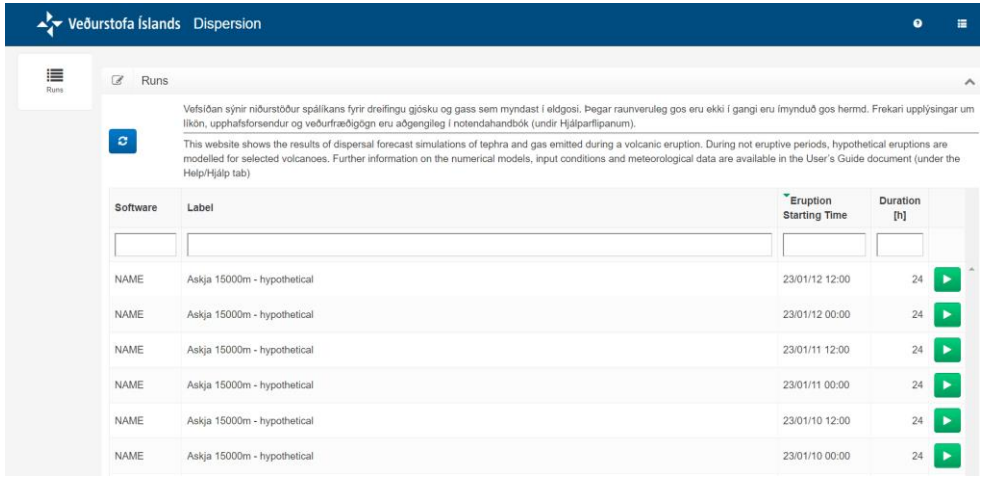
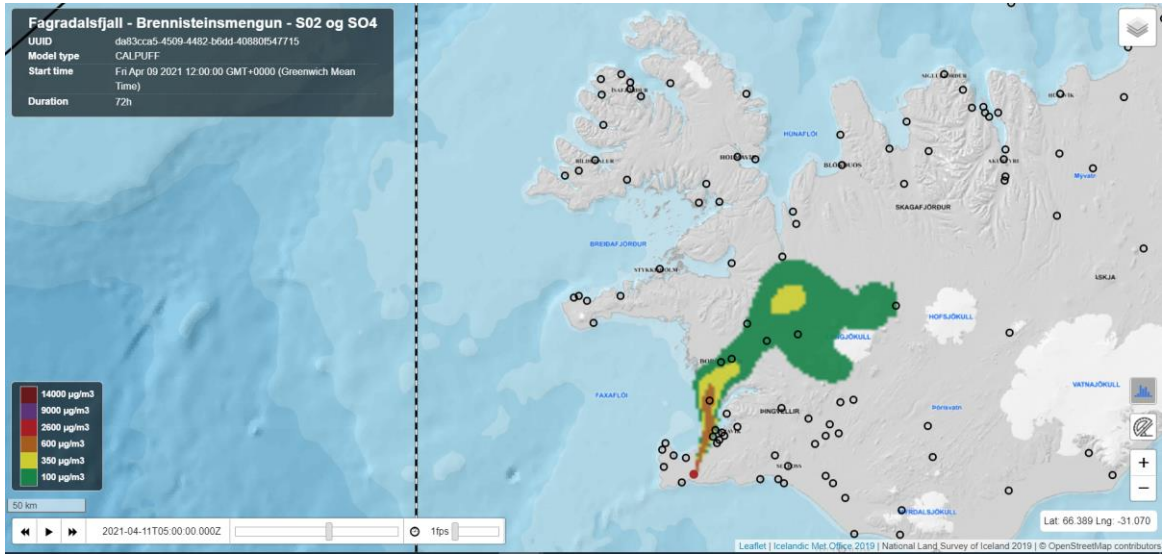
The new forecasting system is accessible by everyone at:

dispersion.vedur.is

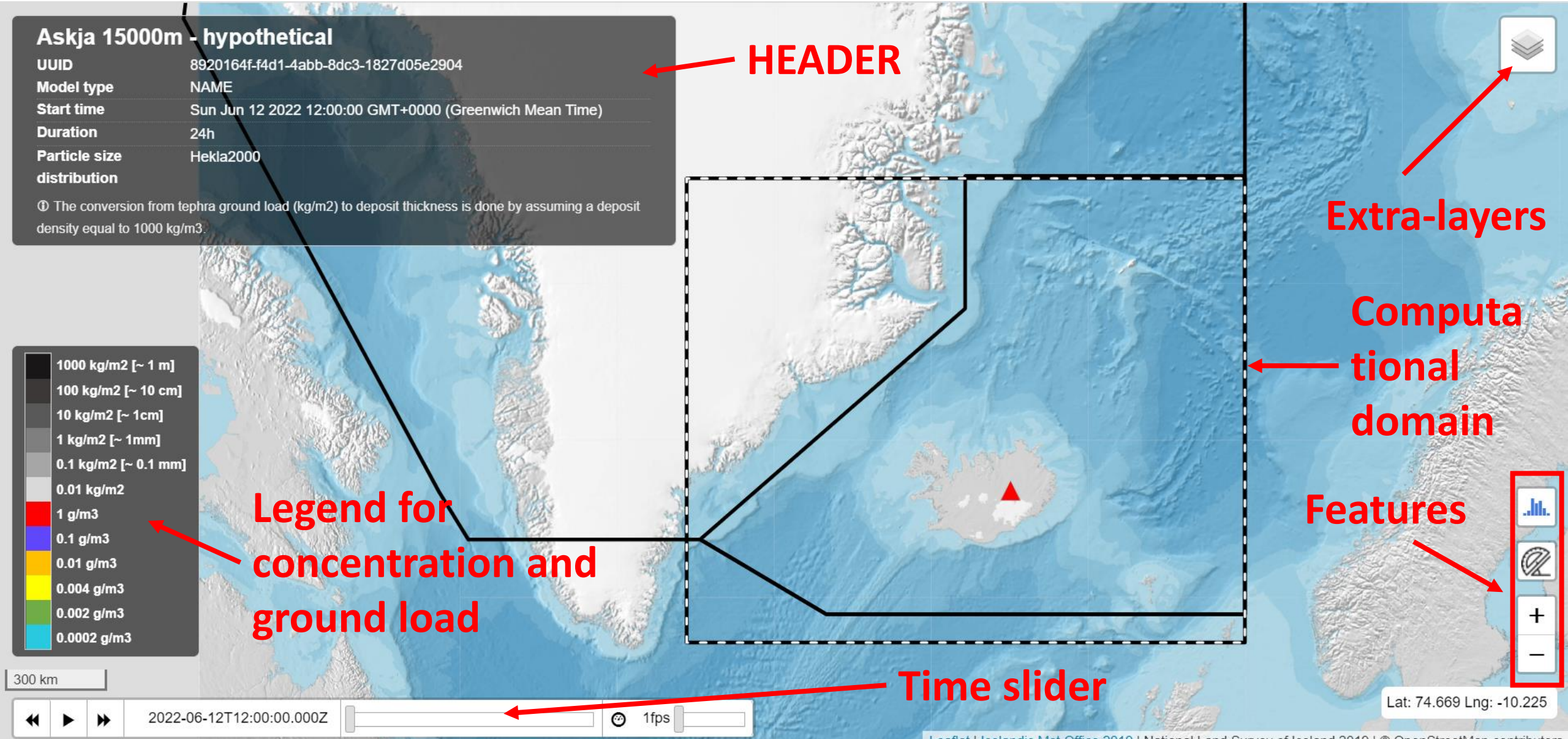
(as well as an EPOS VO-TCS service)

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

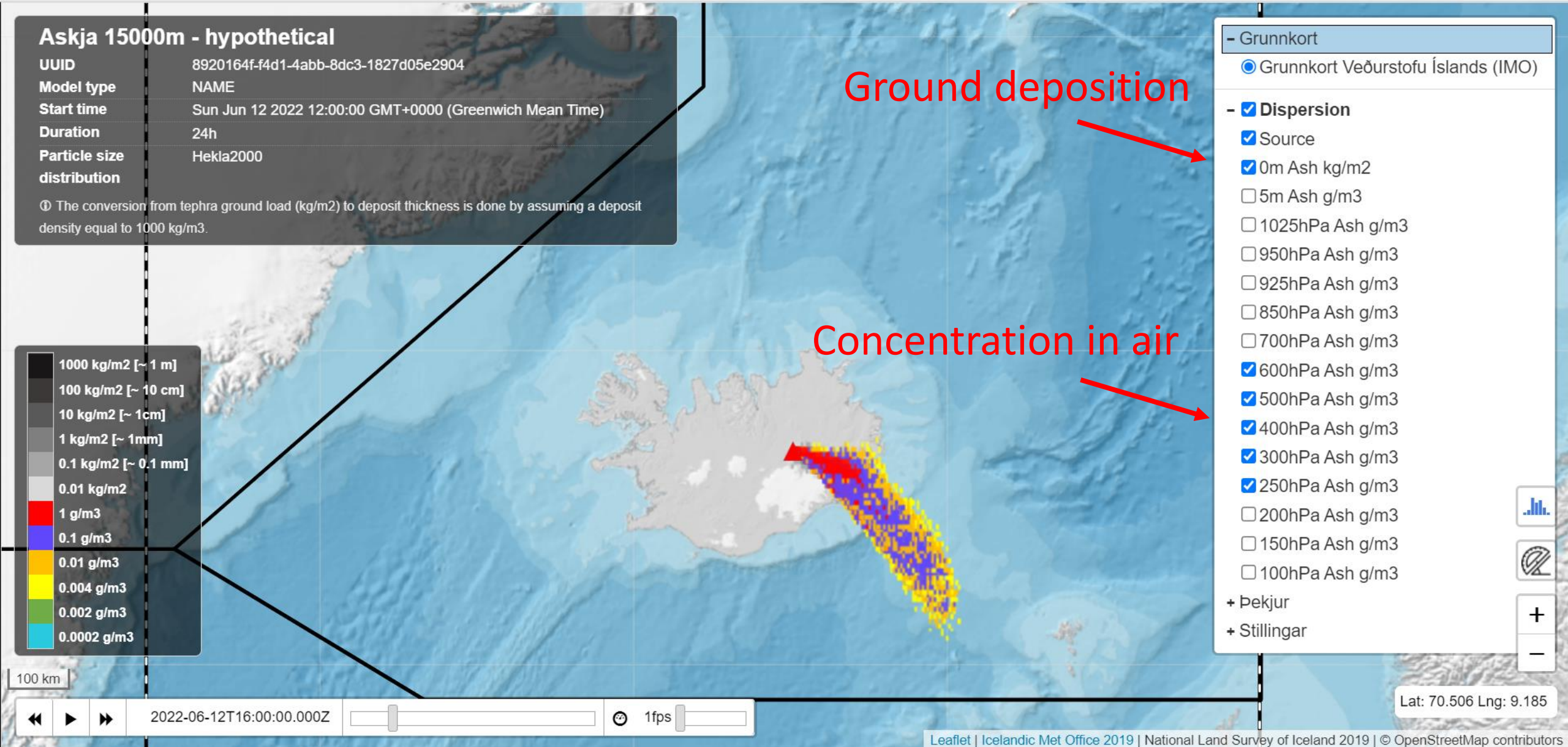




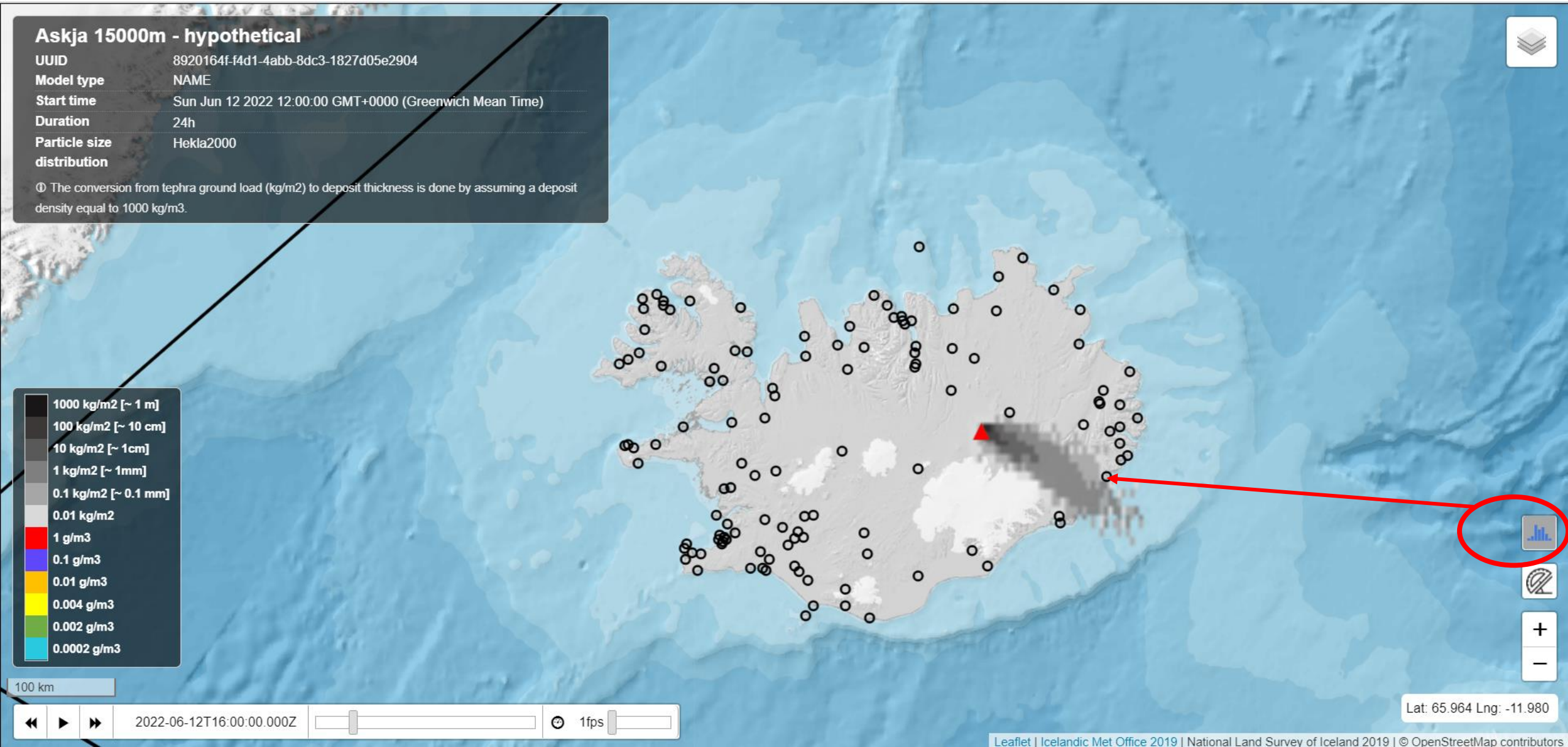
Forecasting volcanic ash transport



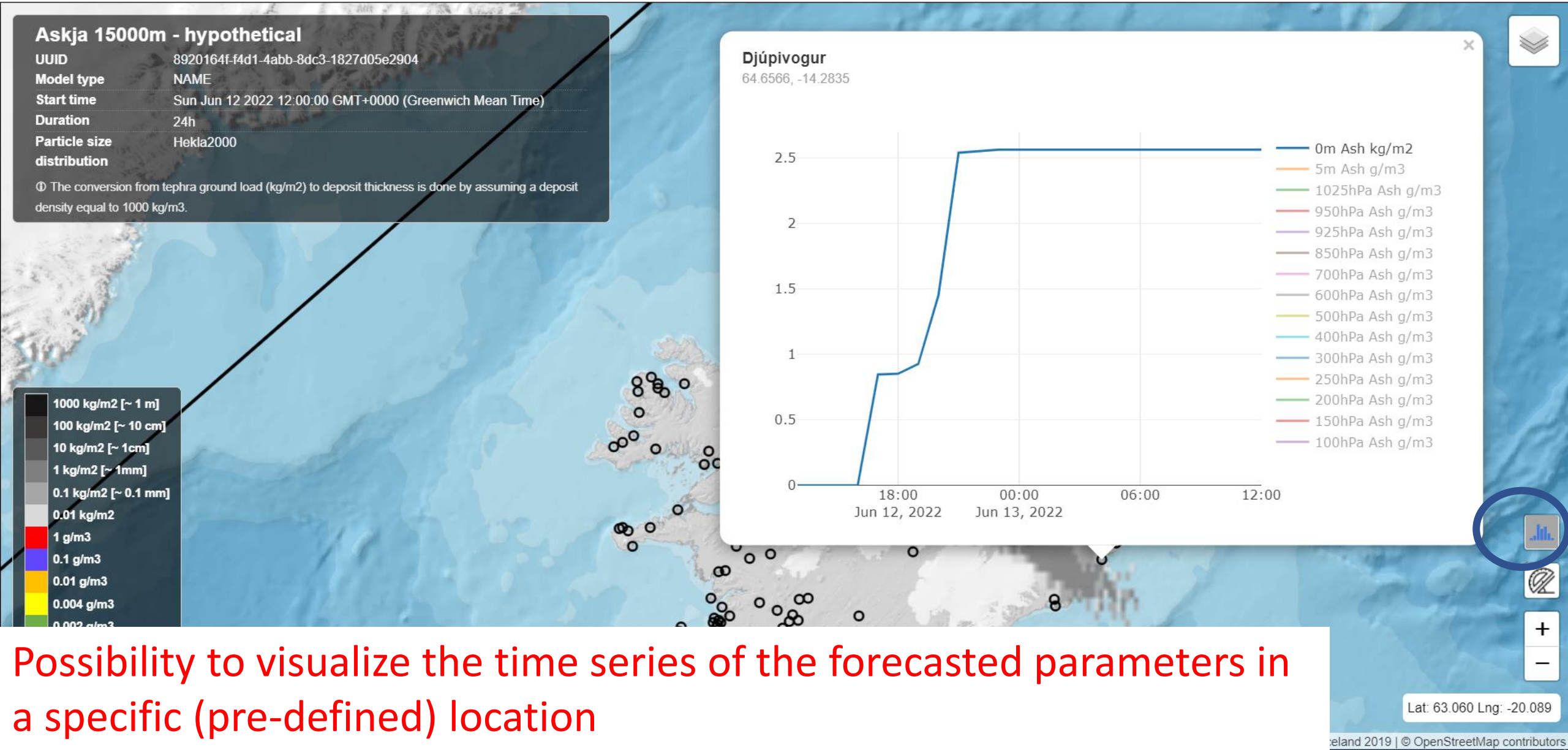
Forecasting volcanic ash transport



Forecasting volcanic ash transport



Forecasting volcanic ash



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 (*)

Contingency plans activated

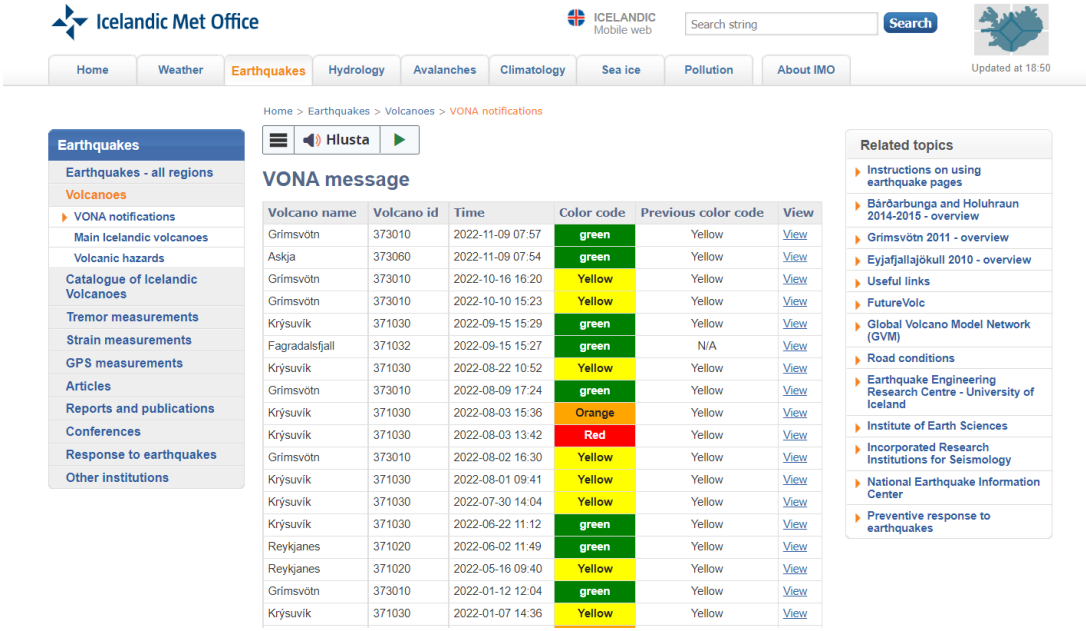
Natural hazard specialist		Meteorologist	
Call to CP	Few minutes	Call to ISAVIA	1-2 minutes
Call IMO personnel	5 min	Call to L-VAAC	Few minutes
Change color code	15-30 min	Sigmet#1	10-20 min
Send out VONA		Sigmet#2	40-50 min

Numerical model forecasts produced in house are used for issuing the first 2 Sigmets

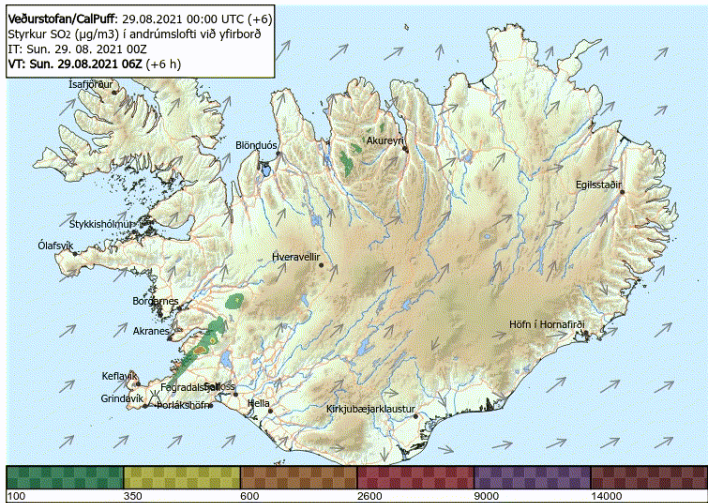
(*) Assessed by analyzing the time spent for these specific actions during the exercises performed in 2019-2022

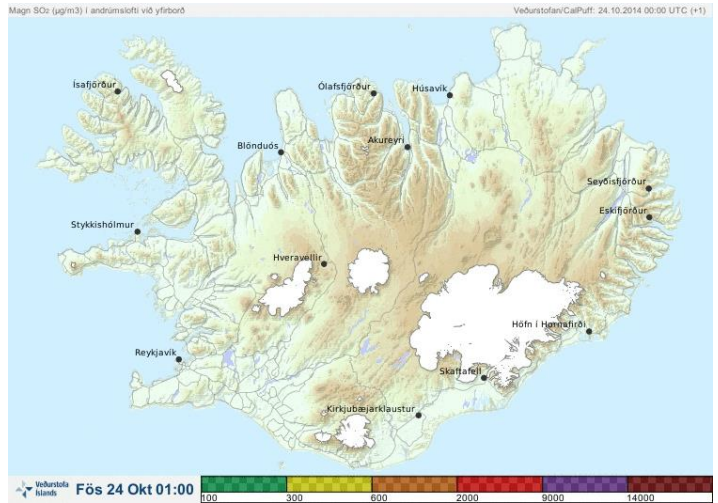
Communication with end-users

- 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



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





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

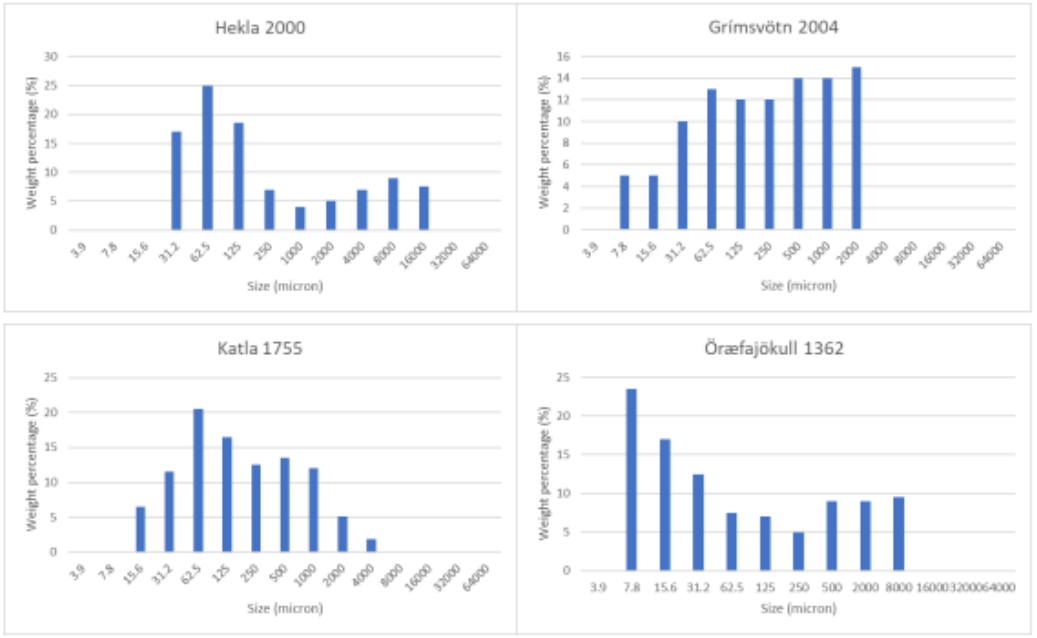
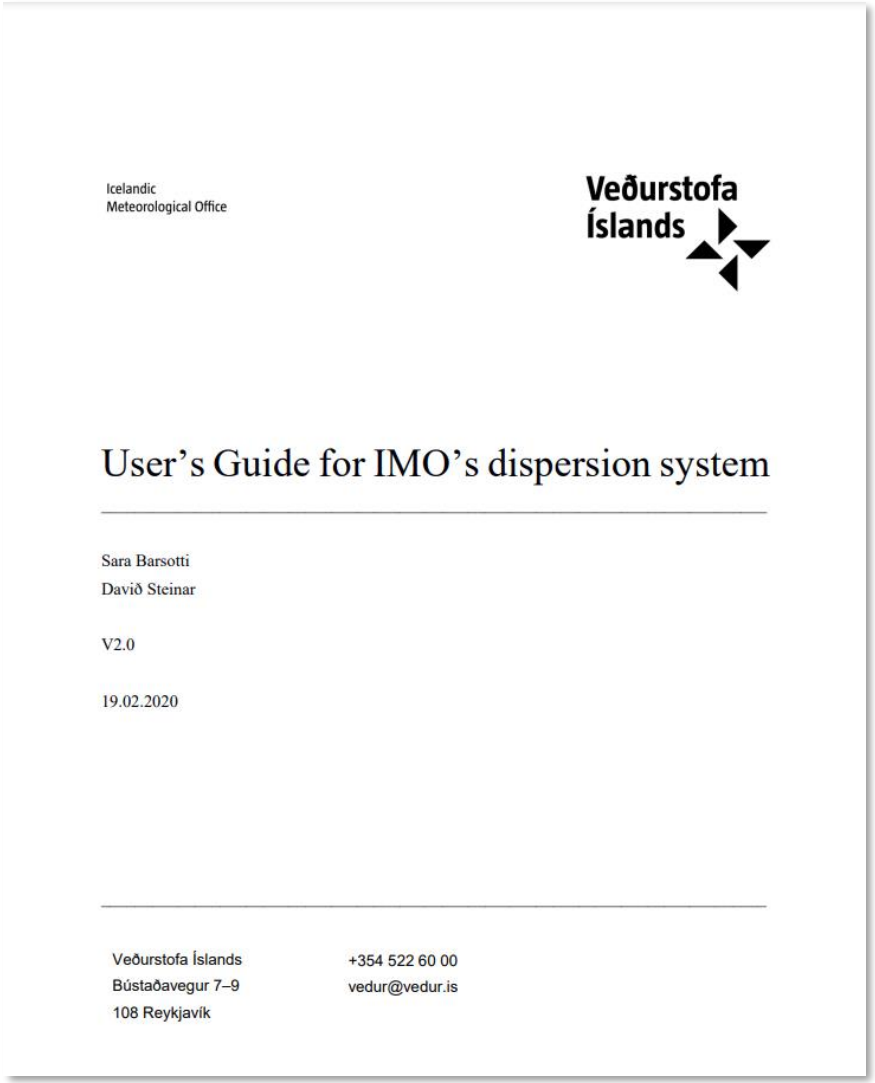


Fig. 5: Four TGSD are available in the current dispersal system. They have been adapted from the ICAO report available at https://earthice.hi.is/sites/earthice.hi.is/files/Pdf_skjol/total_grain-size_distribution_in_selected_icelandic_eruptions_01.pdf.

Preset varieties of grain size distributions



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User's Guide for IMO's dispersion system

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