Icelandic Met Office

Monitoring volcanoes in Iceland and their current status

Sara Barsotti

Coordinator for Volcanic Hazards,

sara@vedur.is

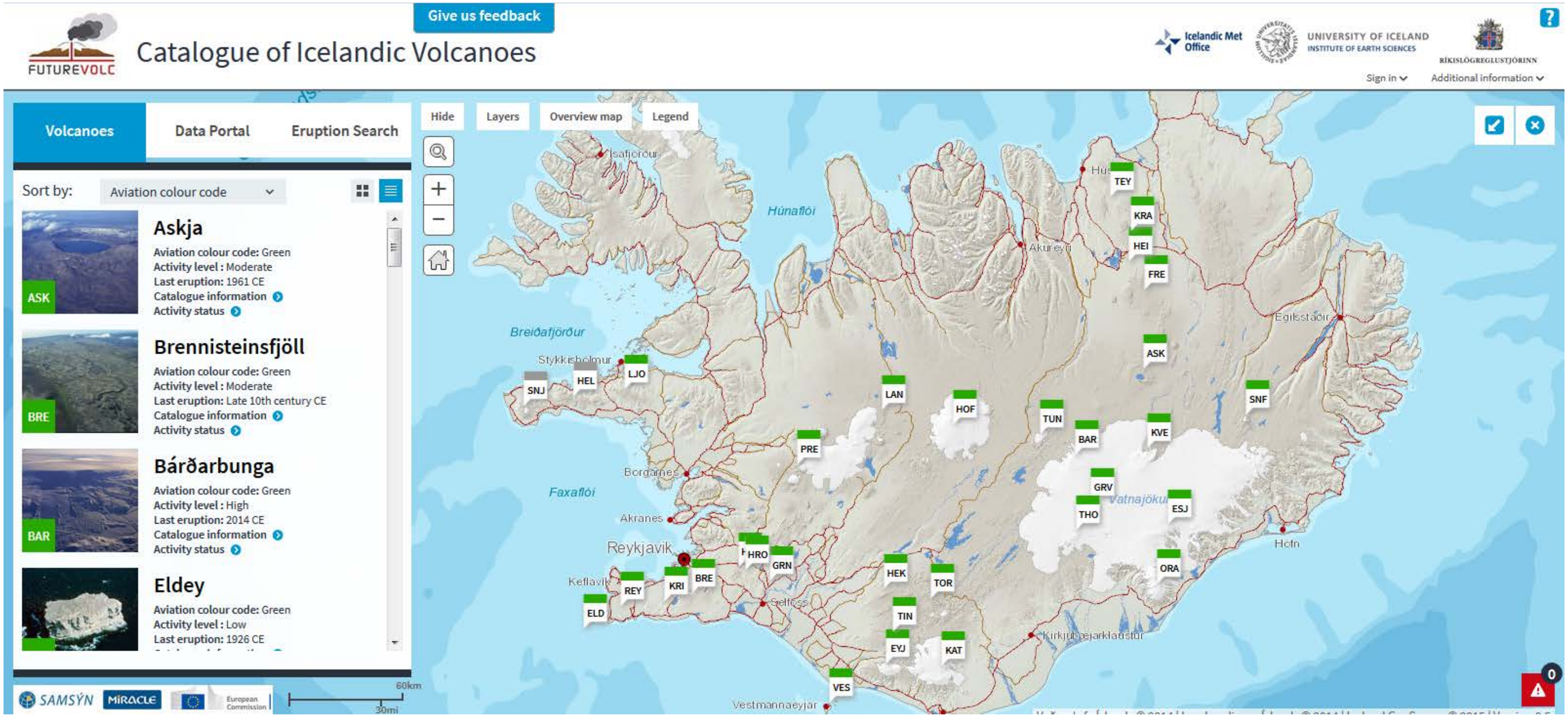
Overview

Icelandic Met Office

- **Volcanoes and volcanic eruption styles in Iceland**
- **Monitoring volcanoes and volcanic eruptions**
- **Current status at**
  - Hekla
  - Katla
  - Bárðarbunga
  - Grímsvötn
  - Öræfajökull

The catalogue of Icelandic Volcanoes – icelandicvolcanoes.is

Icelandic Met Office



It includes historical activity, current seismicity, possible hazards and scenarios, GIS-based map layers to visualize eruption product extensions (lava flows, ash deposits) – ICAO project

Explosive vs. Effusive eruption

Icelandic Met Office

Eyjafjallajökull 2010

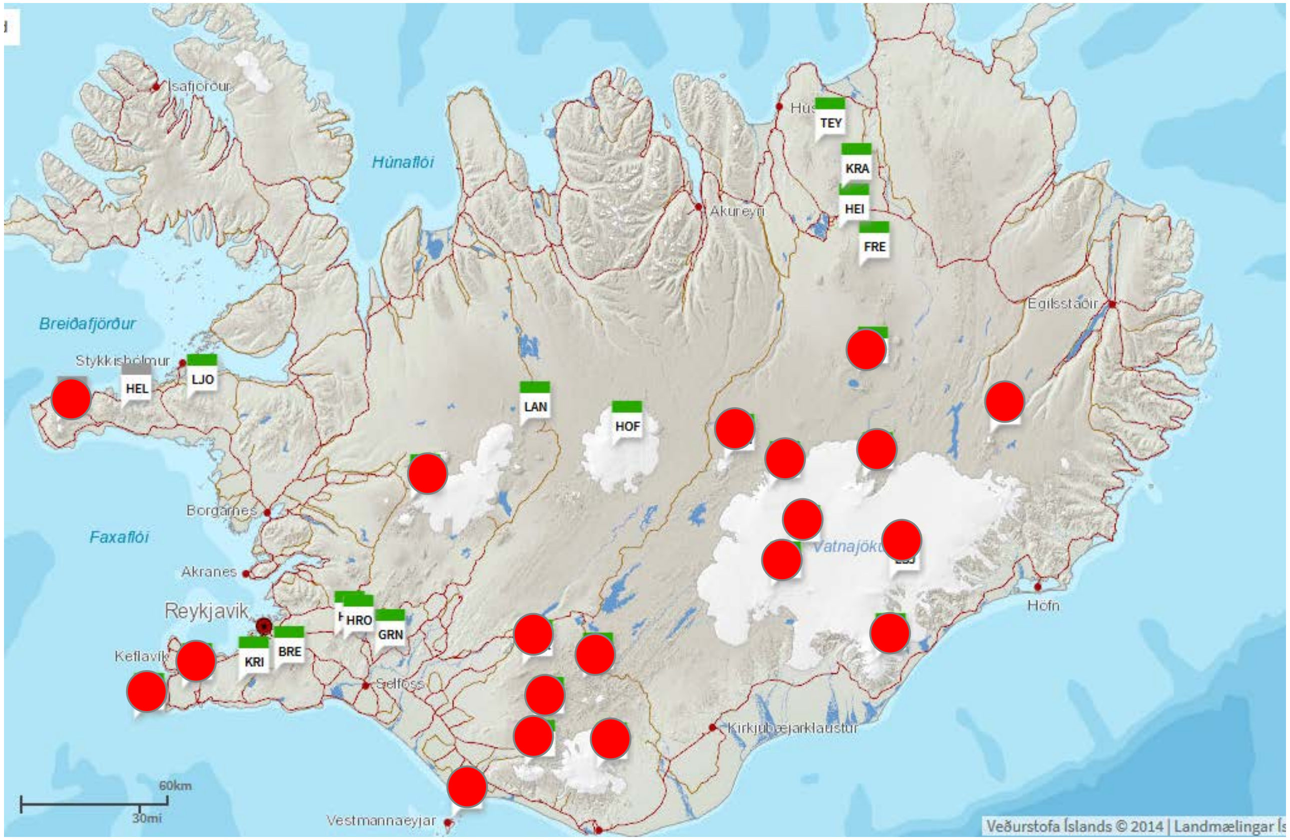
Bárðarbunga - Holuhraun 2014-2015

- Volcanic cloud (possibly up to the stratosphere)
- Tephra fallout
- Lightning
- Floods (if from ice-capped volcano)
- Pyroclastic flows

- Lava flow
- Volcanic gas into the atmosphere (hardly higher than the tropopause)

Volcanic ash hazards from Icelandic volcanoes

Icelandic Met Office



✓ All these volcanoes have volcanic ash as one of the principal hazards

Icelandic Met Office

Eruption in Iceland since 1913

Year	Volcano	VEI	Note	Stile of activity
2014	Holuhraun (Bárðarbunga)	1		Effusive
2011	Grímsvötn	4	Ice	Explosive
2010	Eyjafjallajökull	3	Ice	Explosive/effusive
2004	Grímsvötn	3	Ice	Explosive
2000	Hekla	3		Effusive/explosive
1998	Grímsvötn	3	Ice	Explosive
1996	Gjálp (Grímsvötn)	3	Ice	Subglacial-explosive
1991	Hekla	3		Effusive/explosive
1983	Grímsvötn	2	Ice	Explosive
1980-81	Hekla	3		Effusive/explosive
1975-84	Krafla fires (9 eruptions)	1		Effusive
1973	Heimaey	2		Effusive/explosive
1970	Hekla	3		Effusive/explosive
1963-67	Surtsey	3	Ocean	Explosive/effusive
1961	Askja	2		Effusive
1947-48	Hekla	4		Effusive/explosive
1938	Gjálp (Grímsvötn)	-	Ice	Subglacial
1934	Grímsvötn	3	Ice	Explosive
1922-29	Askja (5-6 eruptions)	2	(lake)	Effusive/explosive
1922	Grímsvötn	3	Ice	Explosive
1918	Katla	4	Ice	Explosive
1913	Hekla	1		Effusive

Instrumental monitoring

No instrumental monitoring

Frequencies of eruptive styles

Icelandic Met Office

Volcano	Purely explosive (or with explosive component)	Purely effusive
Hekla	82%	18%
Katla	97%	3%
Bárðarbunga	90%	10%
Grímsvötn	95%	5%

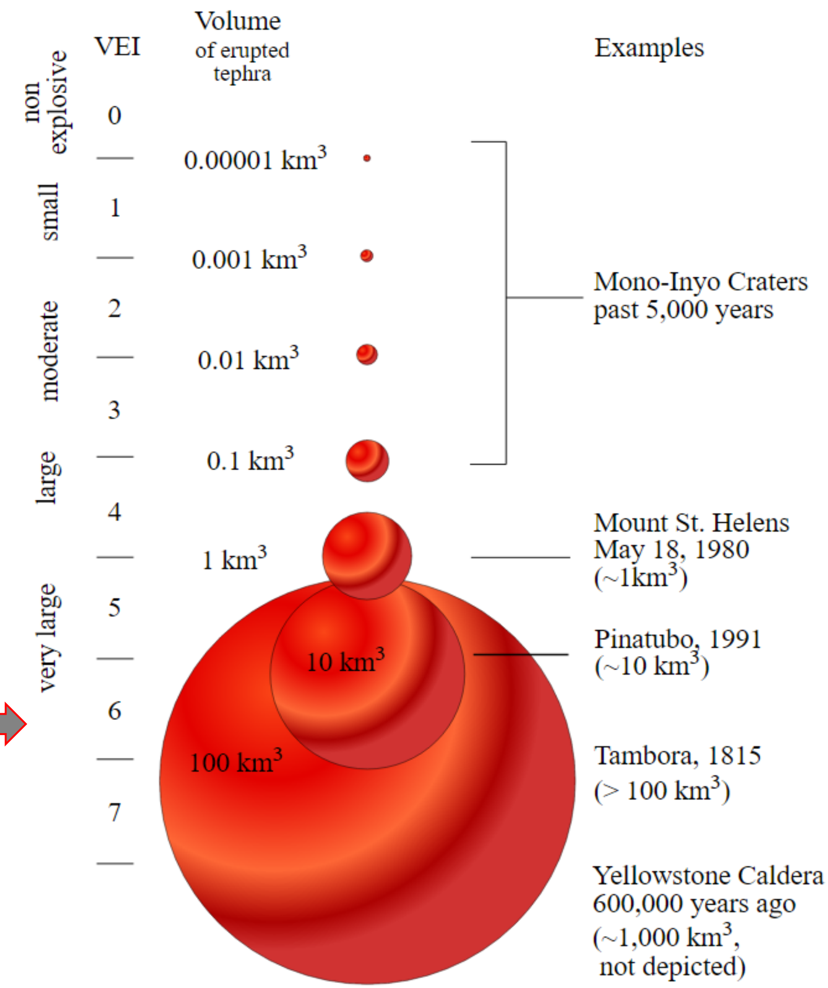
The size of an explosive eruption: the VEI

Icelandic Met Office

Volcanic Explosivity Index:
Erupted volume of tephra is often used as a proxy for magnitude for explosive eruptions.

Katla 934, Hekla 1104, Askja 1875

Öræfajökull 1362, BB-Veiðivötn 1477

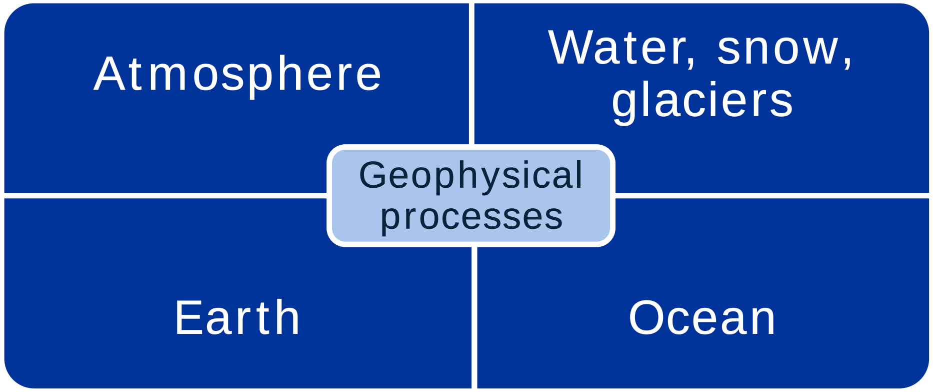


The role of the Icelandic Meteorological Office

Icelandic Met Office

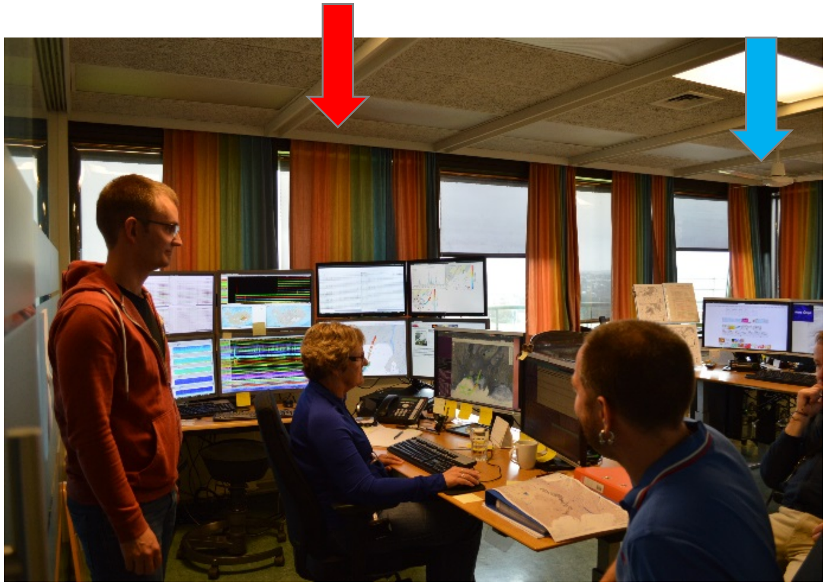
The main purpose of IMO is to contribute towards increased security and efficiency in society by:

- **Monitoring**, analysing, interpreting, informing, giving advice and counsel, providing **warnings** and **forecasts** and where possible, predicting natural processes and natural hazards.
- Issuing public and aviation **alerts** about impending natural hazards, such as volcanic ash, extreme weather and flooding



IMO and IVO

- IVO is the **Icelandic Volcano Observatory** and it coexists within IMO
- Integration of interpretations and multidisciplinary investigation
- Fast and effective communication



Operational response

IMO designes and follows **contingency plans** for all monitored natural hazards and for different field teams.

Regarding volcanoes, our main stakeholders are:

CIVIL PROTECTION and GENERAL PUBLIC	AVIATION sector (L-VAAC, ISAVIA)
triggered by **phone calls and** IMO's web-site	triggered by **phone calls**
1. Possible scenarios and evolution of the ongoing situation 2. Hazards assessment 3. Forecasts of ash/gas dispersal and fallout in the country 4. Scientific support for risk mitigation actions	1. Onset of an eruption 2. Plume height and characteristics of ash cloud 3. Temporal variability of eruption style and intensity

Volcano Observatory‘s tasks

Icelandic Met Office

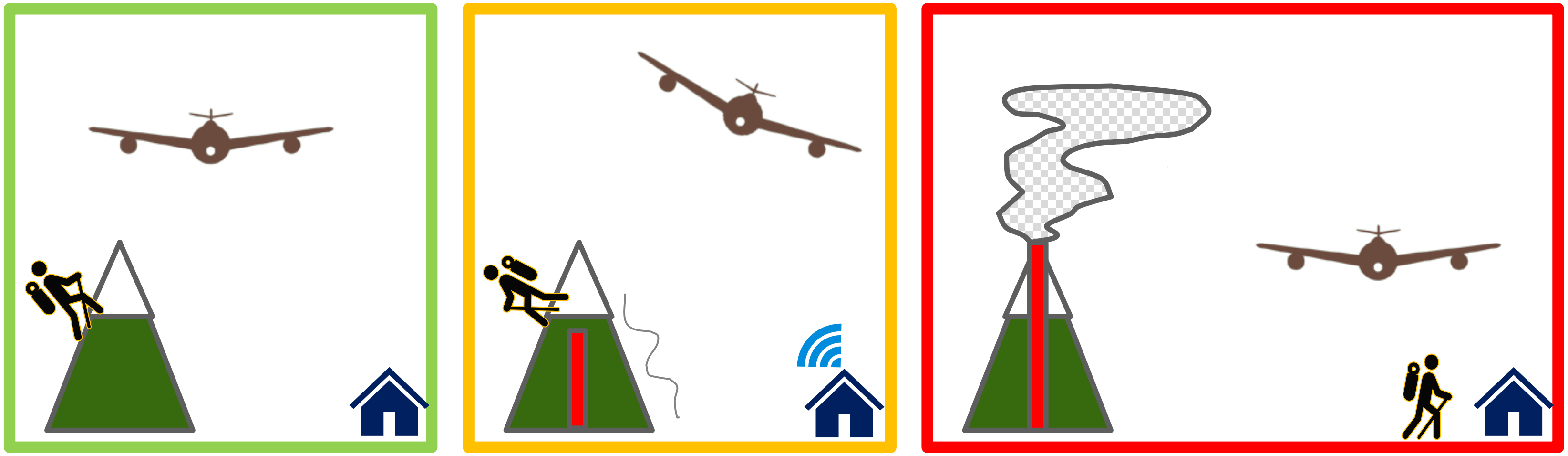
- **To detect and interpret signs of unrest t lead to an eruption →**
  - needs long-term monitoring data to background level as well as real-time monitoring to s on small time scales
- **To assess the possible vo ards and their temporal evolution in case of ar →**
  - needs a background e of historical activity to identify possible hazard real-time monitoring to follow the ongoin event tions in intensity, spatial distribution of the hazard
- **To timely and properly communicate to stakeholder →**
  - needs a response plan and clear indication on the vital information that are needed by the users

… in strong collaboration with the University of Iceland

Monitoring setup

- Multi-parametric monitoring built on three main pillars:

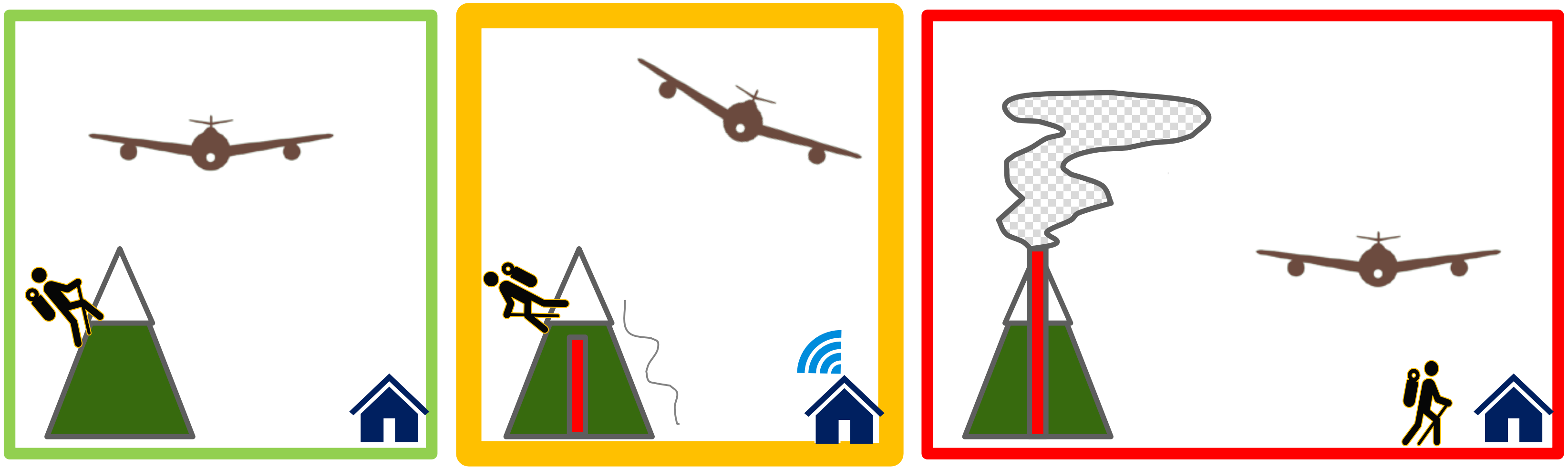
Geophysics and geochemistry	Atmosphere and acoustic	Remote sensing and satellite



Monitoring setup

- Multi-parametric monitoring built on three main pillars:

Geophysics and geochemistry	Atmosphere and acoustic	Remote sensing and satellite

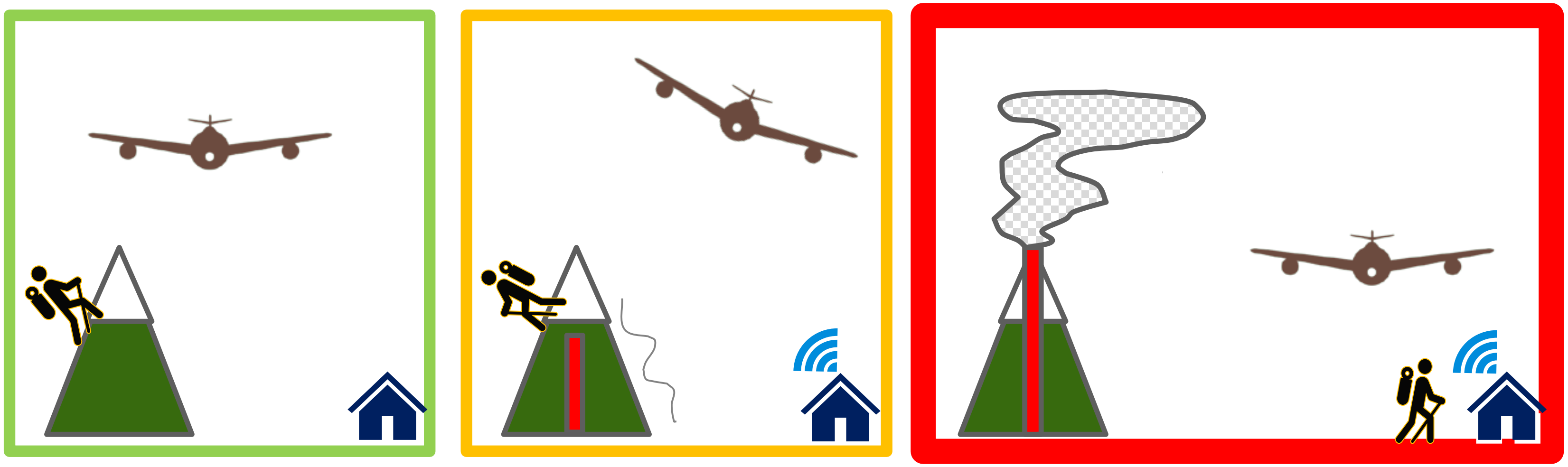


Monitoring setup

Icelandic Met Office

- Multi-parametric monitoring built on three main pillars:

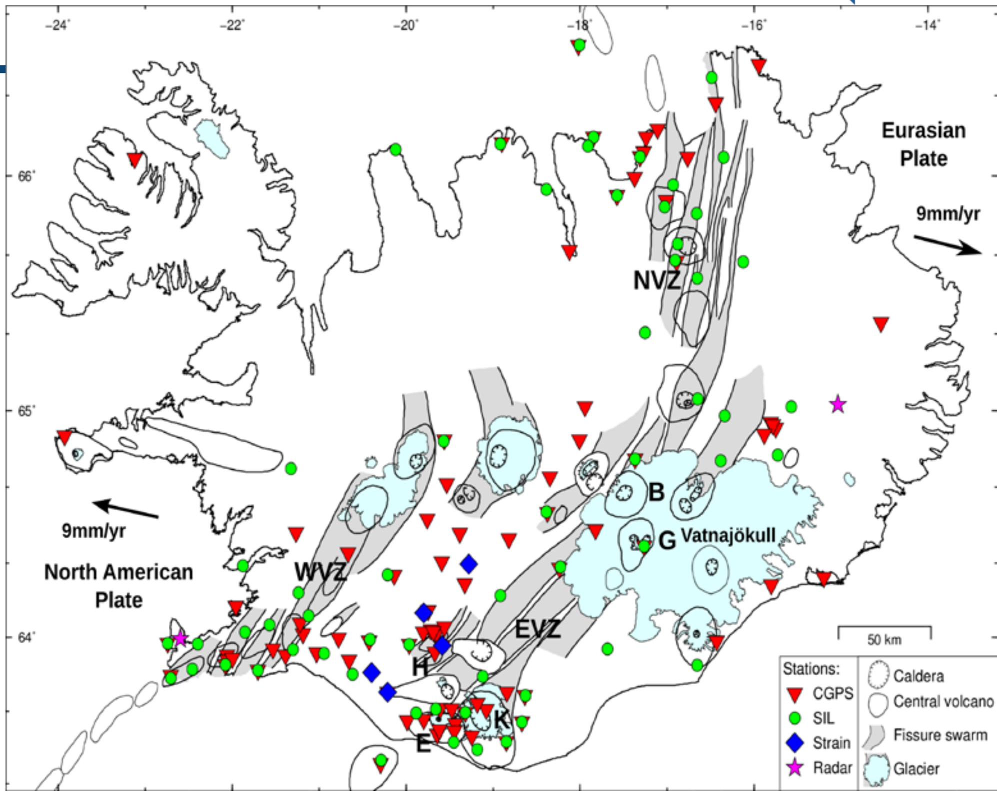
Geophysics and geochemistry	Atmosphere and acoustic	Remote sensing and satellite



Monitoring and Research: geophysical and geochemical monitoring for forecasting purposes

Icelandic Met Office

- ~ 70 seismic stations
- 145 hydrological gauging stations
- 70 GPS
- 5 strain-meter stations
- 3 MultiGas devices
- 1+(6) continuous DOAS (SO_2)
- Conductivity sensors (glacial outlet rivers)

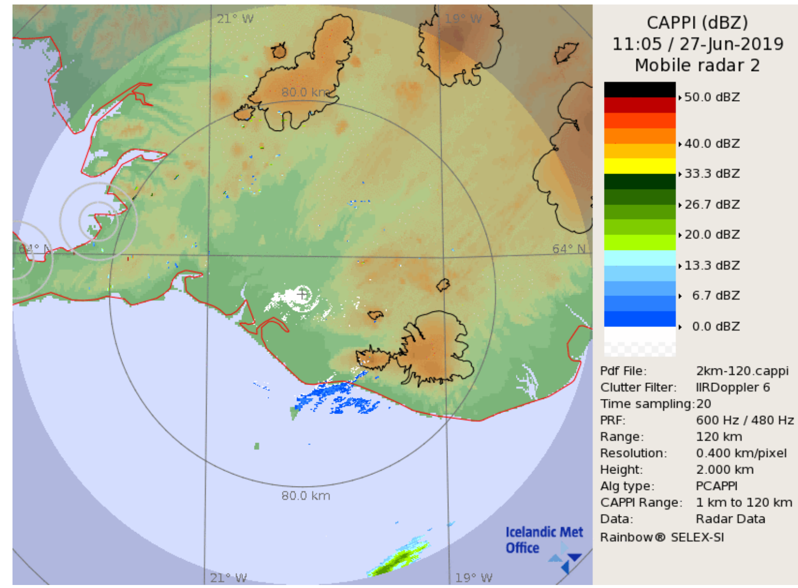


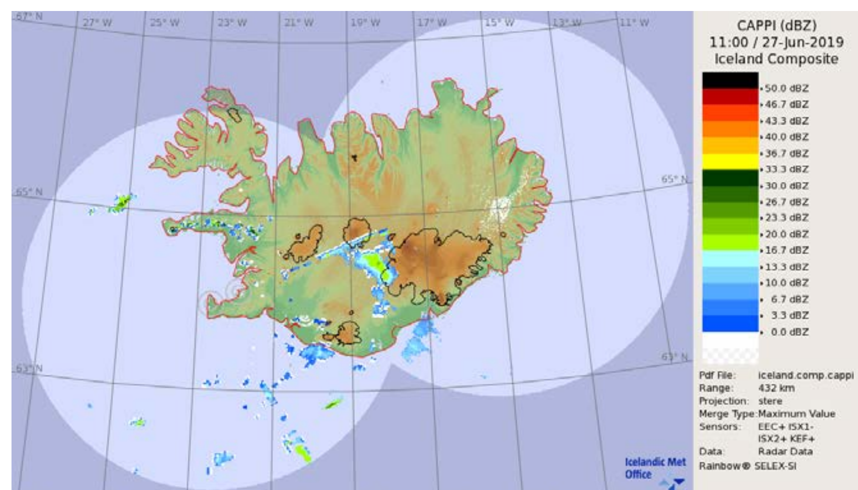
- InSAR
- Satellite acquisition (e.g. Landsat, Sentinel)
- FTIR
- Water chemistry sensors (dissolved CO_2)

Monitoring and Research: ash cloud detection and investigation during an eruption

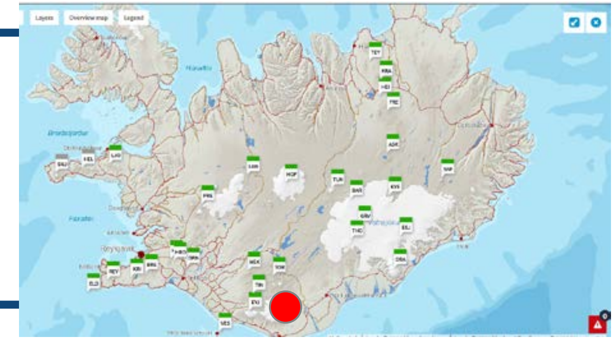
Icelandic Met Office

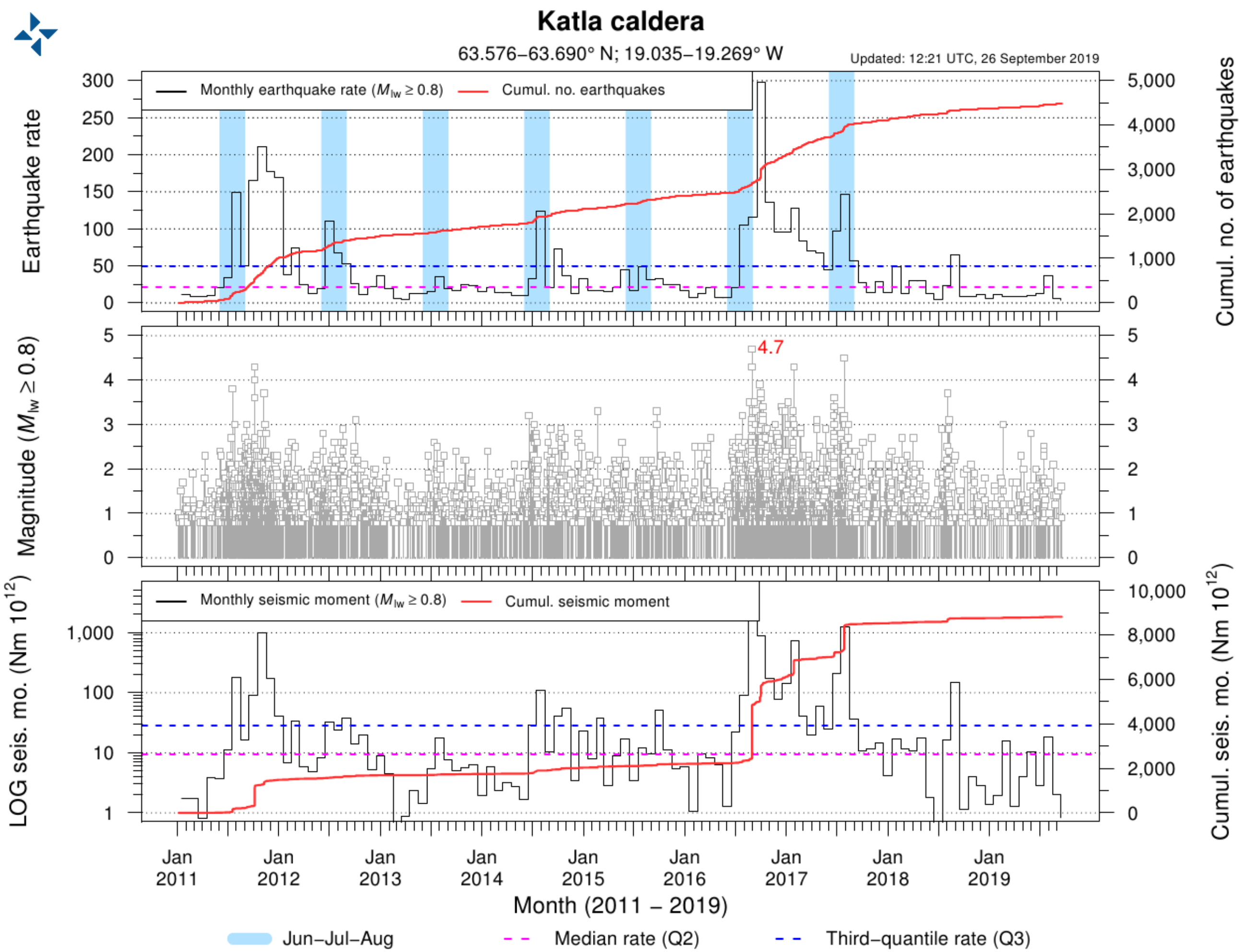
- C-band weather radar close to Keflavík airport since Jan 1991
  - has detected 7 eruptions
- C-band weather radar in East Iceland, operational since April 2012
- 2 X-band mobile radars
- 2 Lidars (one mobile)
- 7-ceilometers network
- 5 infrasound arrays
- Mobile radio-soundings
- Lightning-detection devices
- Satellite thermal detection products (Modis, Landsat,Sentinel, MIROVA)
- Webcams





Current status: Katla

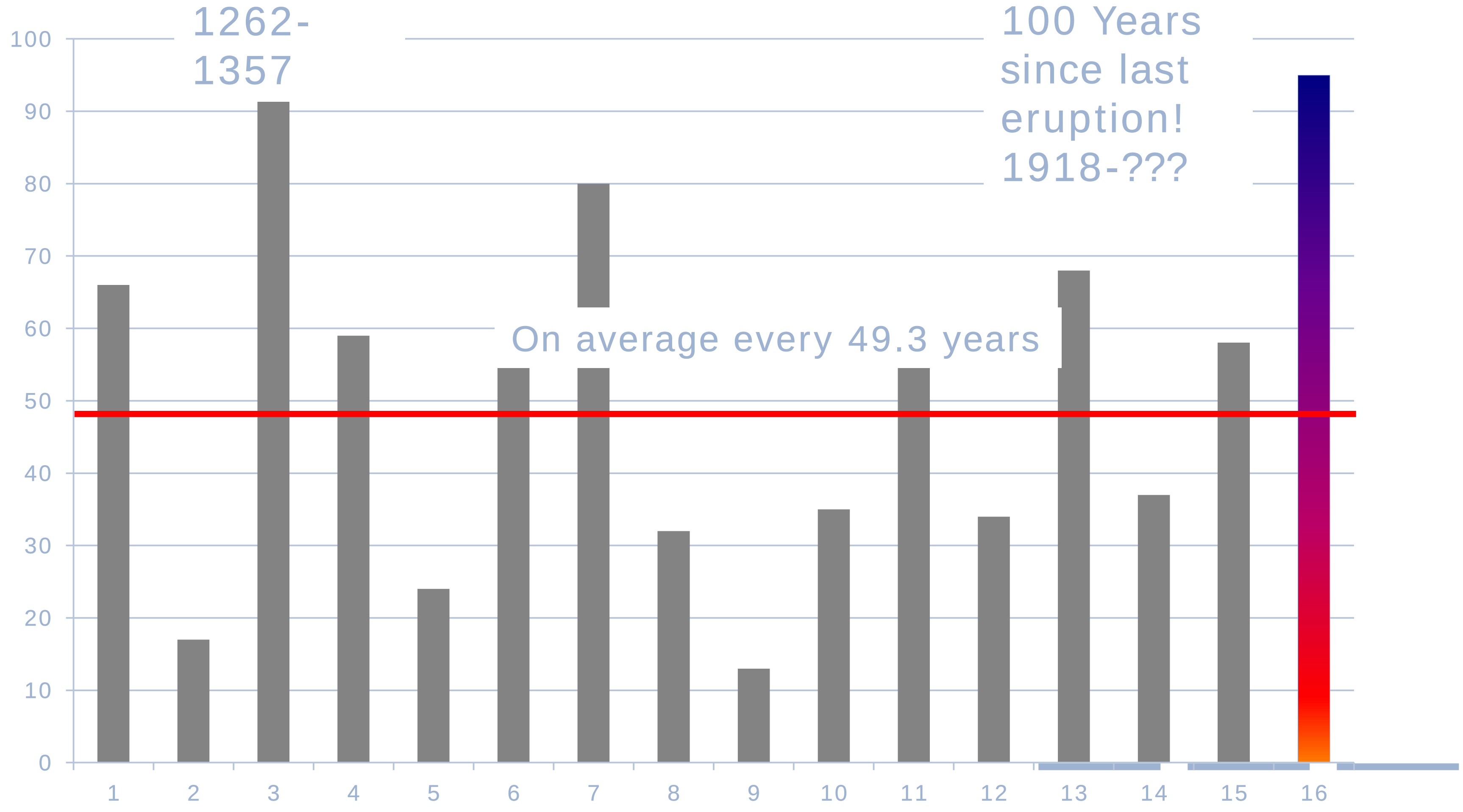




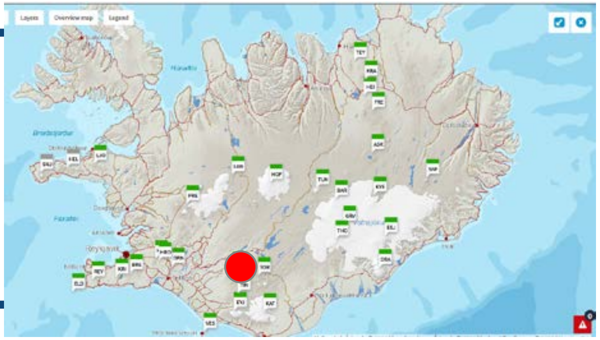
- Unrest declared during the winter 2016 – quiet since then, except for occasional floods and gas release
- No detectable increase rate in ground deformation

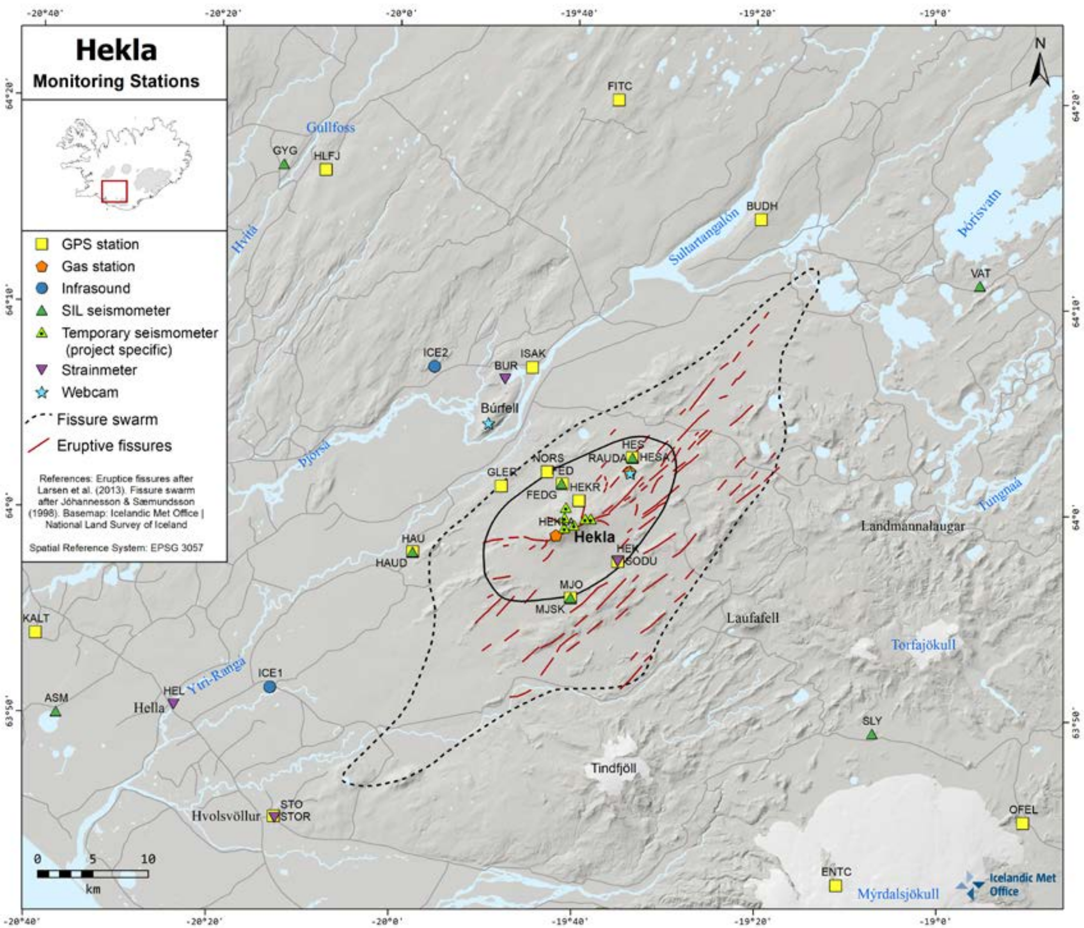
Recurrence time of Katla's eruptions since 1179

16 eruptions confirmed in historical records



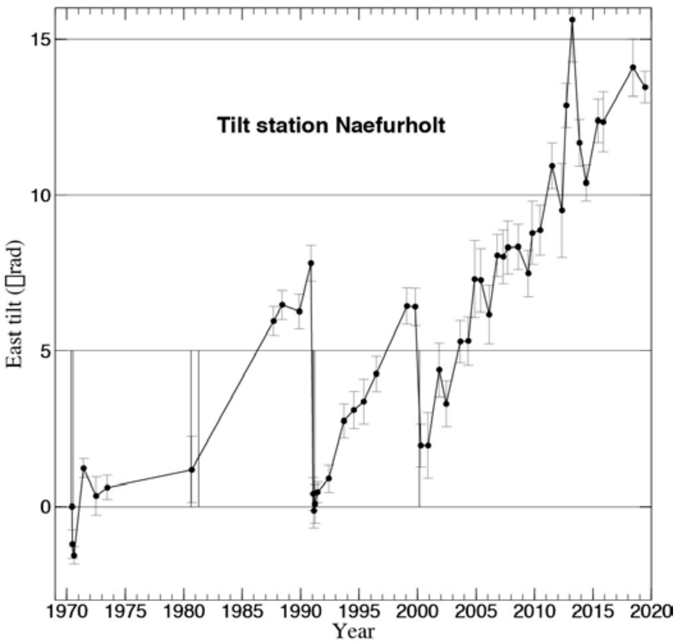
Current status: Hekla

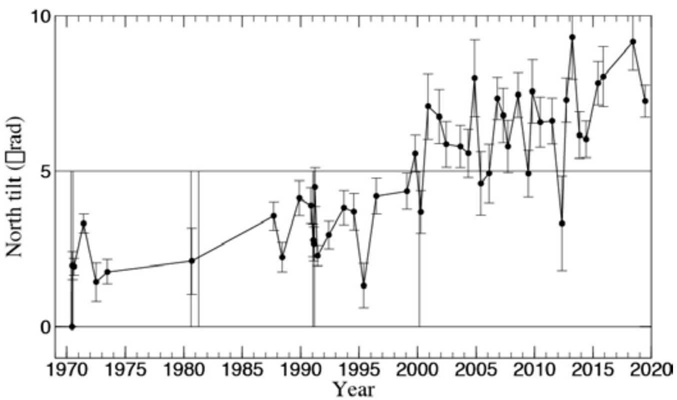


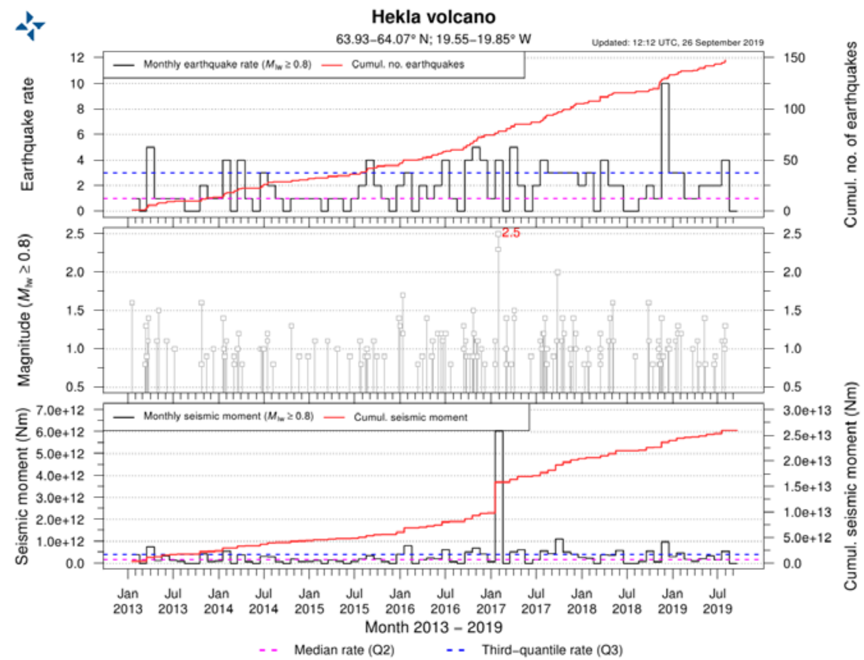


- Monitored with extensive and multi-parametric network
- It has shown very short precursory signals in past eruptions
- Alert system has been setup for seismicity

Current status: Hekla

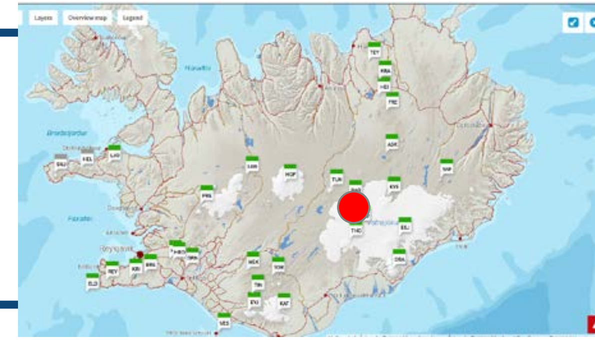


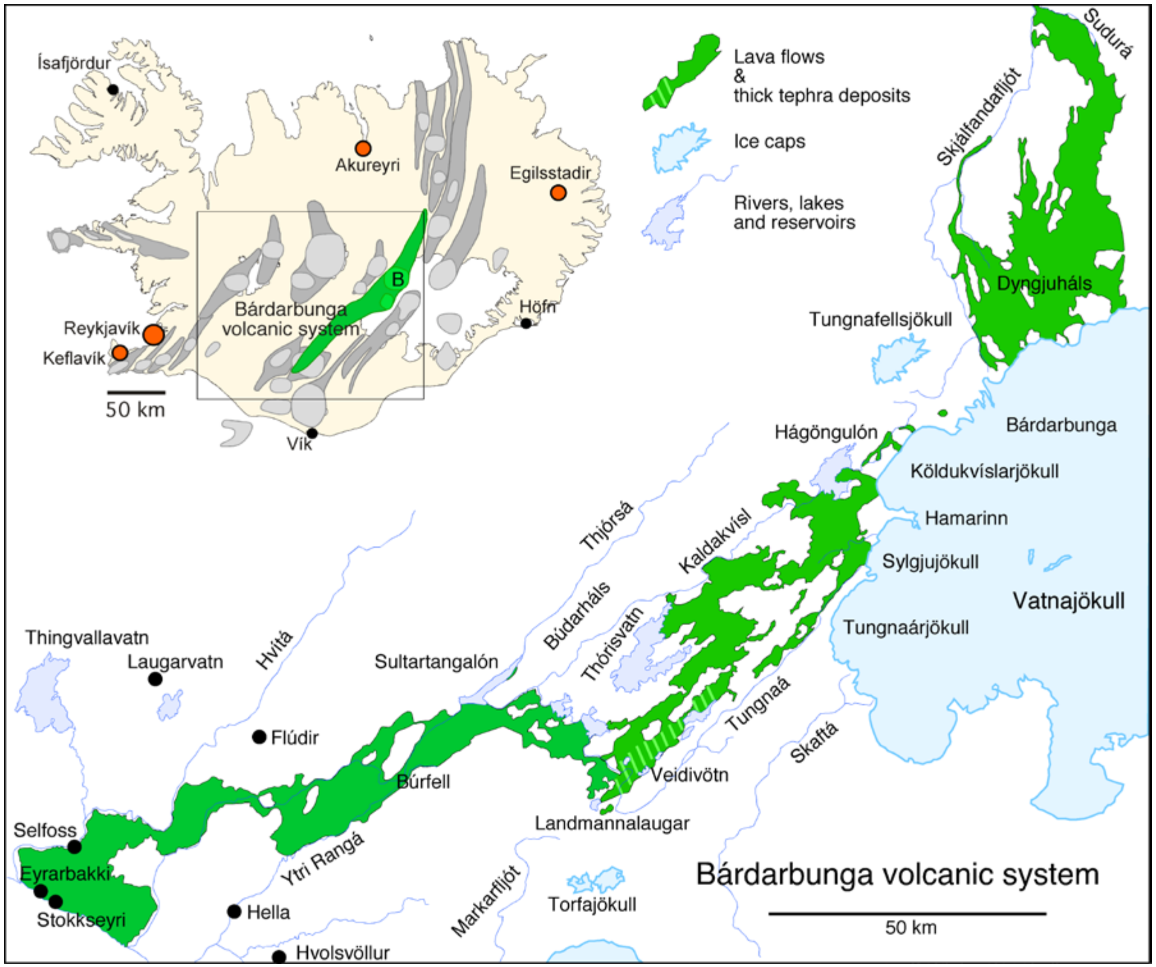




- Hekla is in an inflating phase since 2000.
- The seismicity level is very low but it increases periodically.

Current status: Bárðarbunga



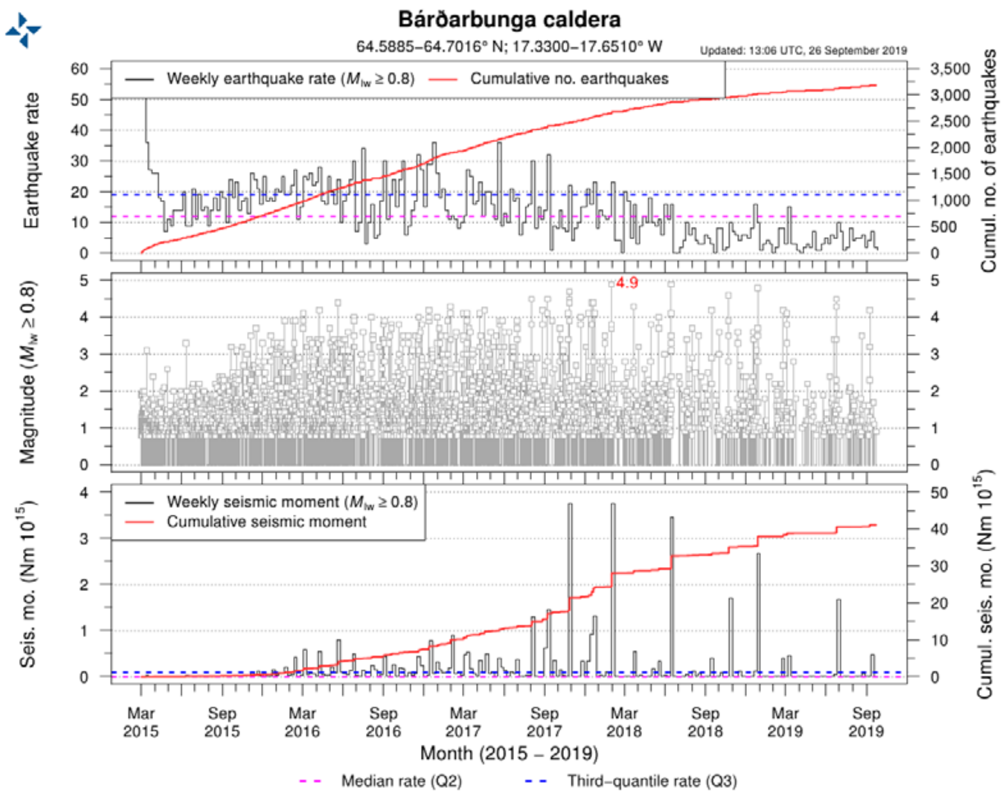


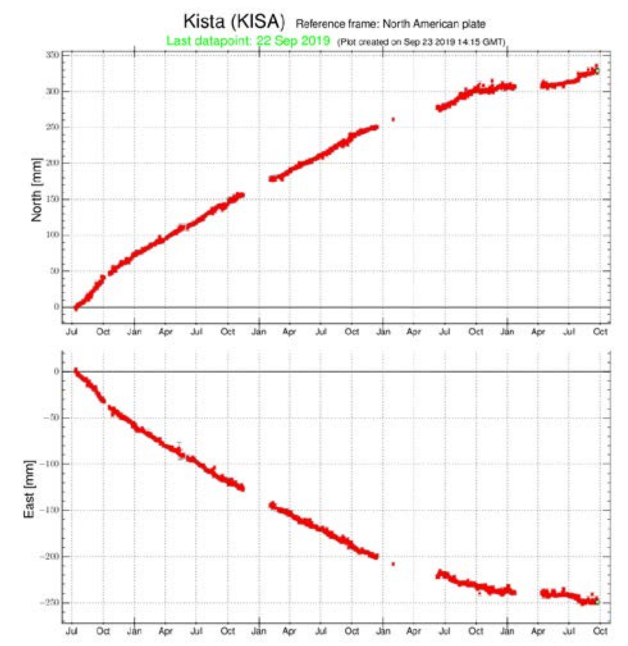
- 190 km long and up to 25 km wide
- Last eruption in 2014-2015
- With a vertical caldera collapse of 65m

Current status: Bárðarbunga

Icelandic Met Office

- Seismic activity since the end of the eruption – still ongoing with periodical large earthquakes
- Signs of inflation from the GPS network
- Indication of caldera floor uplift

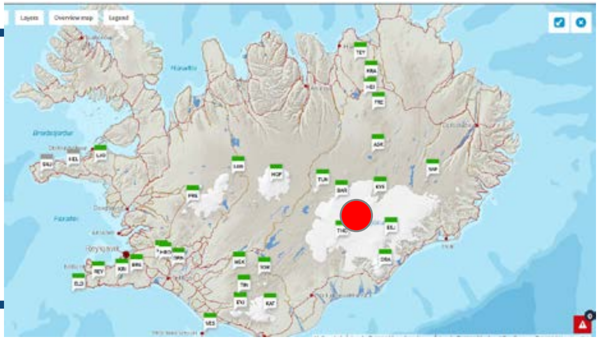


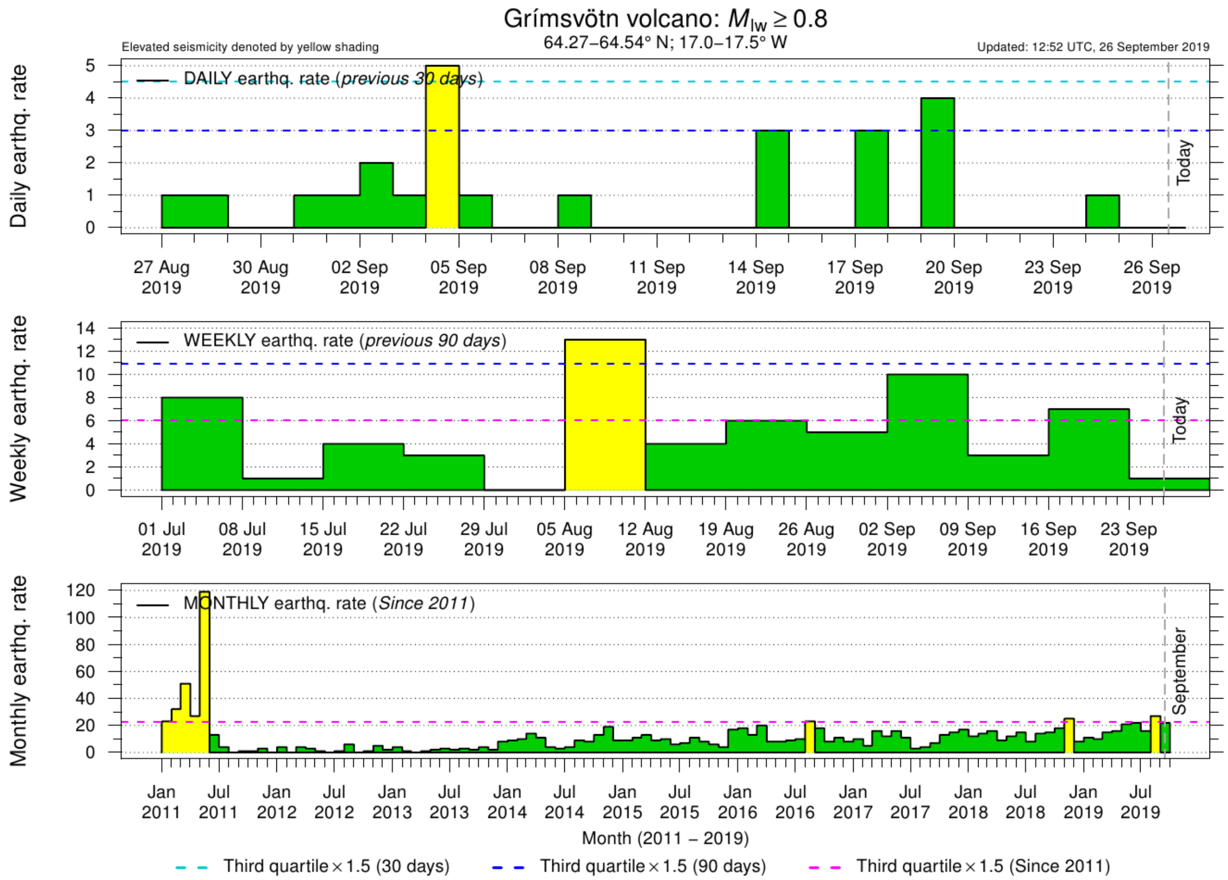


Current status: Bárðarbunga

- Since the end of the eruption the **deep** seismicity started to increase between 2016-2018. The rate of the deep seismicity has been apparently increasing further since autumn 2018.
- The **deformation rate** is slowing down (as shown well from KISA and VONC) stations. Since October-November 2018 the deformation has been flattening.
- The **gas** did not show any significant changes between 2018-2019. But the big difference in the gas composition (i.e. an increase in H_2) occurred between 2016-2018.
- Bárðarbunga is in recharging phase

Current status: Grímsvötn

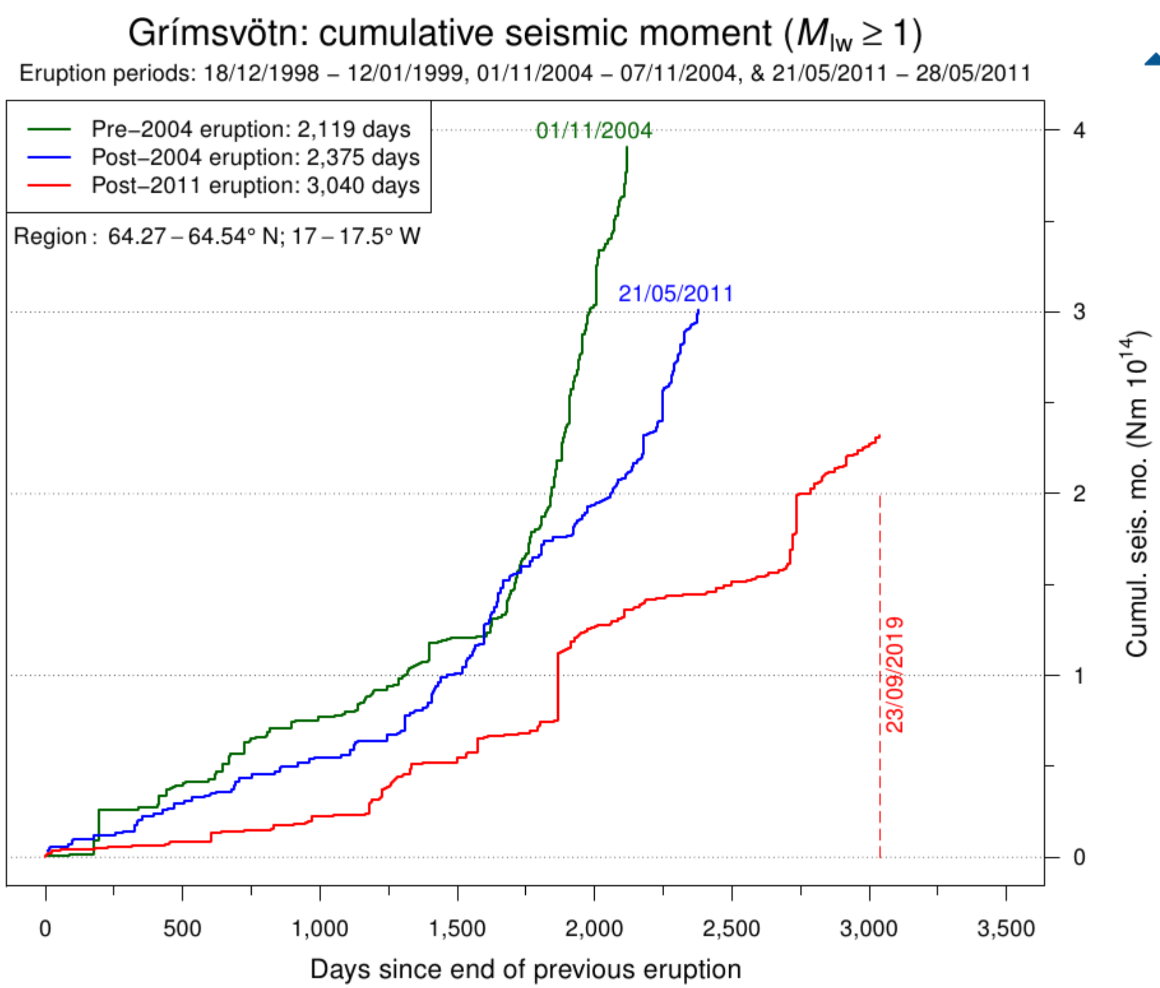




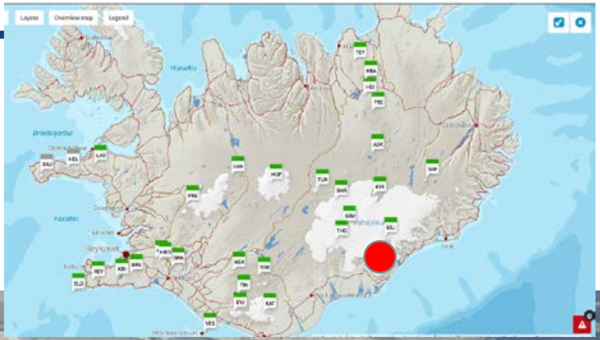
- One of the most frequently erupting volcanoes
- It has shown quite regular trend between eruptions
- We expect it will follow a similar trend before the next eruption, as well

Current status: Grímsvötn

Icelandic Met Office



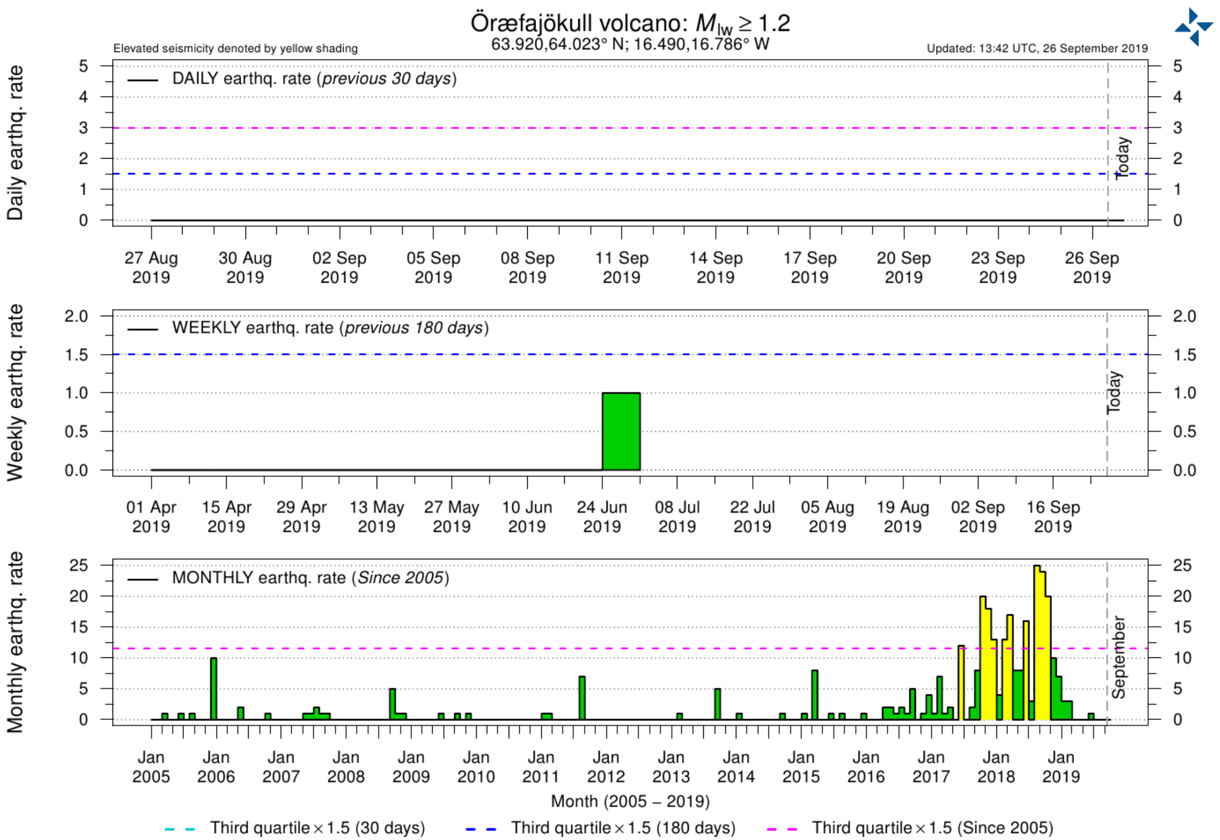
Current status: Öræfajökull



- 3x4 km ice-filled caldera
- 2000 m high
- ~14km from the coastline (at the shortest)
- ~ 257 km from Reykjavík
- In 1362 VEI=6 and in 1727 VEI=4

Current status: Öræfajökull

Icelandic Met Office



- Since September 2017 the volcanic unrest became clear
- Aviation color code was changed to yellow and moved back to green in May 2018

Current status: Öræfajökull

Icelandic Met Office

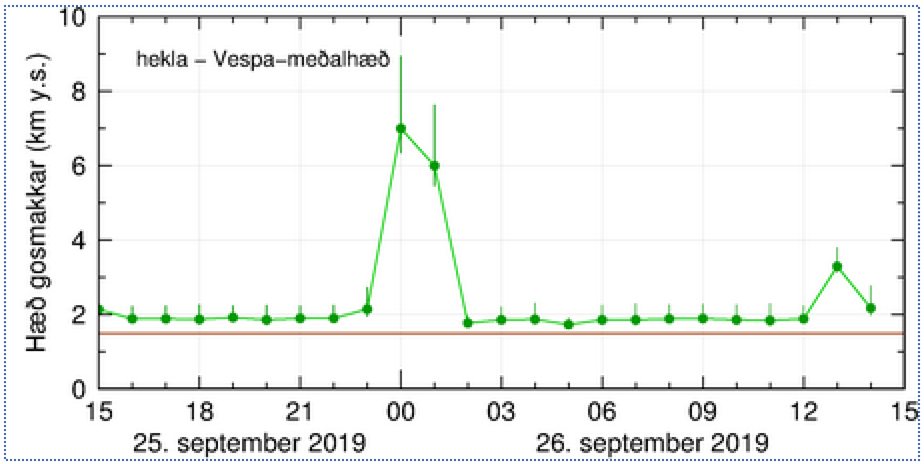
- Seismic and deformation (InSAR and GPS) data suggest that magma inflow is most likely still on-going but at a lower rate (since Oct-Nov 2018).

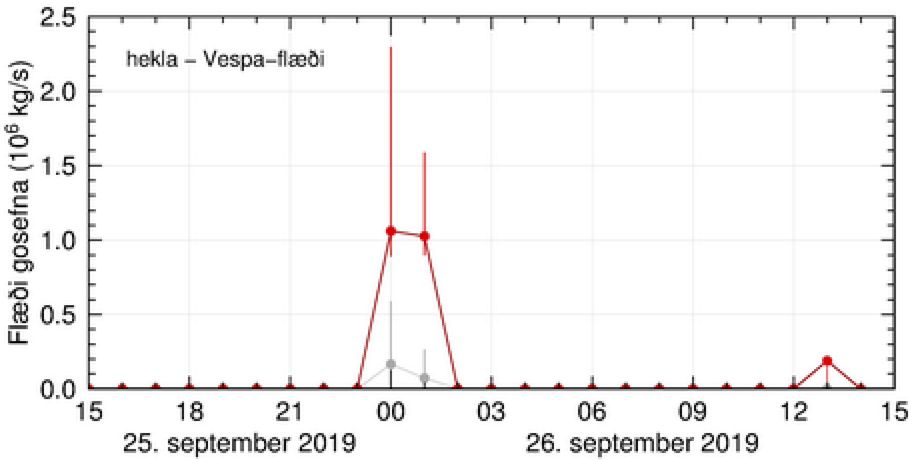
- Geothermal fluids are still released from the system, but the gas concentration does not represent a health hazard.

Observation and estimation of plume height

- The new VESPA system calculates automatically the hourly plume height and the MFR (http://brunnur.vedur.is/radar/vespa/)
- Plume height on the hour is estimated as the mean, weighted by uncertainties, for all scans
- Inversion for source parameters in the 1D PlumeMoM model using the radar plume height and vertical atmospheric profile from the ECMWF numerical weather prediction model

Hekla - Hæð gosmakkar og flæði



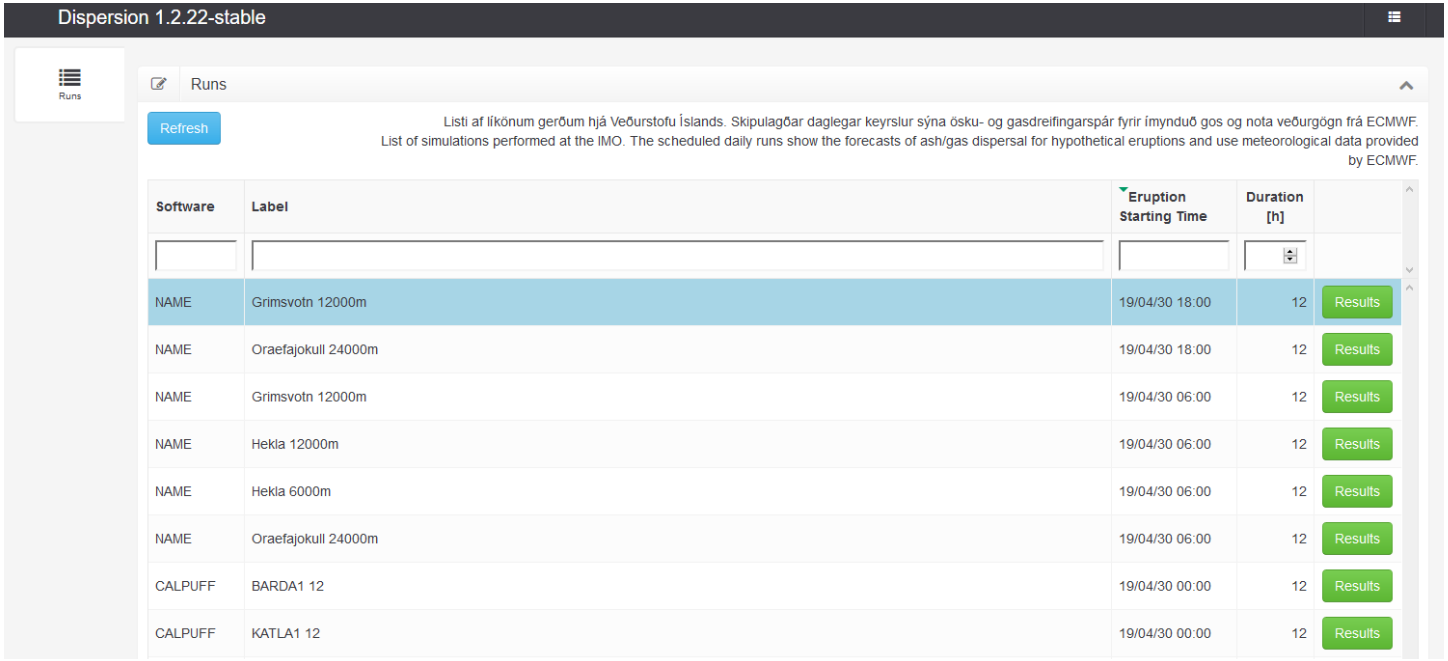


Daily simulations of tephra dispersal

Icelandic Met Office

A more flexible system to run the dispersal simulations has been developed to assimilate the newest data coming from the observational system:

Daily results are available at *dispersion.vedur.is*



Ash dispersal simulations

Icelandic Met Office

Multiple simulations are produced on a daily basis for Öræfajökull:

- 3 scenarios (6000m, 12000m, 24000m plume height)
- 4 starting times a day (06, 12, 18, 24)

Requested	Label	Started	Completed	Eruption Starting Time	Duration [h]	Elevation [m]	Column Height [m]	Latitude	Longitude	Priority	Grib Table Parameter		
	raefajokull												
12/05 07:37	Oraefajokull 24000m	07:37	07:43	12/05 06:00	12	2010	24000	64.05	-16.633	400	203	Files	Results
12/05 07:37	Oraefajokull 6000m	07:38	07:42	12/05 18:00	12	2010	6000	64.05	-16.633	200	221	Files	Results
12/06 07:38	Oraefajokull 12000m	07:39	07:45	12/06 06:00	12	2010	12000	64.05	-16.633	400	202	Files	Results
12/06 07:38	Oraefajokull 12000m	07:39	07:44	12/06 12:00	12	2010	12000	64.05	-16.633	300	212	Files	Results
12/06 07:38	Oraefajokull 6000m	07:39	07:44	12/06 18:00	12	2010	6000	64.05	-16.633	200	221	Files	Results
12/06 07:38	Oraefajokull 24000m	07:44	07:46	12/07 00:00	12	2010	24000	64.05	-16.633	100	233	Files	Results
12/05 07:37	Oraefajokull 6000m	07:37	07:43	12/05 06:00	12	2010	6000	64.05	-16.633	400	201	Files	Results
12/05 07:37	Oraefajokull 6000m	07:38	07:43	12/05 12:00	12	2010	6000	64.05	-16.633	300	211	Files	Results

Thank you!

Icelandic Met Office