Volcanic activity and observational networks in Iceland

Icelandic Met Office

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Icelandic Meteorological Office

Presentation outline

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- **The role of IMO and IVO**
- **Current status of key volcanoes**
  - Hekla
  - Katla
  - Bárðarbunga
  - Grímsvötn
  - Öræfajökull
- **Overview of IMO monitoring network**
- **Operational procedures and real-time estimate of plume height, mass eruption rate and ash dispersion modelling**

The role of the Icelandic Meteorological Office

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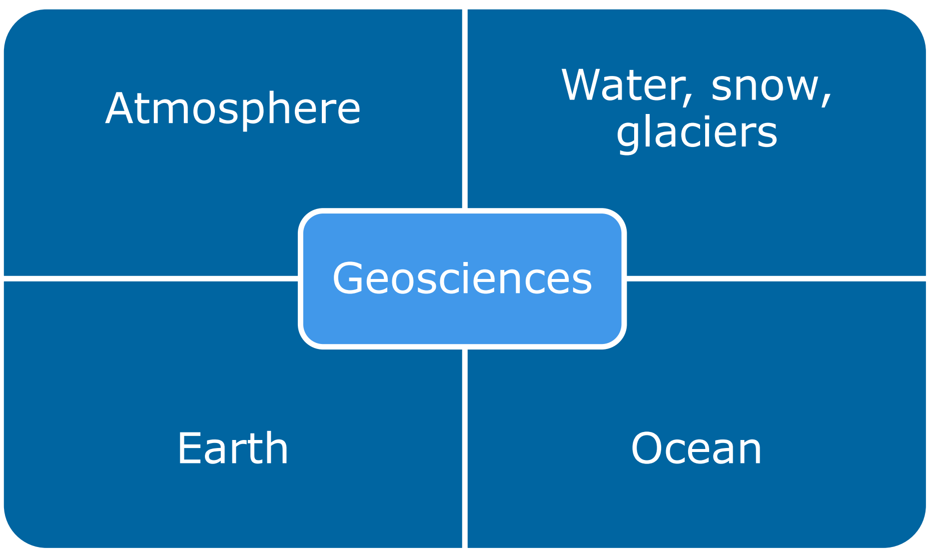
The main purpose of IMO is to contribute towards increased security and efficiency in society by:

- **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.



Icelandic Volcano Observatory (IVO) tasks

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- **To detect and interpret signs of unrest that might lead to an eruption →**

A long-term timeseries of monitoring data is essential to understand what is normal background activity as well as real-time monitoring to detect changes on small time scales

- **To assess the possible volcanic hazards and their temporal evolution in case of an eruption →**

Requires a background knowledge of historical activity to identify possible hazards as well as real-time monitoring to follow the ongoing event and variations in intensity and spatial distribution of the hazard

- **To communicate information to stakeholders in a timely and effective manner →**

A efficient response plan is necessary and knowledge of the vital information that is required by the stakeholders

Volcanism in Iceland

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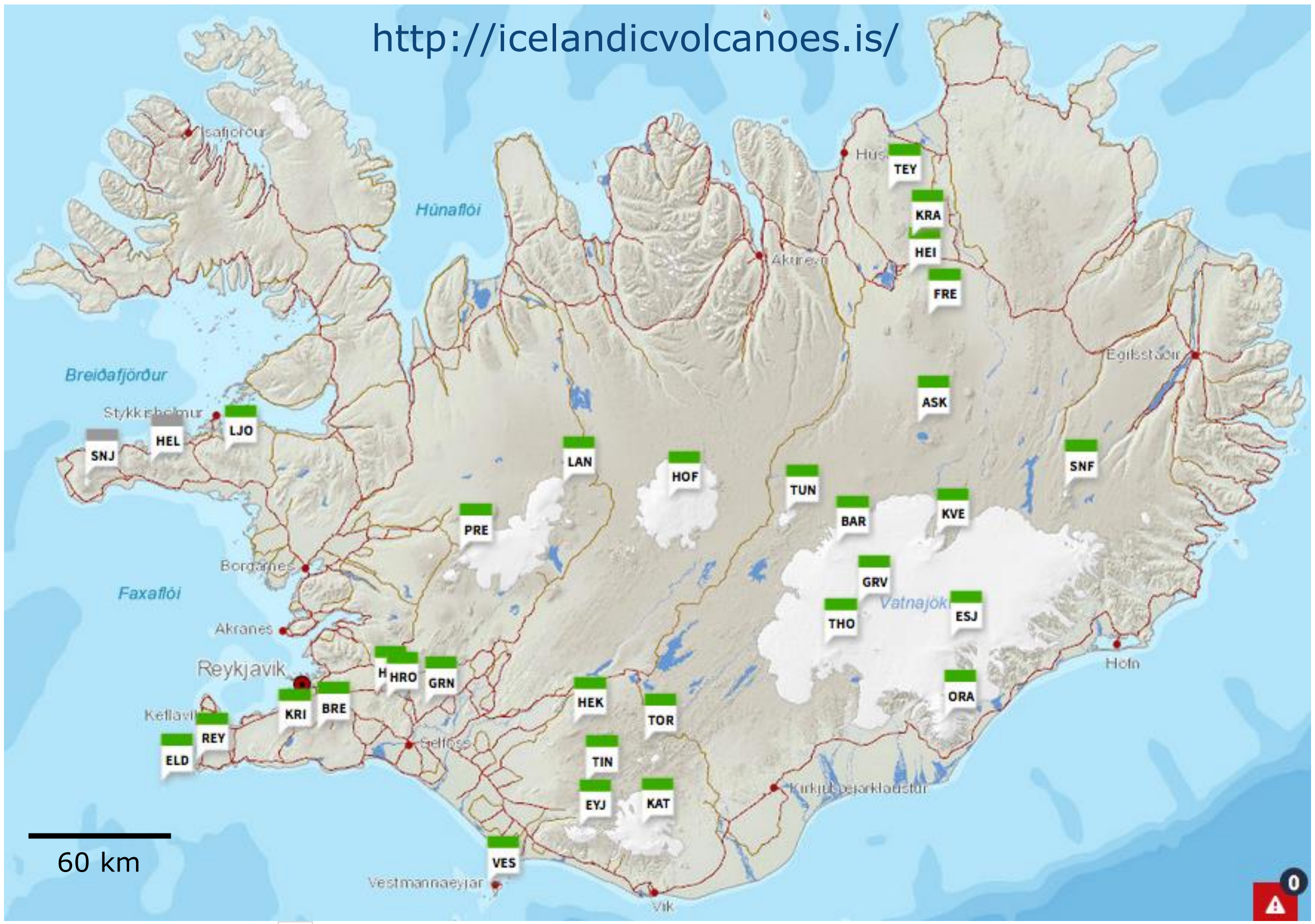

GREY: Volcano appears quiet but is not monitored adequately. Absence of unrest unconfirmed.

GREEN: Volcano is in normal, non-eruptive state.
or, after a change from a higher alert level:
Volcanic activity considered to have ceased, and volcano reverted to its normal, non-eruptive state.

- 32 active volcanic systems (central volcano + fissure)
- They erupted at least once in the last 10,000 years and may erupt again

Direct hazards during volcanic eruptions

- Many types of hazardous phenomena can occur during volcanic eruptions:
  - Lava flows
  - Pyroclastic flows
  - Landslides
  - Bombs
  - Tephra (ash) fallout
  - Lightning
  - Gas release
  - Jökulhlaups
- The occurrence of some or all of these hazards depends mostly on:
  - The type of magma (rheology, gas content)
  - Intensity of the eruption
  - The location where the eruption takes place

Iceland volcanic systems and target volcanoes for monitoring

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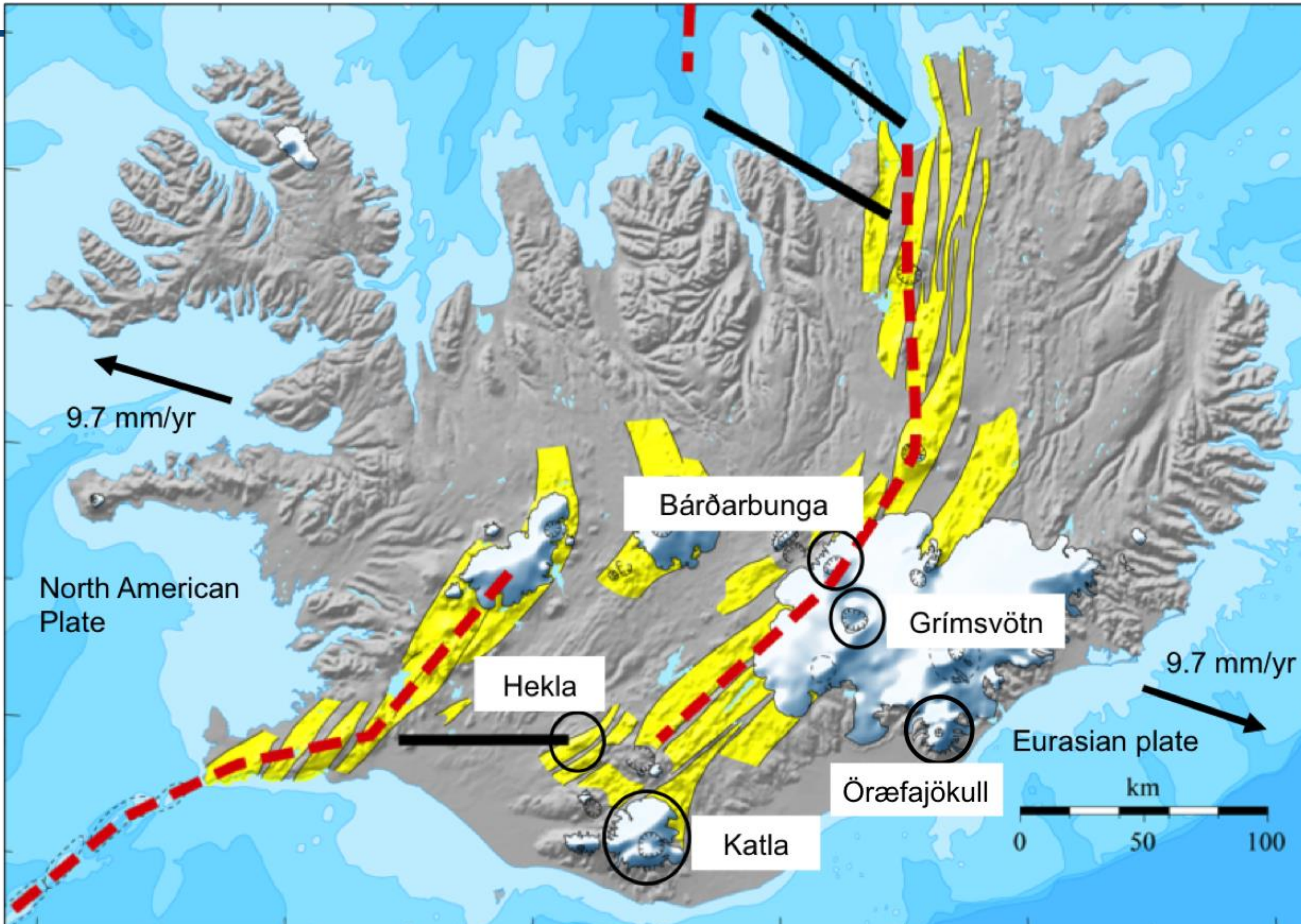

Katla eruption 1918

http://earthice.hi.is/katla_eruption_1918

- One of the most dangerous volcanoes in Iceland

- Katla erupted roughly twice/century for the last 1100 years, with the last confirmed subaerial eruption in 1918

Current status: Katla

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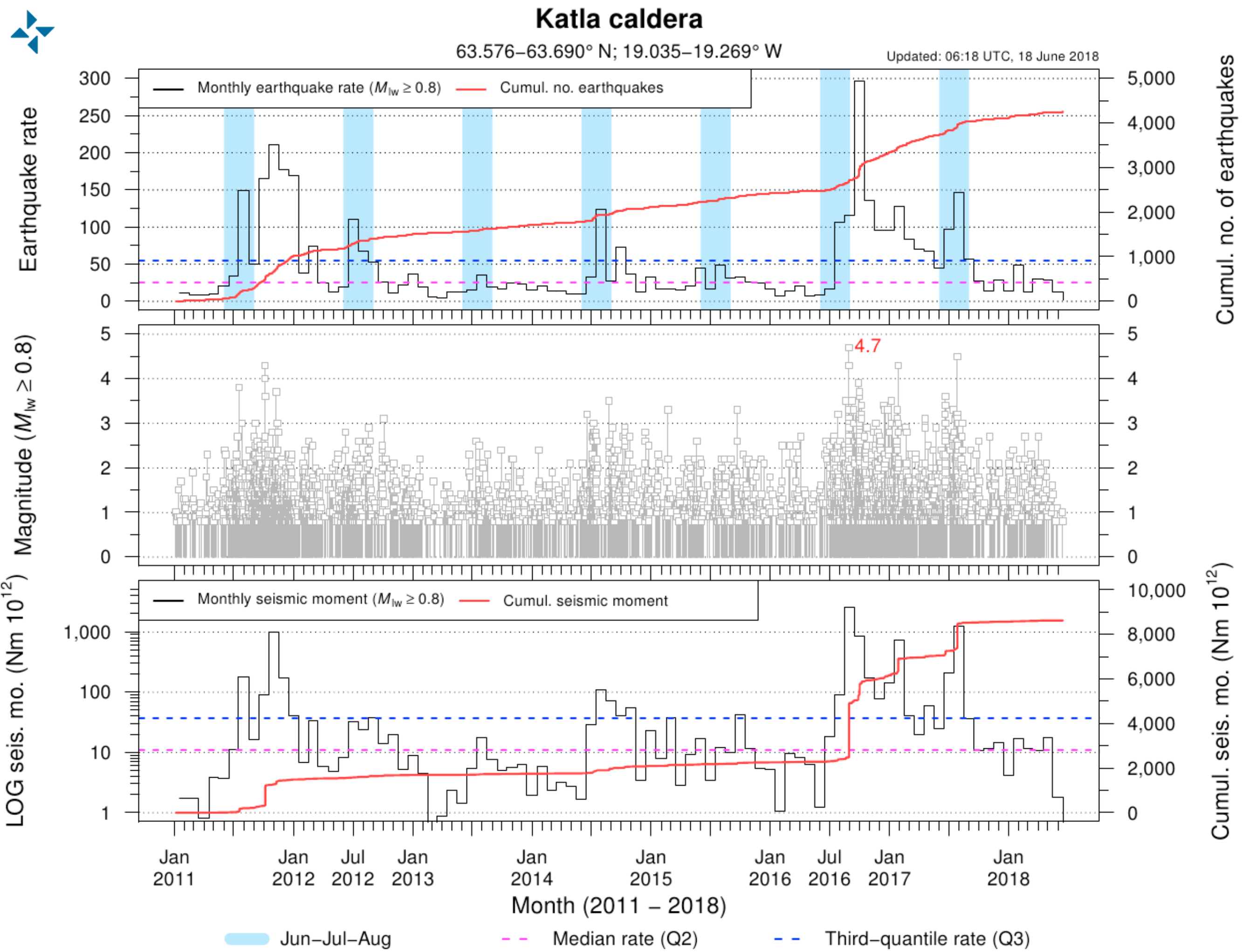

- Elevated seismicity higher than background activity (due to ice melting + possibility some magmatic contribution) prolonged during the winter
- Activity has returned to background levels since the end of 2017
- No detectable increase rate in ground deformation

Hekla volcano

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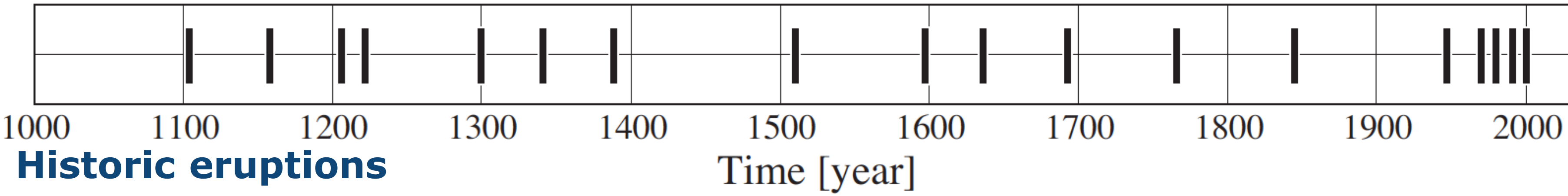

Historic eruptions

Photo credit: Evgenia Ilyinskaya, 22 June 2014

Current status: Hekla

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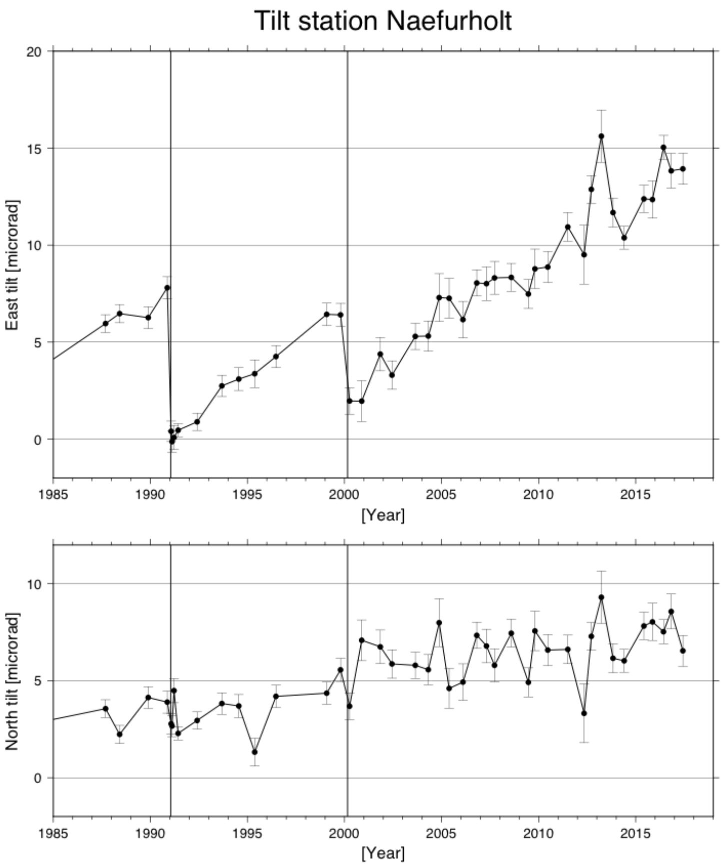
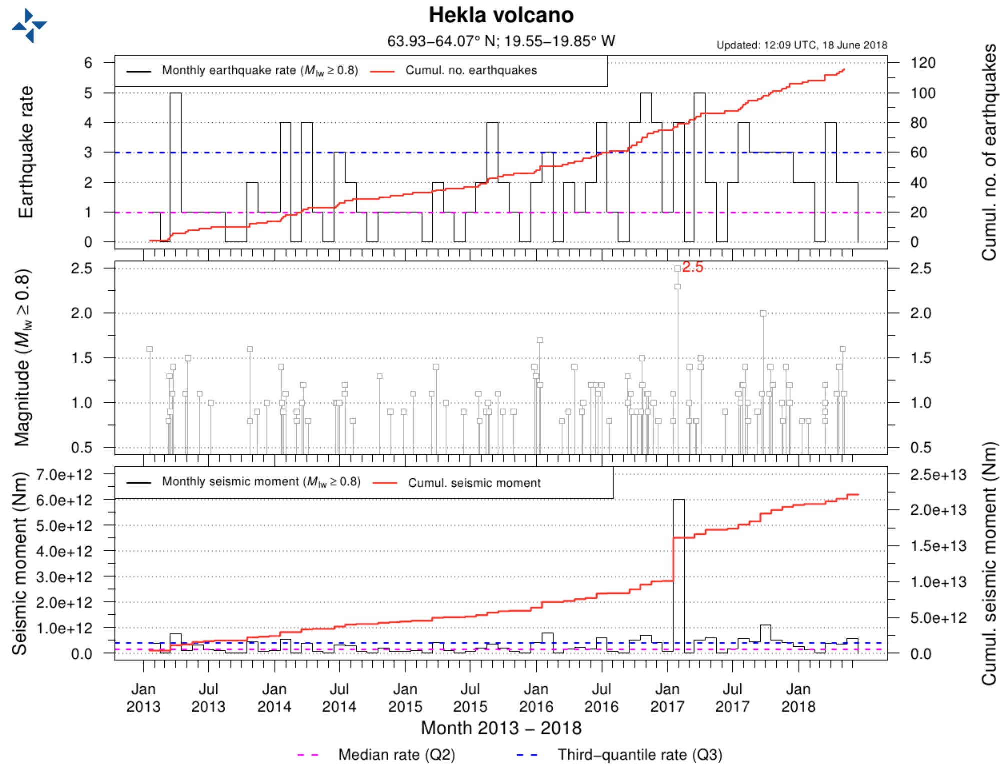
East

North



Data provided by Erik Sturkell



- Hekla has been inflating since 2000.
- The seismicity level is very low but it increases periodically.

Grimsvötn

Photo credit: *Ólafur Sigurjónsson, Forsæti, 21 May 2011*

Photo credit: *Anna Lindal, 1 June 2011*

Current status: Grímsvötn

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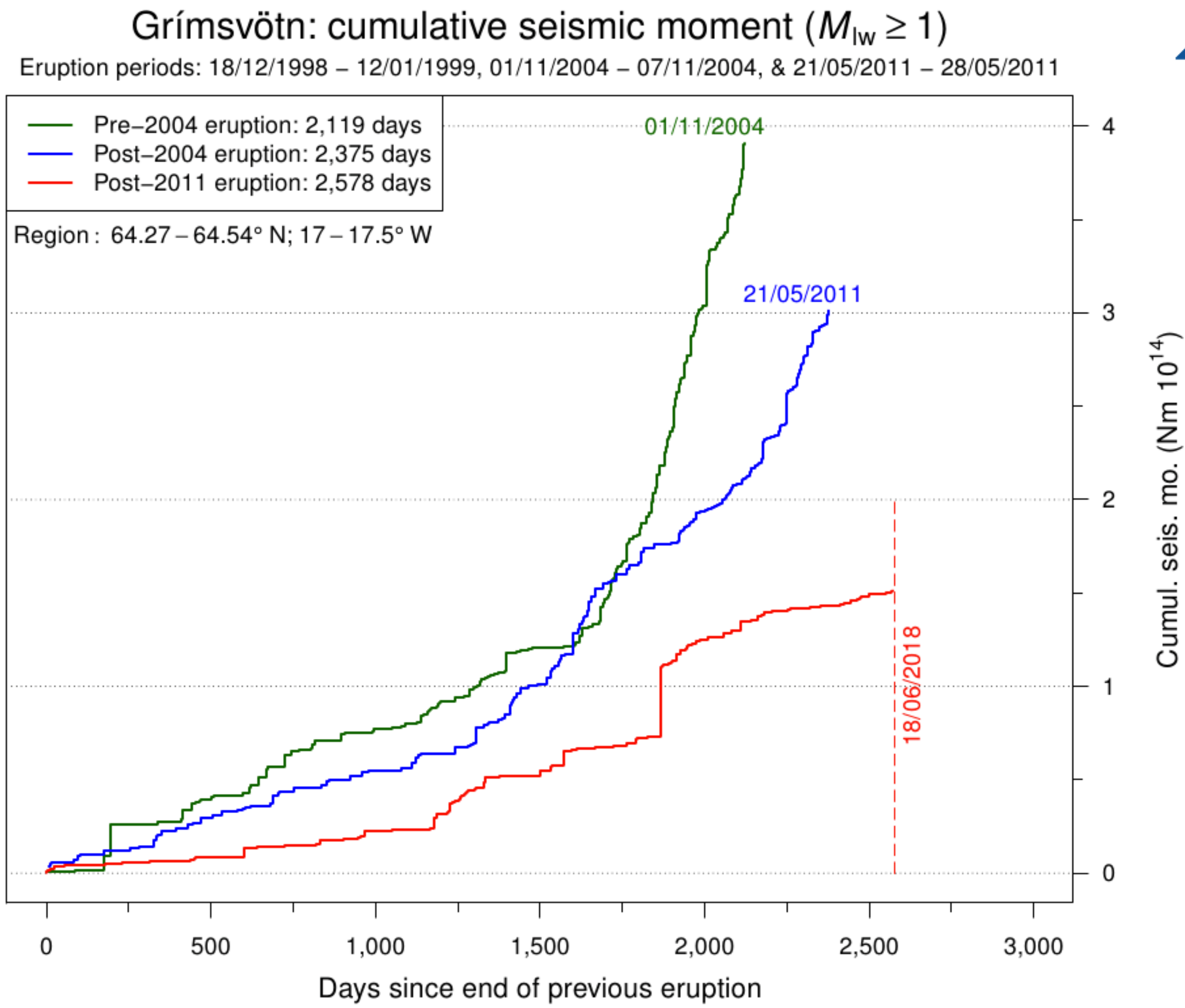
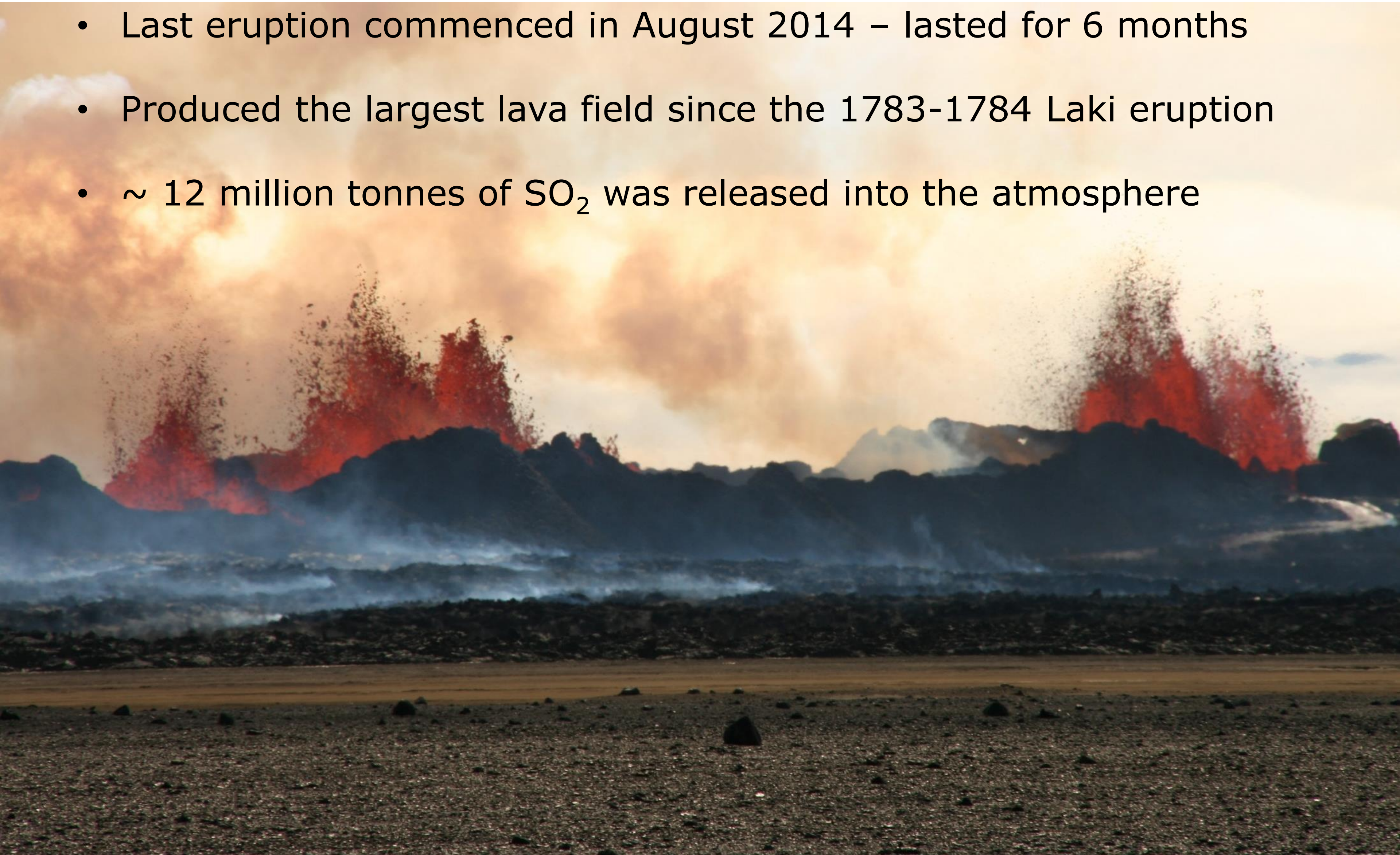


It has displayed quite regular trends between eruptions

The current expectation is it will follow a similar trend prior to the next eruption

Bárðarbunga



- Last eruption commenced in August 2014 – lasted for 6 months
- Produced the largest lava field since the 1783-1784 Laki eruption
- ~ 12 million tonnes of SO_2 was released into the atmosphere

Current status: Bárðarbunga

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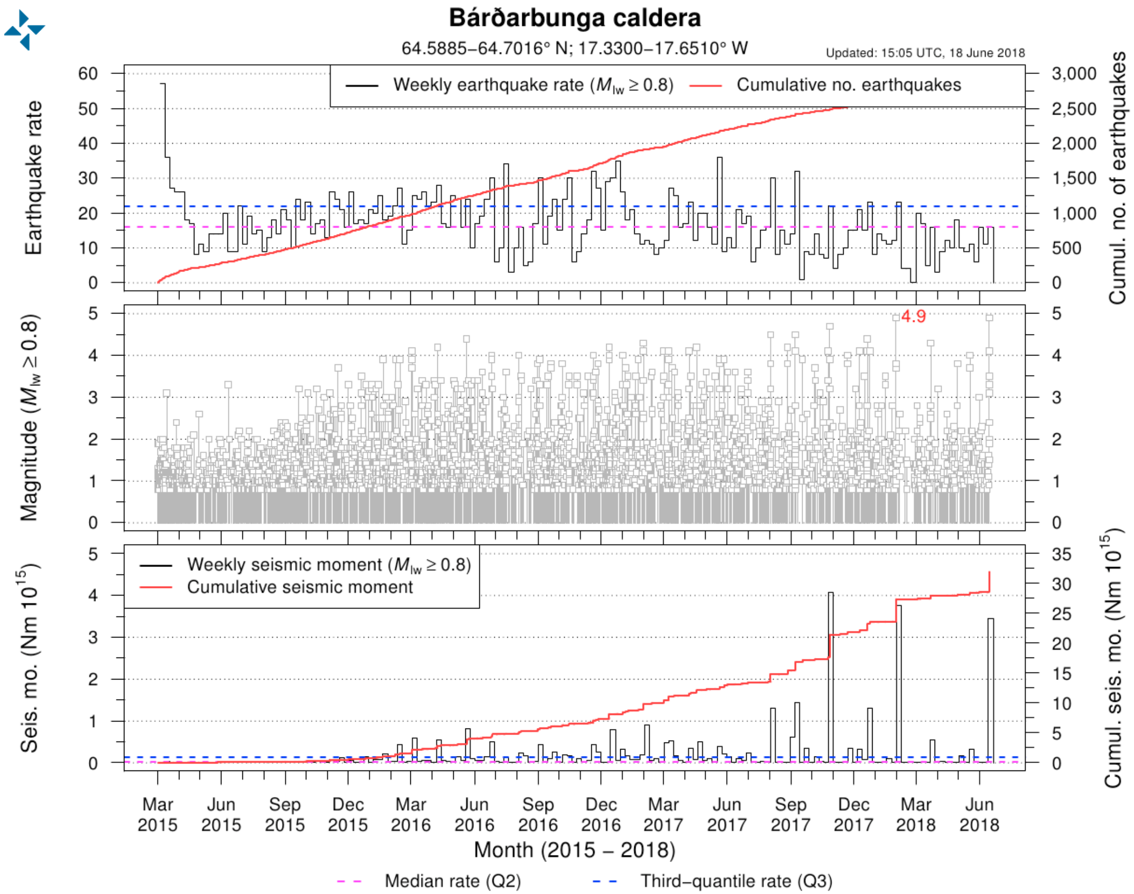
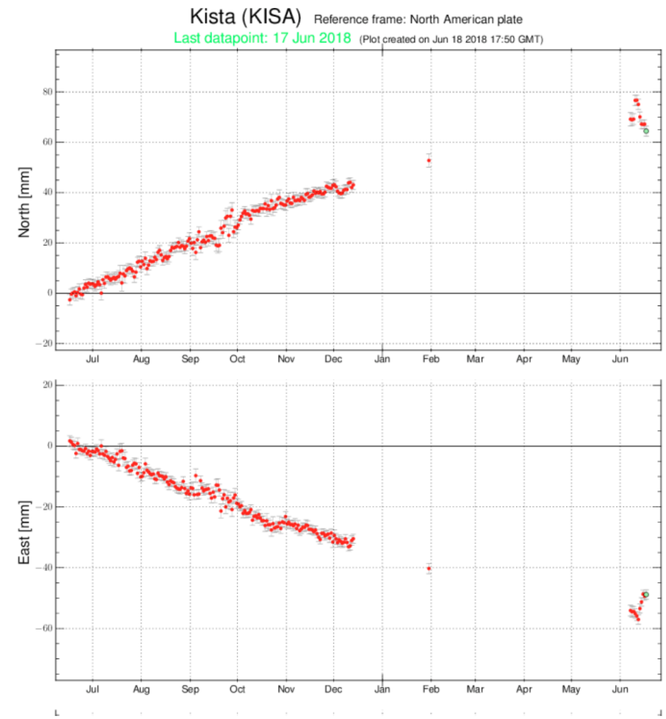


Seismic activity since the end of the eruption – still ongoing with large earthquakes periodically

Signs of inflation from the GPS and InSAR

Indication of caldera floor uplift from seismicity



Öræfajökull volcano

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Historic eruptions:

- **1727-1728 (VEI 4)**
- **1362 (VEI 6)**

Photo credit: Douglas Byatt

Current status: Öræfajökull

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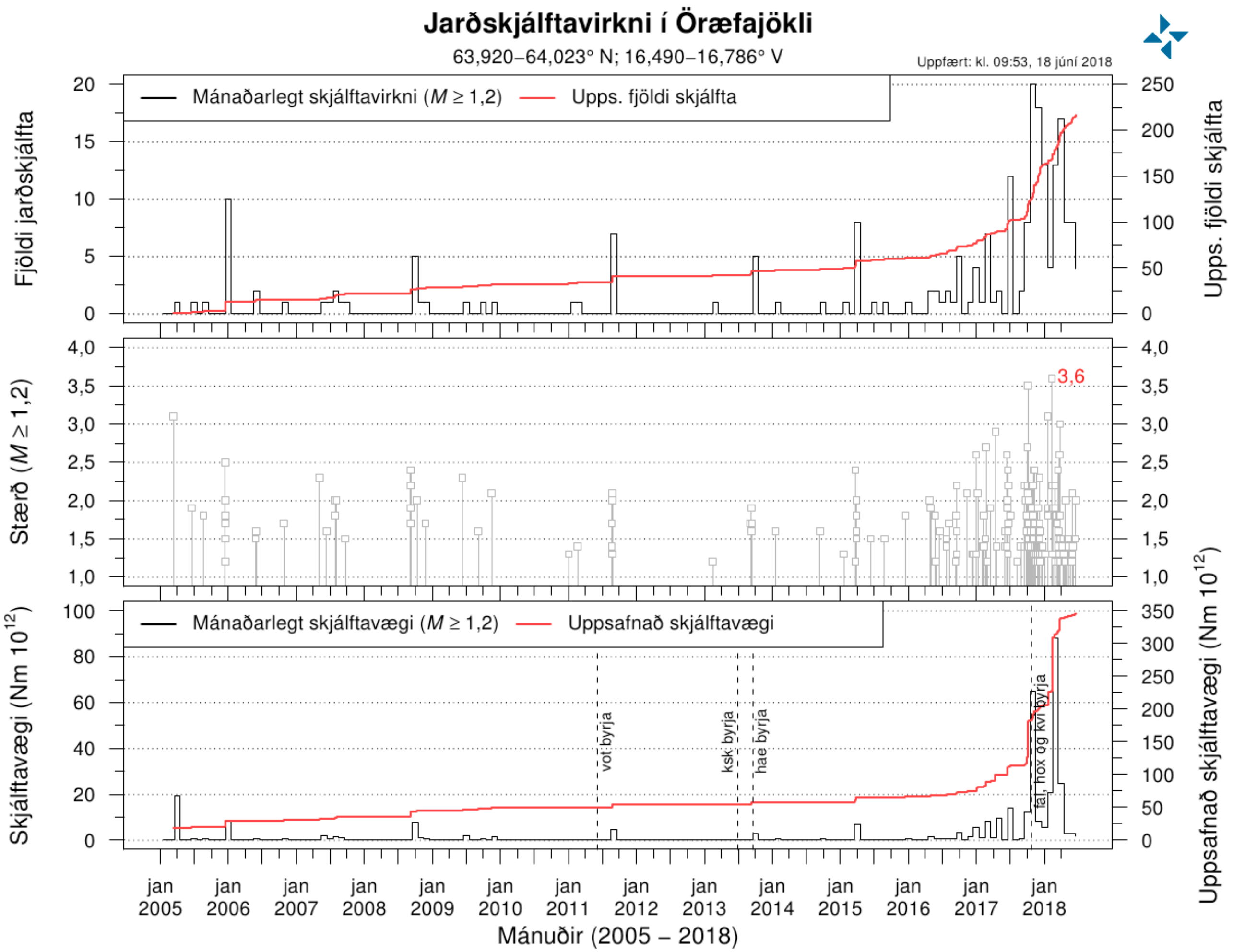

- The seismicity appears to be increasing
- Deformation measurements suggest slow outward motion

Monitoring and Research: monitoring network for forecasting purposes

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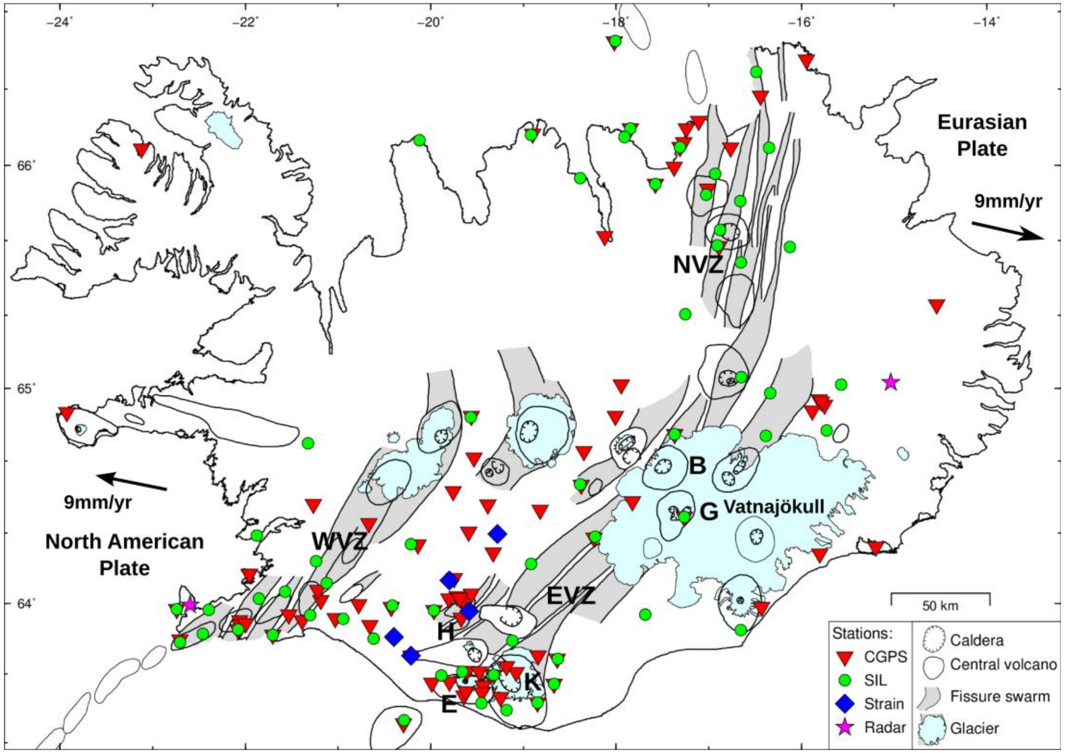
- **70 seismic stations**
- **70 cGPS stations**
- **5 strainmeter stations**
- **2+(1) multigas devices**
- **2+(2) continuous DOAS (SO_2)**
- **FTIR (H_2O, CO_2, CO, SO_2)**
- **2 gas from glacial outlet river stations (SO_2 and H_2S)**
- **145 hydrological gauging stations**



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

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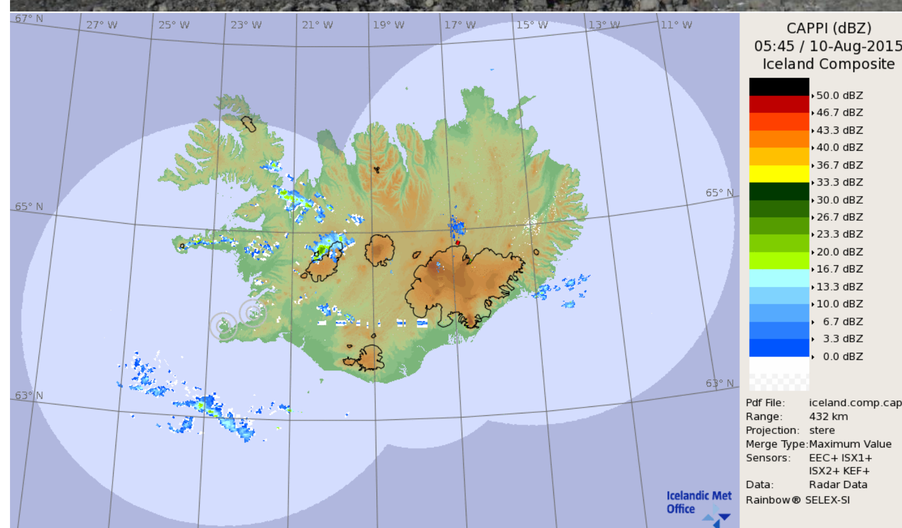
- **C-band weather radar close to Keflavík airport since Jan 1991**
  - has detected 7 eruptions
- **C-band weather radar in East Iceland, operational since April 2012**
- **2 X-band mobile radars**
- **2 Lidars (one mobile)**
- **7-ceilometers network**
- **Mobile radio-soundings**
- **Lightning-detection devices**
- **Infrasound network (operated in collaboration with University of Florence)**
- **Satellite thermal detection products (Modis, Landsat, Sentinel, MIROVA)**



Time (on average)	Data/products available	IMO's actions	ISAVIA's action	LVAAC-actions
	• Monitoring data • Historical records and past eruption datasets	Interpretation of signals reflecting either an imminent or ongoing eruption		
T0		• Call #1 to Isavia and L-VAAC • VONA #1	Draw a 120NM cilinder around the volcano	Initialize the VAA procedure
T0+ 15min		Sigmet #1	Shift the cilinder with the wind speed and direction specified in the Sigmet #1	
	• Radar data • Internal numerical modelling based on pre-defined scenarios	Initialize the dispersal runs with observations		
T0+ 40 min		• Call #2 to Isavia and L-VAAC • Sigmet #2 • VONA #2	Draw the polygon based on Sigmet #2 (SRA starts to be effective)	
	• #2 sigmet • Numerical modelling • Satellite/lidar/radar observations			
T0+ 90 min				VAA graphs sent to IMO
	VAA graphical charts	Sigmet #3		

Primary Stakeholders for Eruptive Source Parameters

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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

Observation and estimation of plume height

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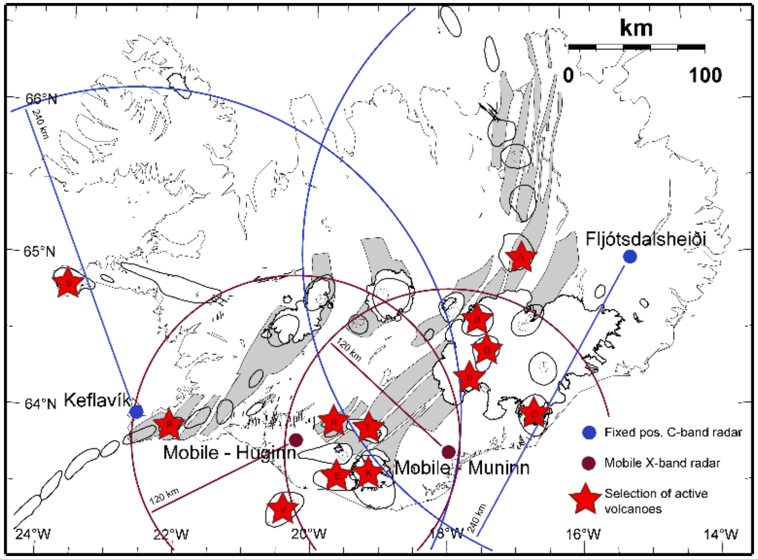
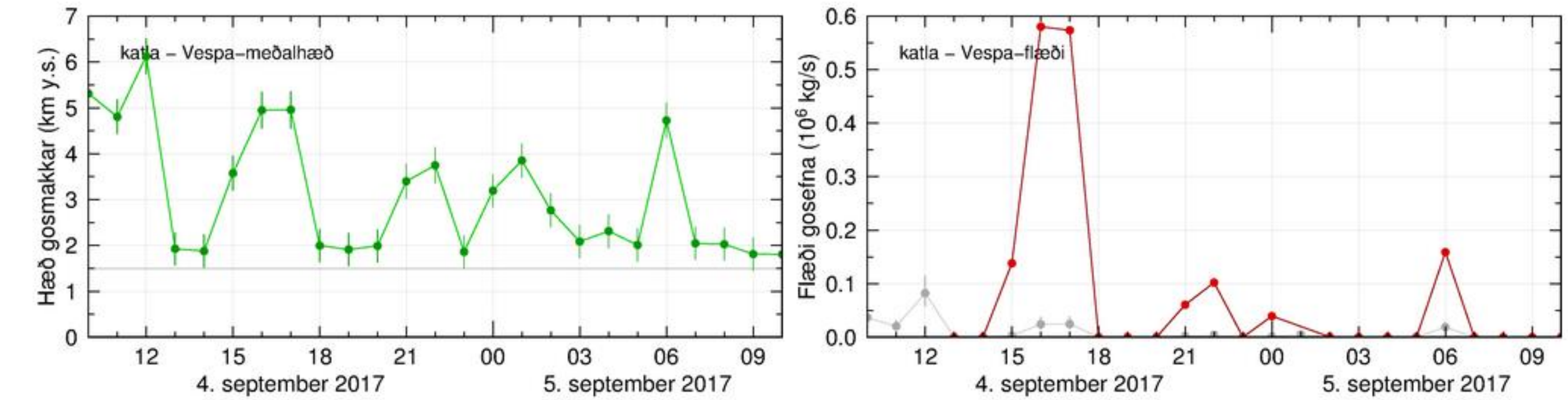
- The radar network allows to cover almost ***completely*** the entire country
- The new VESPA system calculates automatically the hourly plume height and the MFR (http://brunnur.vedur.is/radar/vespa/)



Katla - Hæð gosmakkar og flæði



The VESPA System
Volcanic Eruptive Source Parameter Assessment

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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

Automatic Plume Height Estimates http://brunnur.vedur.is/radar/vespa/

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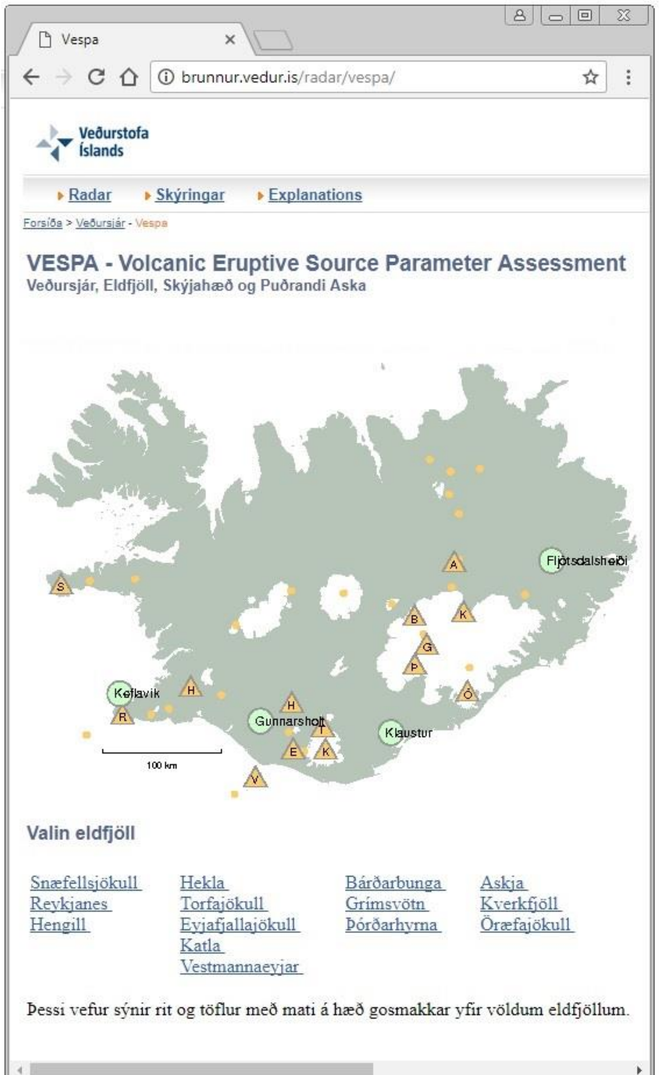
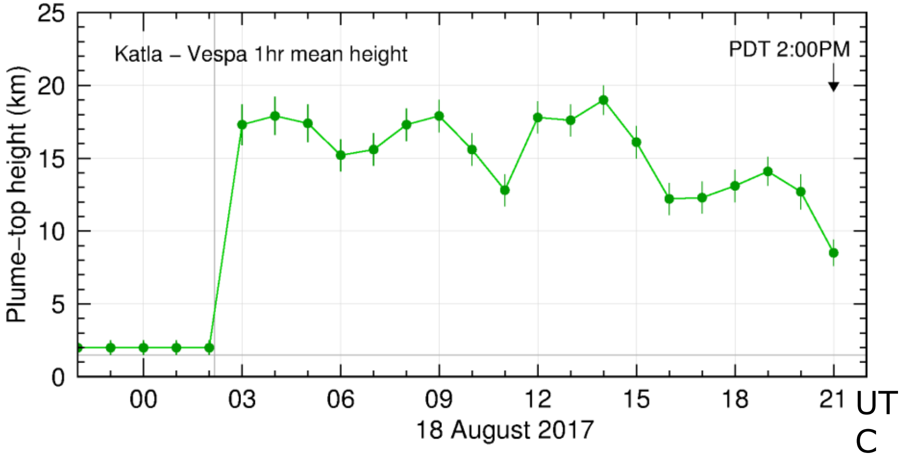
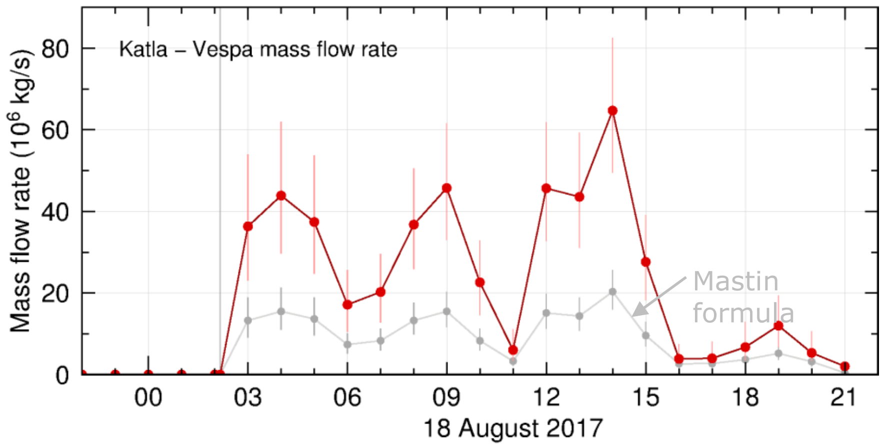
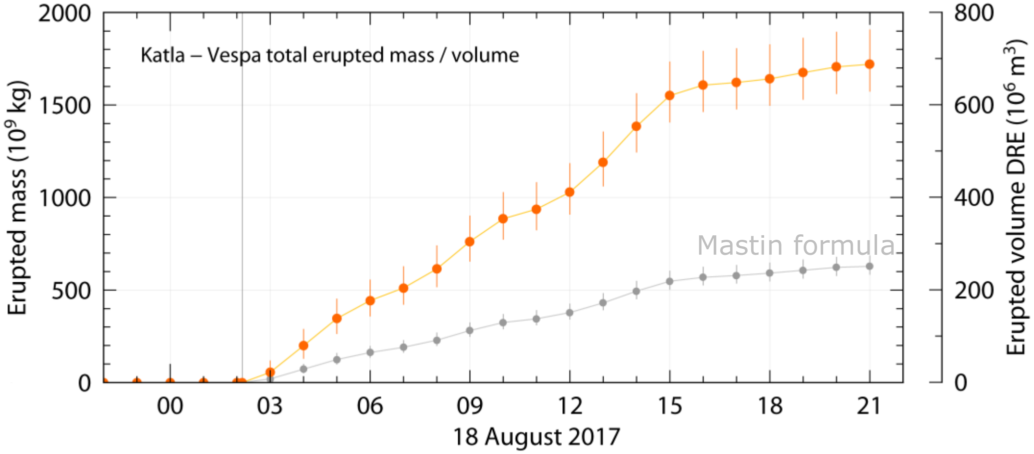


EXERCISE: Eruption of Katla
Started 19 hours ago: 18 August at 02:10 UTC







Ash dispersal simulations

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Multiple simulations are produced on a daily basis for target volcanoes:

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

Results available at: dispersion.vedur.is

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

Ash Dispersal Forecast
VOL-CALPUFF* dispersion model

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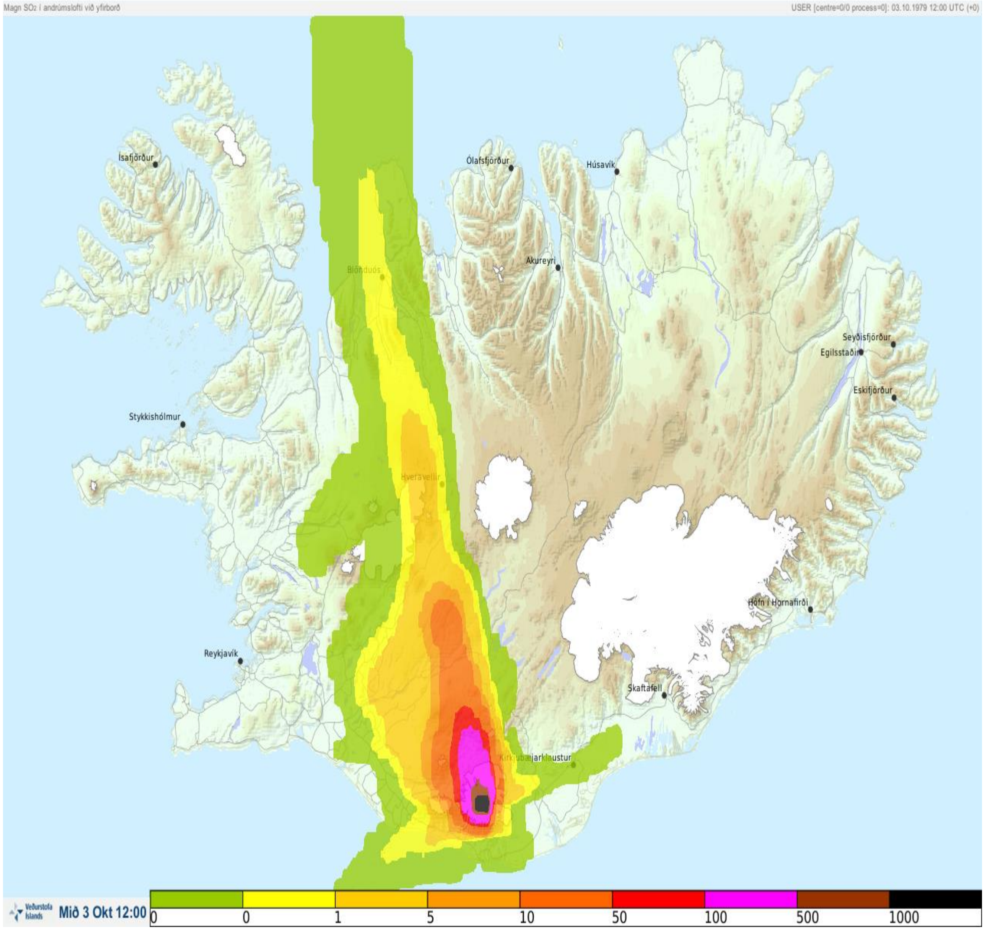
Dispersion model initialized by

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

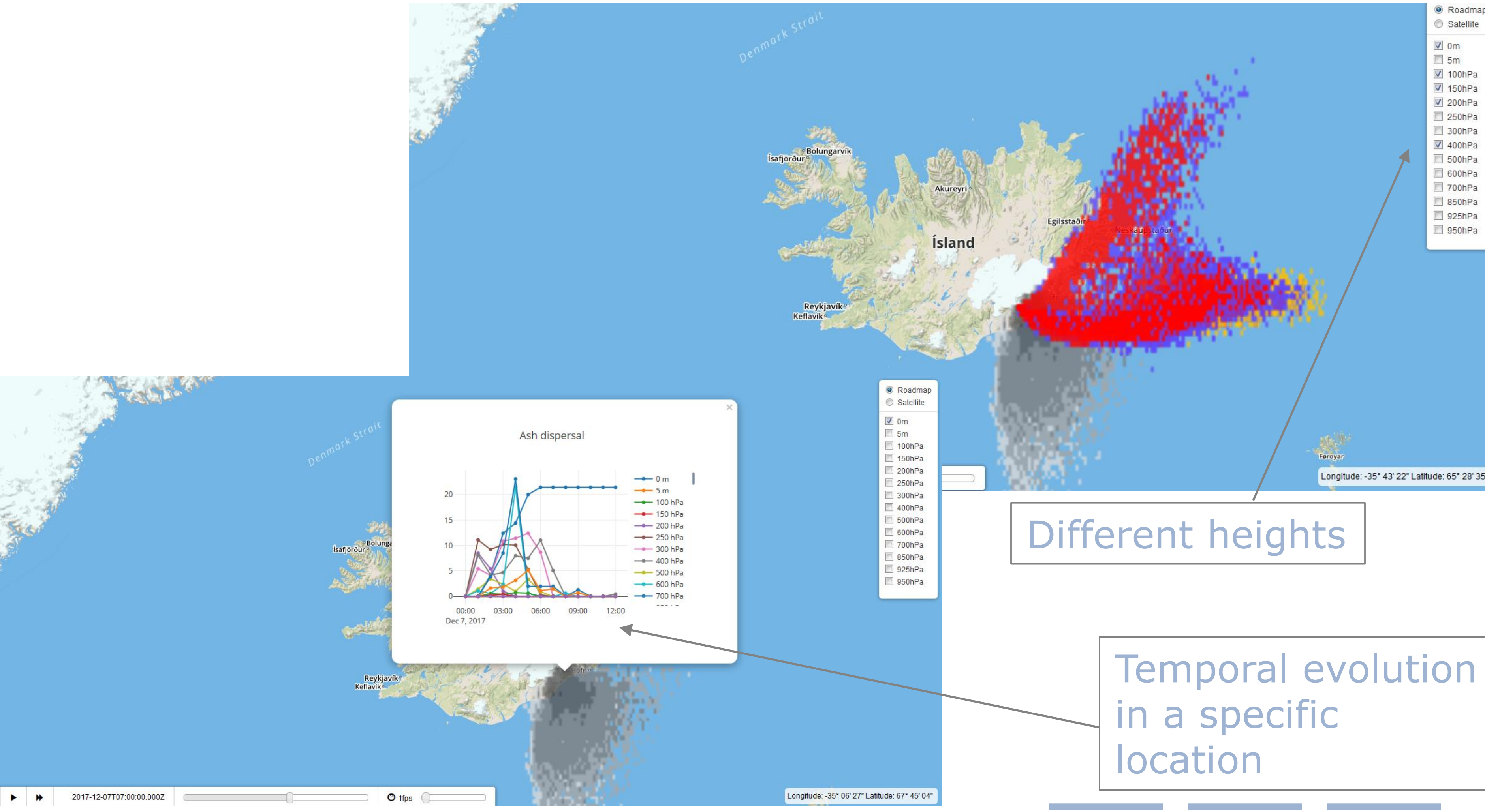
Ash dispersal forecasts are generated for the IMO web in 1 hr timesteps for the next few days



Tephra ground deposits (kg/m²)

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

Ash dispersal simulations



Different heights

Temporal evolution in a specific location

Integration with EUNADICS-AV

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- Some overlap with ash-dispersal modelling, although models at different scales and aimed at different uses – how can this work be optimised as not to confuse stakeholders?
- Volcano observatory staff are occupied during an eruption – need to put a strategy in place now for automated data retrieval
- Difficulties foreseen in incorporating ground-based LiDAR measurements
- Additional data is available from the volcano observatories that could be used to constrain models
- Mobile observatory to be setup next month near Hekla volcano
- http://icelandicvolcanos.is/#

Thank you to:

- Coworkers at the Icelandic Met Office and the University of Iceland
- FUTUREVOLC partners and collaborators
- Committee on Earth Observation Satellites (CEOS) and GEO Geohazards Supersites and Natural Laboratories (GSNL
- ASI, DLR, ESA and CSA

Takk Fyrir!