Vorþing Veðurfræðifélagsins og ISAVIA
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Icelandic Met Office

Volcanic hazards to the aviation

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Credits: Reuters

Overview

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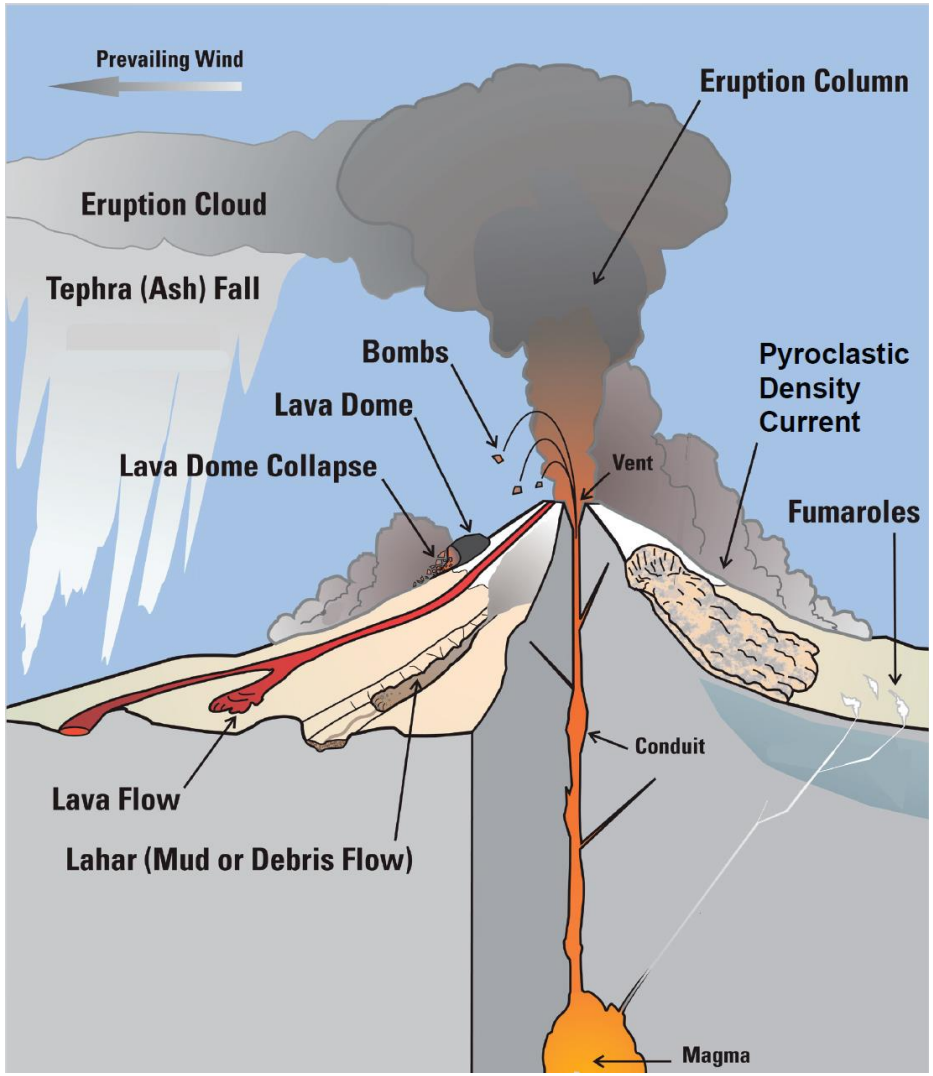
- Why volcanoes represent an hazard for the aviation?
- Volcanic hazards in Iceland
- The importance of the early-warning
- What Veðurstofa (the State Volcano Observatory) could do to mitigate this risk?
- Conclusion

When a volcano erupts…



A multitude of phenomena might occur, including:

- *Pyroclastic flows*
- *Tephra fallout*
- *Volcanic ash cloud*
- *Bombs*
- *Lava flows*
- *Lahar*
- *Landslide*
- *Jökulhlaup*
- *Gas pollution*
- *Earthquakes*

When a volcano erupts…

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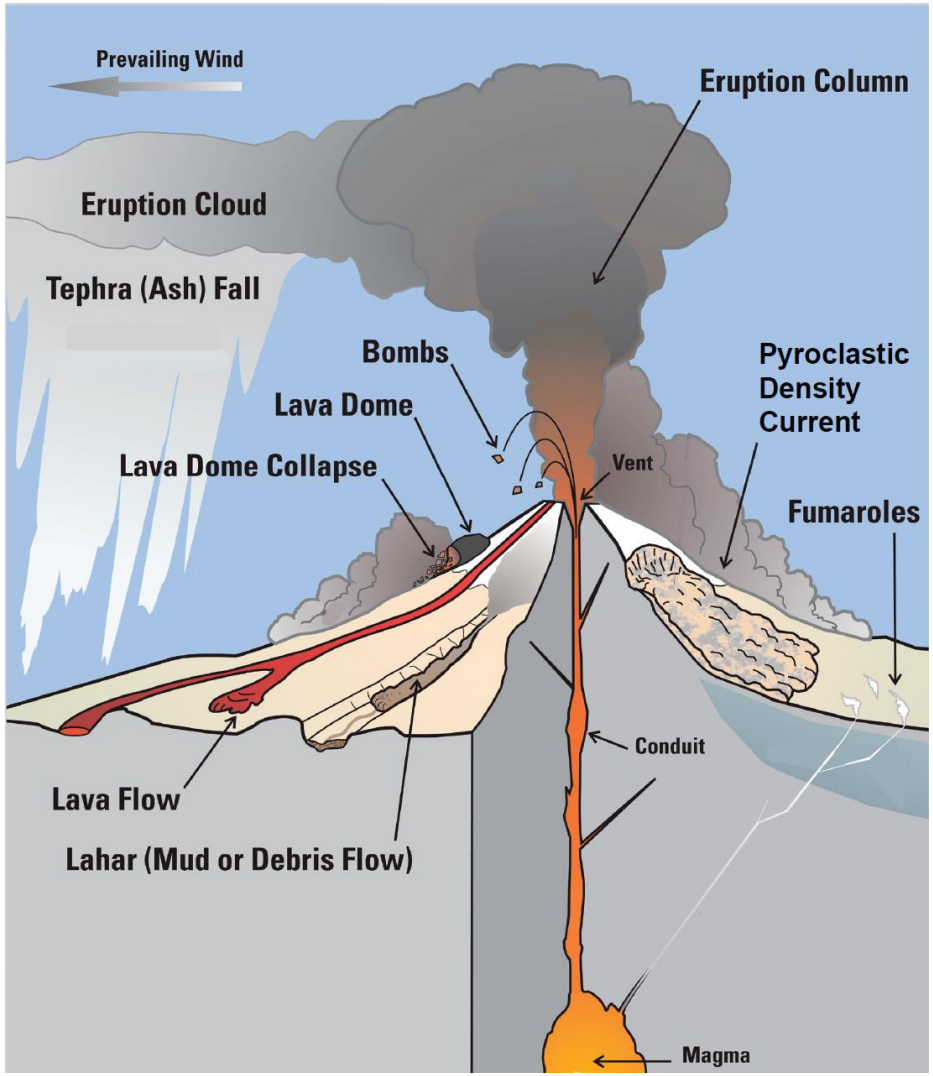

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Tephra

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Term	*Size*
Ballistic	d > 64 mm
Lapilli	2 mm < d < 64 mm
Ash	d < 2 mm
Fine ash	d < 0.063 mm

On the ground

- Health issues
- Roofs/building collapse
- Poor visibility conditions
- Dangerous road conditions
- Contamination of water reservoirs and vegetation
- Damages to electrical infrastructures
- **Transportation system disruptions**
- Impact on telecommunication networks

In the atmopshere

- **Volcanic ashes represent a threat to aviation due to its possible ingestion by turbine engines and their potential failure**
- Triggering factors for climate changes

Tephra and aircrafts

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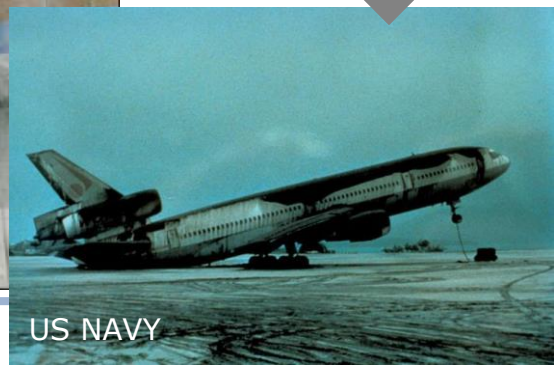
Ash deposits inside the jet engine that encountered the ash cloud from Redoubt Volcano on 15 December 1989.

El Reventador (Ecuador) 2002 – Grounded aircrafts at Quito airport

Philippines in June 1991 after the eruption of Mount Pinatubo



Severity and numbers of encounters in the world

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Class	Criteria
0	• Sulfur odor noted in cabin. • Anomalous atmospheric haze observed. • Electrostatic discharge (St. Elmo's fire) on windshield, nose, or engine cowls. • Ash reported or suspected by flight crew but no other effects or damage noted.
1	• Light dust observed in cabin. • Ash deposits on exterior of aircraft. • Fluctuations in exhaust gas temperature with return to normal values.
2	• Heavy cabin dust. • Contamination of air handling and air conditioning systems requiring use of oxygen. • Abrasion damage to exterior surfaces, engine inlet, and compressor fan blades. • Pitting, frosting, or breaking of windscreen or windows. • Minor plugging of pitot-static system, insufficient to affect instrument readings. • Deposition of ash in engine.
3	• Vibration or surging of engine(s). • Plugging of pitot-static system to give erroneous instrument readings. • Contamination of engine oil or hydraulic system fluids. • Damage to electrical or computer systems. • Engine damage.
4	• Temporary engine failure requiring in-flight restart of engine.
5	• Engine failure or other damage leading to crash.

Severity class	1953-2016 Number	1953-2016 Subtotal	2010-2016 Number	2010-2016 Subtotal
Class 5	0		0	
Class 4	9		0	
Class 3	24		8	
Class 2	67		14	
Subtotal of damaging encounters with volcanic ash		100		22
Class 1	53		40	
Class >0	3		0	
Subtotal of encounters with volcanic ash		56		40
Class 0	82		60	
Incidents with insufficient data to assign severity	15		0	
Total number of incidents reported	253		122	

Guffanti et al. 2010
Christmann et al. 2015

Rising plume dynamics

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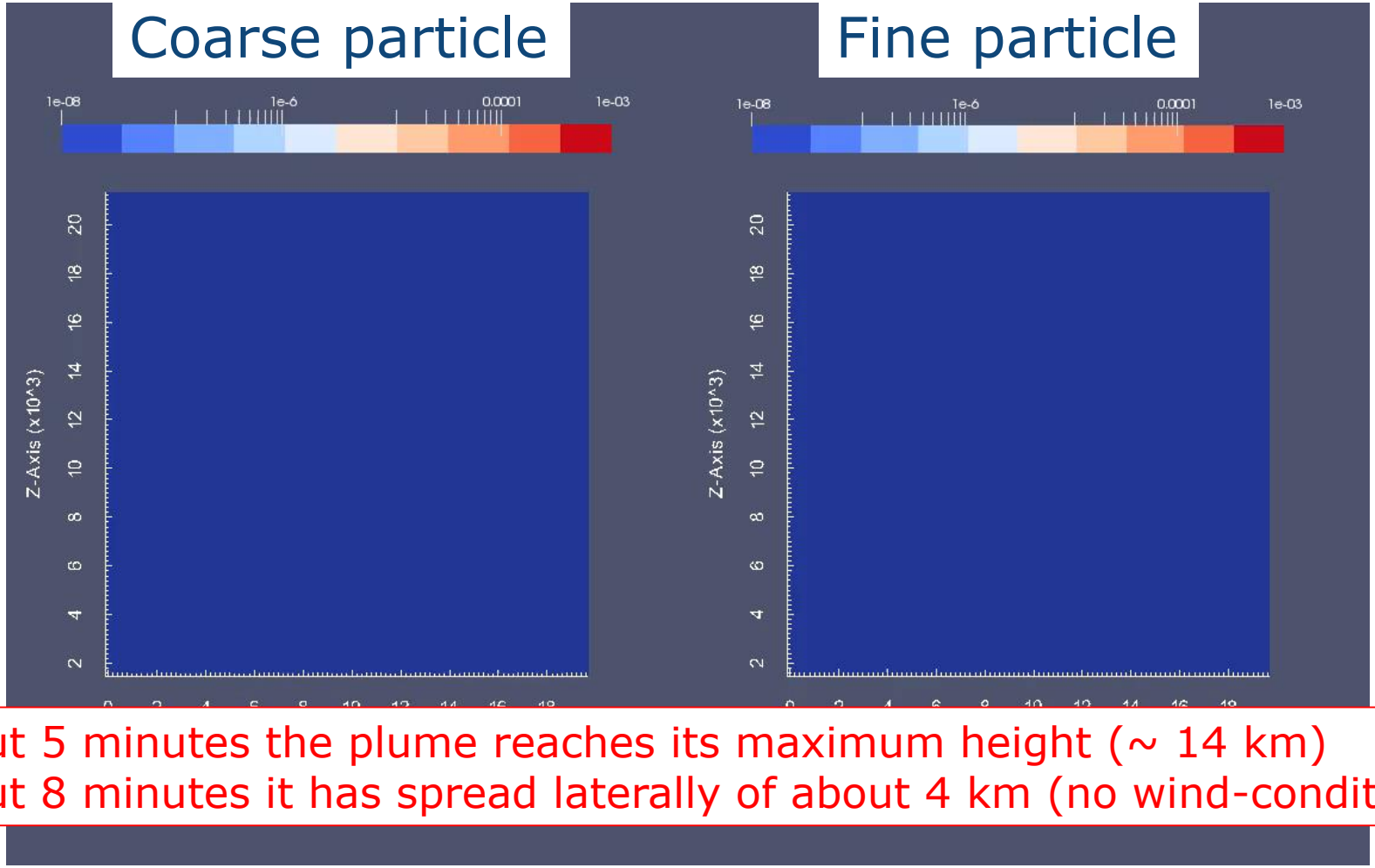

In about 5 minutes the plume reaches its maximum height (~ 14 km)
In about 8 minutes it has spread laterally of about 4 km (no wind-condition)

Plume simulated with PDAC model (Esposti Ongaro and Cerminara, 2016)

Volcanic hazards from the Icelandic volcanoes

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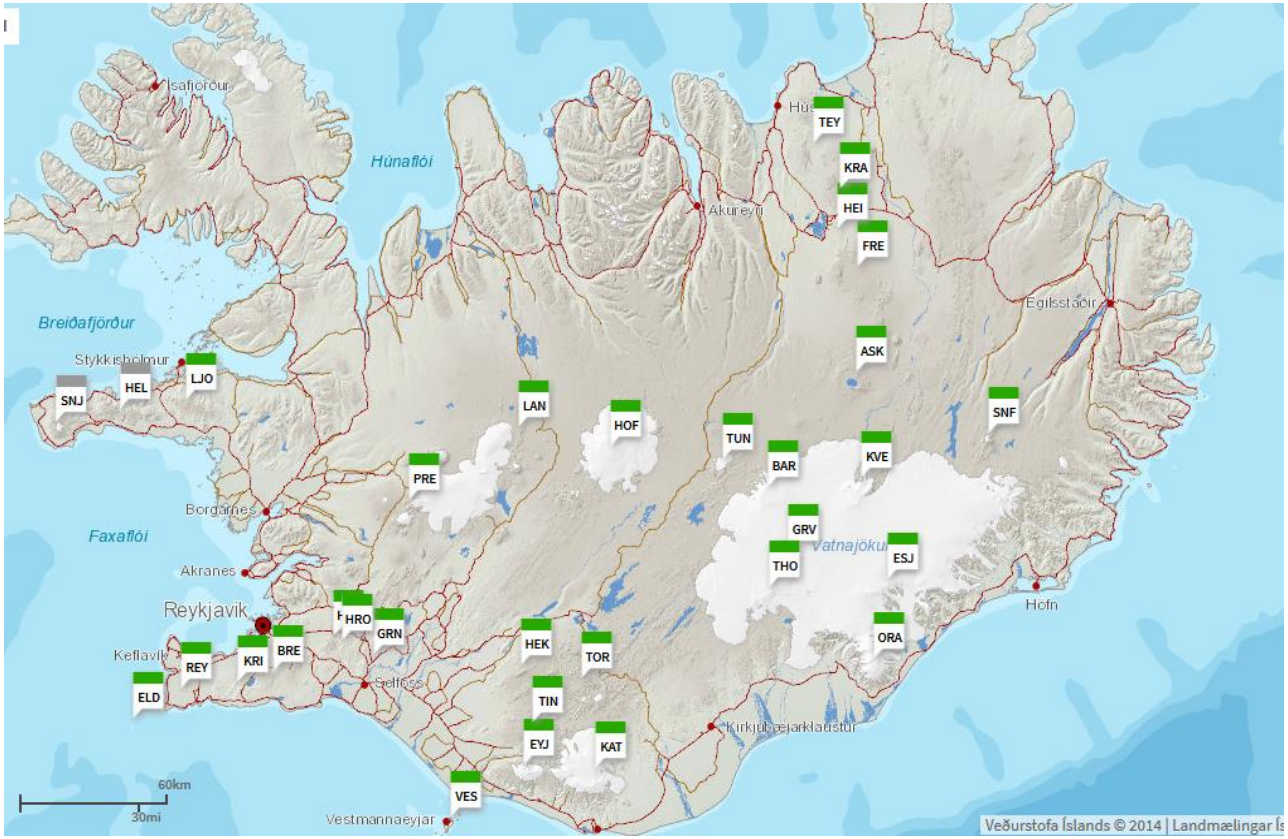

Icelandic eruption frequency: once every 3-4 years
Most of the 32 Icelandic central volcanoes and their associated fissures could produce **both** explosive or effusive eruptions

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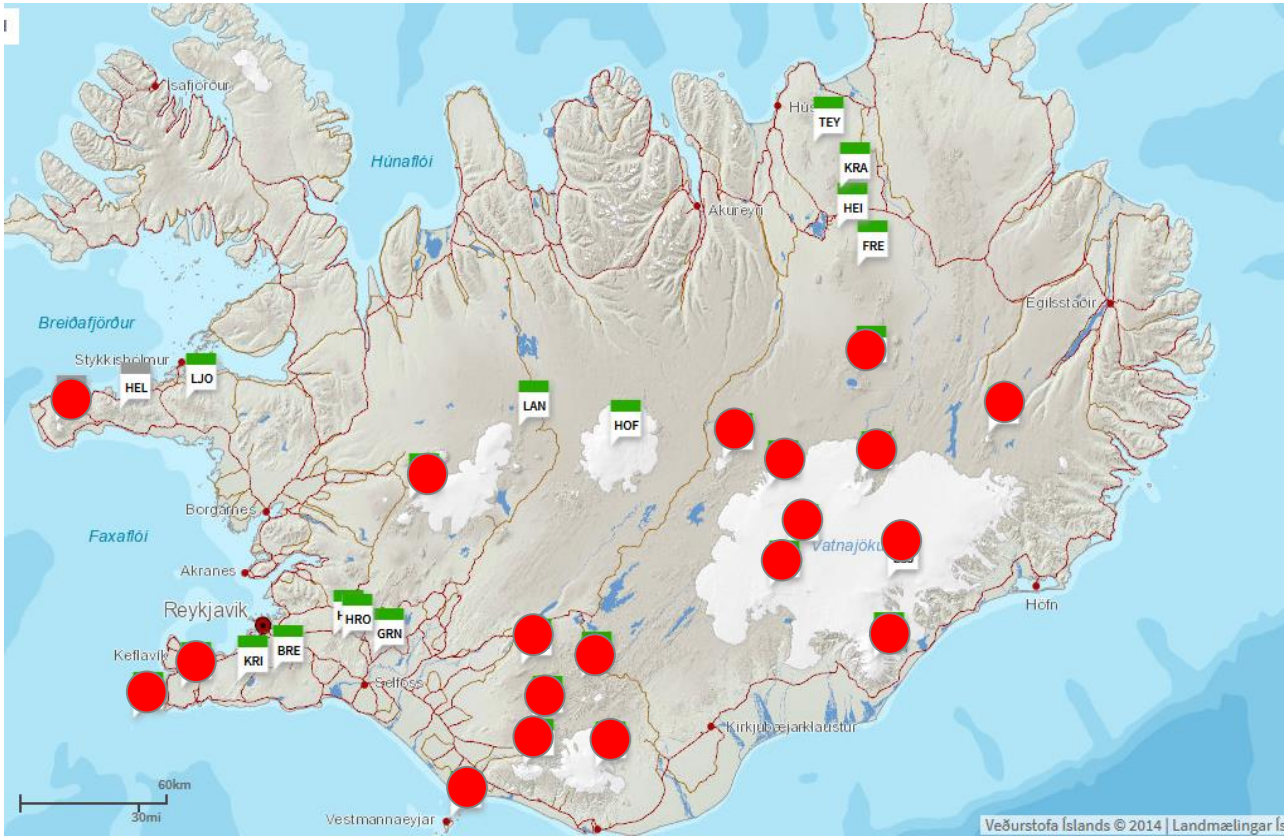

All these volcanoes have volcanic ash as one of the principal hazards (both due to nature of magma or presence of ice/water)

Volcanic hazards in Iceland

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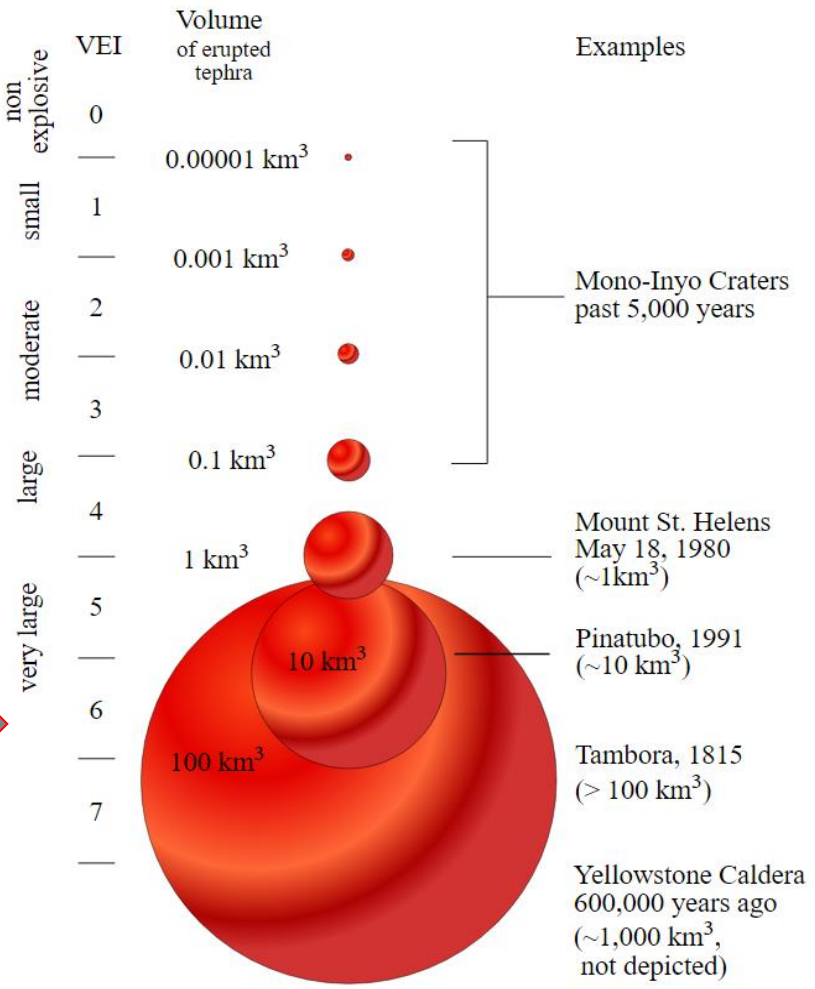
Volcanic Explosivity Index:
Erupted volume of tephra is often used as a proxy for magnitude for explosive eruptions.

Katla 934, Hekla 1104, Askja 1875

Öræfajökull 1362, BB-Veiðivötn 1477



Volcanic hazards in Iceland

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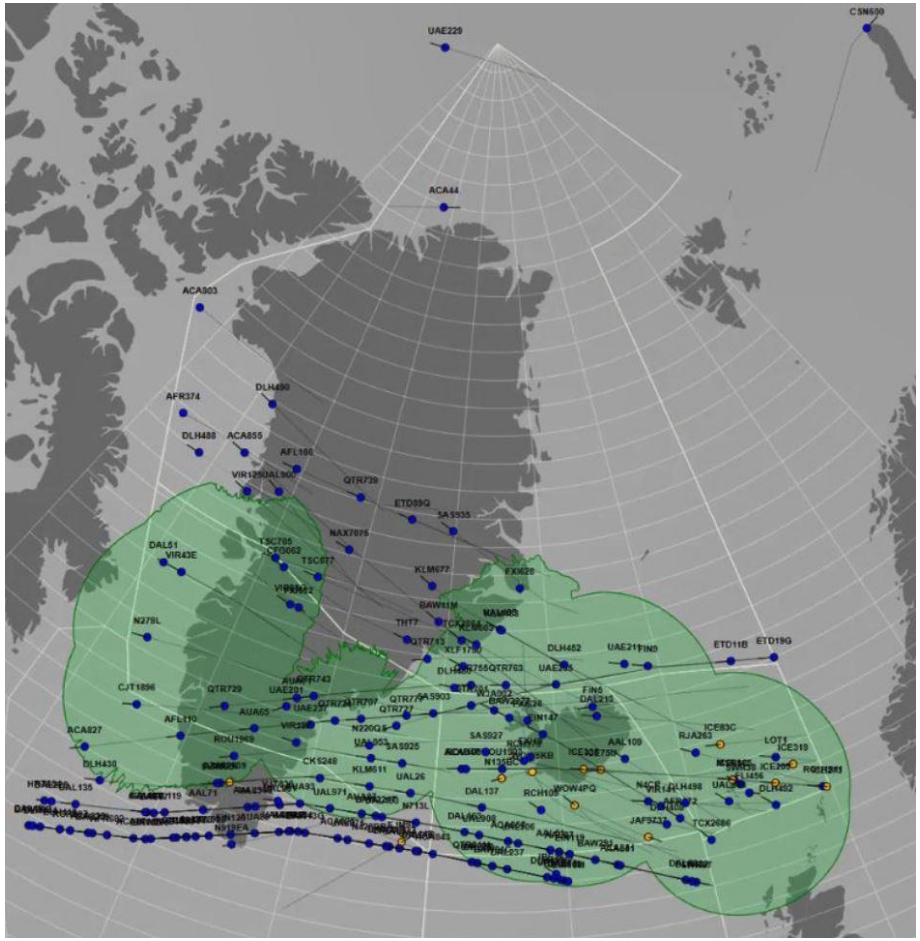
Precursory time at Hekla volcano

	Eruption Date	First Precursory Earthquakes	First Strain Signal	First tremor detected	Warning Issued	Eruption beginning	Time interval from first detection to eruption start	Time interval from warning issuance to eruption start	Reference
Hekla 2000	26. Feb 2000	17:07	17:47	17:20	Yes - 17:38 (IMO)	18:17	70 min.	39 min	http://hraun.vedur.is/ja/heklufrettir.html
Hekla 1991	17. Jan 1991	16:36	c.a. 16:30	17:05	Yes	17:00	30 min.	30 min	http://opensample.info/earthquake-activity-related-to-the-1991-eruption-of-the-hekla-volcano-iceland
Hekla 1980	17. Aug 1980	13:04 / 13:10			No	13:27	23 min.	0 min	http://link.springer.com/article/10.1007/s00445-003-0285-y
Hekla 1970	5. May 1970			20:58 (Burst in tremor 21:18)	No	21:23	5-25 min.	0 min	http://link.springer.com/article/10.1007/s00445-003-0285-y

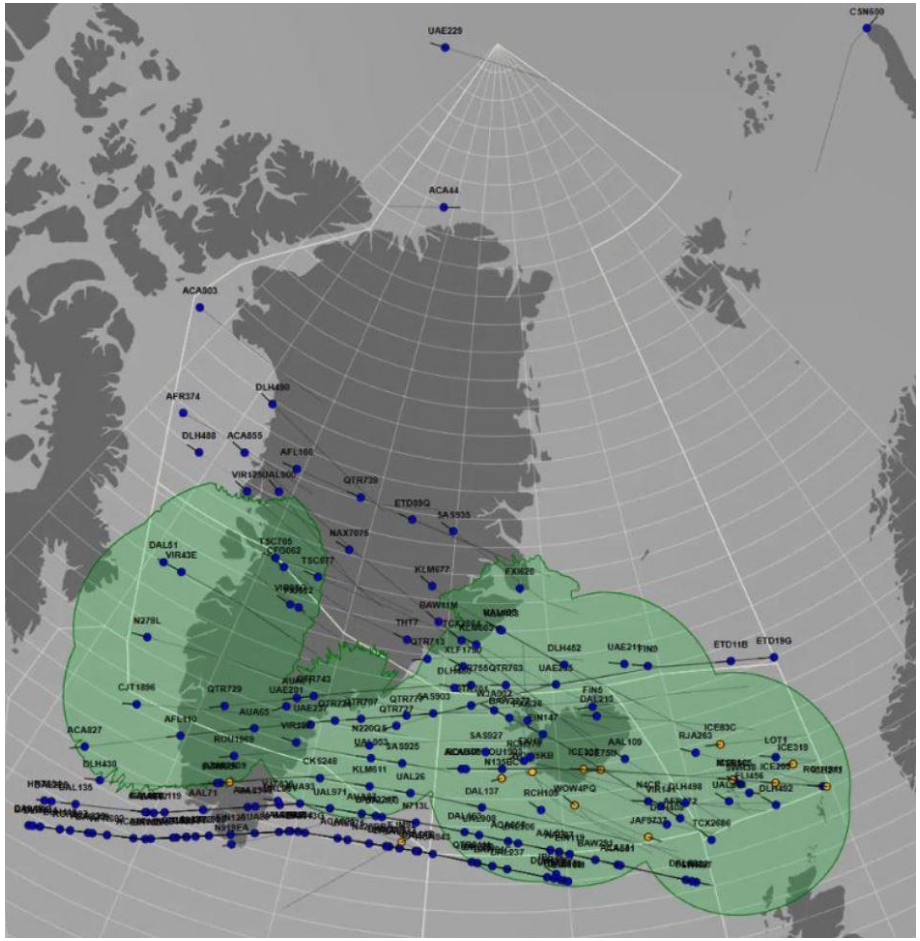
High risk in Iceland



Daily flights on an average summer day (provided by ISAVIA)

- High number of flights passing over Iceland
- Plume rising shows a very fast dynamics
- Several “explosive” volcanoes
- Potentially large eruptions
- Occasionally, short precursors (e.g. Hekla volcano)

High risk in Iceland



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Importance of knowing as soon as possible if something is going to happen

What is an early-warning?

The capability of ***detecting*** an unrest phase which might evolve into an imminent eruption

and

providing a timely warning of associated volcanic hazards

This depends on two main factors:

the volcanic context and the level of surveillance

nature of the volcano	how well a volcano is monitored
type of the eruption (explosive vs. effusive)	how quick and reliable is the data interpretation undertaken by the specialists on duty
magma migration processes	how quickly and efficiently the information is disseminated

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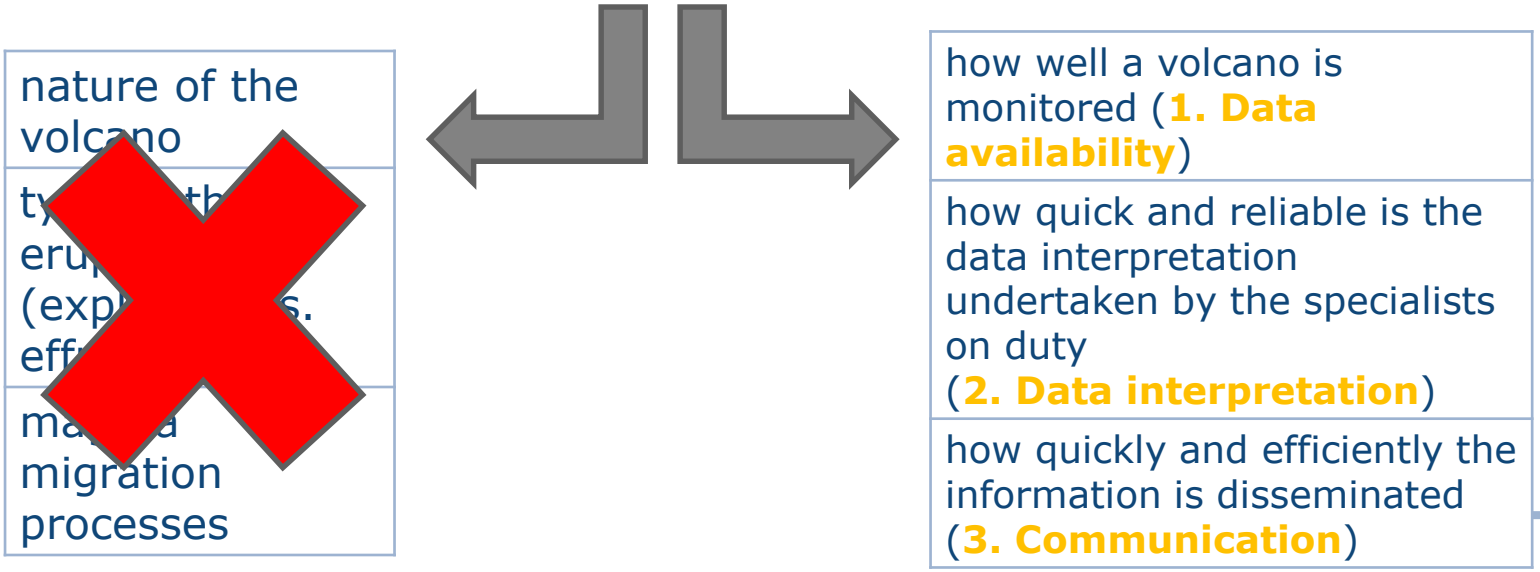
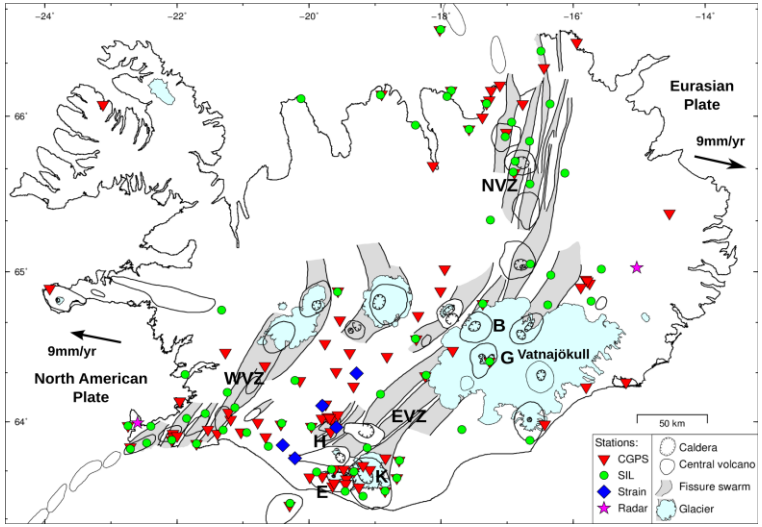
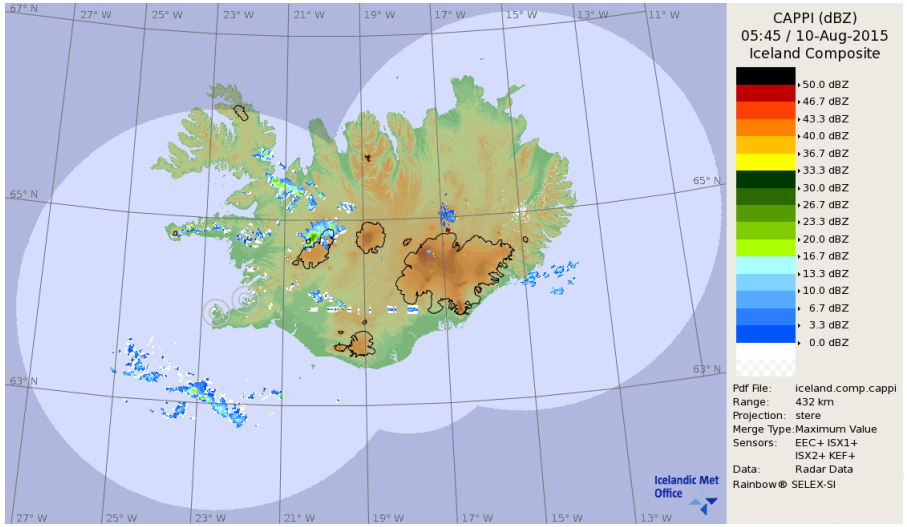


What Veðurstofa does to mitigate this risk?

- Operates extended monitoring network to detect changes in the volcanic system that might indicate magma movement in the crust (**geophysical network**)
- Operates a variety of sensors for the detection and observation of the sub-aerial phase of the eruption (**remote sensing network**)
- Develops **automatic** system for the monitoring data processing
- Provides a **24-hours** monitoring service
- **Practices** regularly the procedure in place to respond to crises
- Collaborates closely with **end-users**, e.g. ISAVIA and Civil Protection





Conclusion

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- Volcanic eruption can represent a serious hazard for the aviation, particularly ash-rich eruptions
- In Iceland the risk of ash cloud encounter is elevated because of the presence of several explosive volcanoes, the high numbers of flights, short precursors
- Veðurstofa Íslands, the State Volcano Observatory, works constantly to improve the early-warning system implemented in the monitoring room
- VÍ works closely with Isavia, and in general with stake-holders, to improve the capability to respond to emergencies
- Hekla volcano is a special case and it needs special attention…

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