1.3 Early Warning for All in Volcanology: Case Study Series, Part III (Iceland)

Thisarticle isthe thirdcontributionin our EW4All case-study series,launched following the “Advancing Volcanic Hazards in EW4All” workshop held in Geneva in July 2025. The series highlights practical examples of how the four pillars of the Early Warnings for All (EW4All) initiative are being integrated to strengthen volcanic early warning systems. Two case studies have now been published, showcasing diverse experiences and approaches from different contexts.

Through these contributions, we aim to share experiences, lessons learned, and examples of cross-pillar collaboration that can support and inspire the wider volcanological community. We warmly thank all contributors for sharing their perspectives and experiences, and we look forward to expanding this collection over time.

A new operational multi-hazard approach for communicating volcanichazards inIceland

The Icelandic Meteorological Office (IMO) is the Icelandic governmental agency tasked with monitoring and advising on natural hazards including volcanic activity. It has a duty to collect, analyse, and disseminate data on natural phenomena to both othergovernmentagencies and the general public, and is an advisor to the Department of Civil Protection. IMO is the State Volcano Observatory and works closely with the London Volcanic Ash Advisory Centre in preparation for, and during, explosive volcanic eruptions but since 2021 there has been a need for increased attention to ground-based volcanic hazards.

In March 2021 the Reykjanes Peninsula in southwest Iceland hosted its first eruption in 781 years (Sæmundsson et al. 2020) following several years of volcanic unrest in the area (Sigmundsson et al. 2022). The Fagradalsfjall eruption lasted 6 months and was followed by two nearby eruptions, in August 2022 and July 2023, each lasting less than a month. In October 2023, inflation was detected in Svartsengi, north of the town of Grindavík (population 3,580 in 2023) and on 10 November a major rifting event took place with an associated 15 km dyke propagation and graben formation (Parks et al. 2025) leading to extensive property damage (Figure 1) and a complete evacuation of the area – the majority of who have not yet returned.

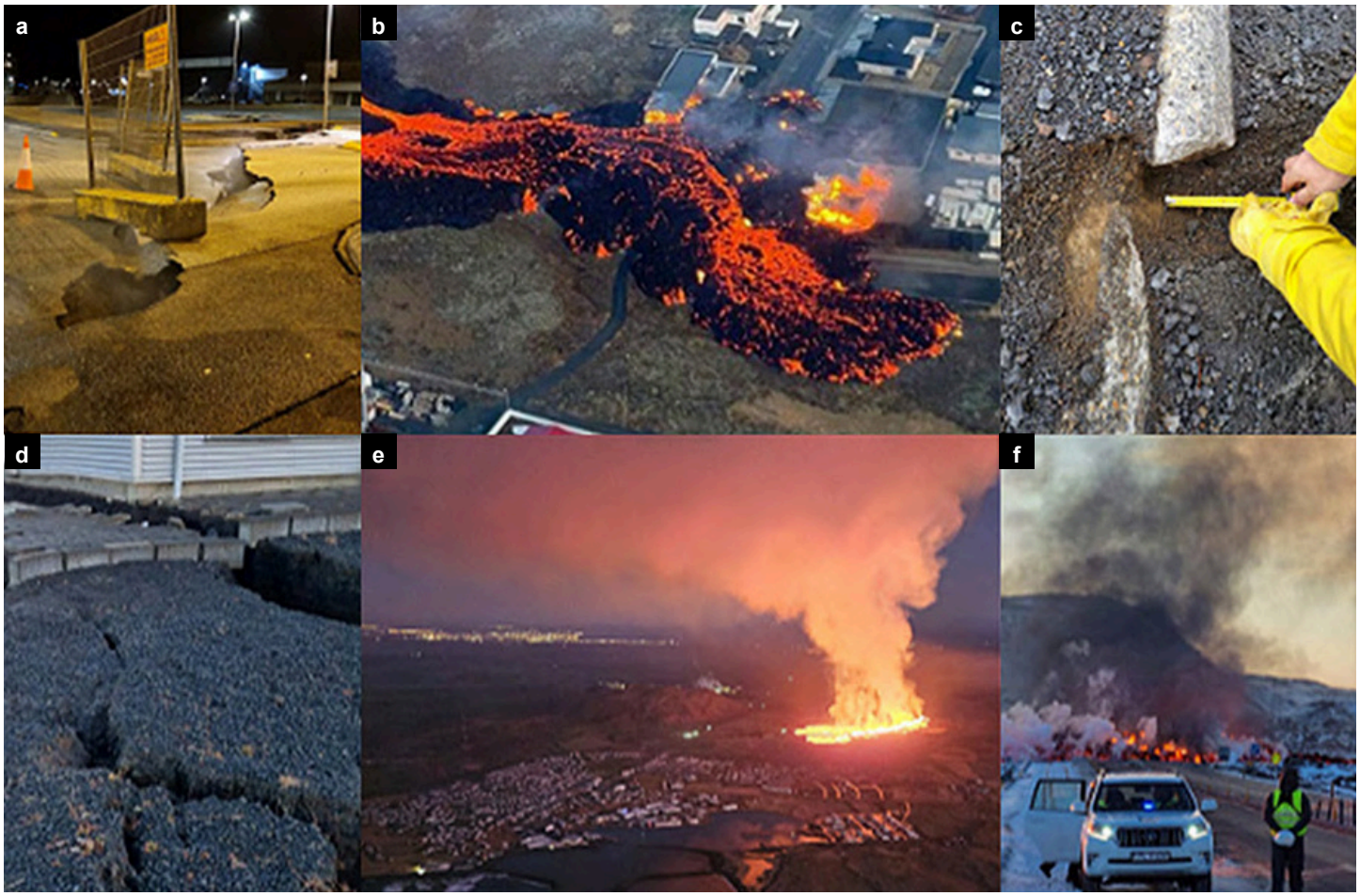

Figure 1 a) Main graben fault through centre of Grindavík; b) the only lava flow to enter Grindavík during this eruptive period (14 January 2024, Hólmfríður Dagný/ruv.is); c) evidence of strike-slip movement on faults cutting the town; d) damage to building foundations; e) January 2024 eruptive fissure outside of Grindavik town (Björn Oddsson/ Civil Protection); f) lava cuts the main road to Grindavík, Svartsengi powerplant, and the Blue Lagoon.

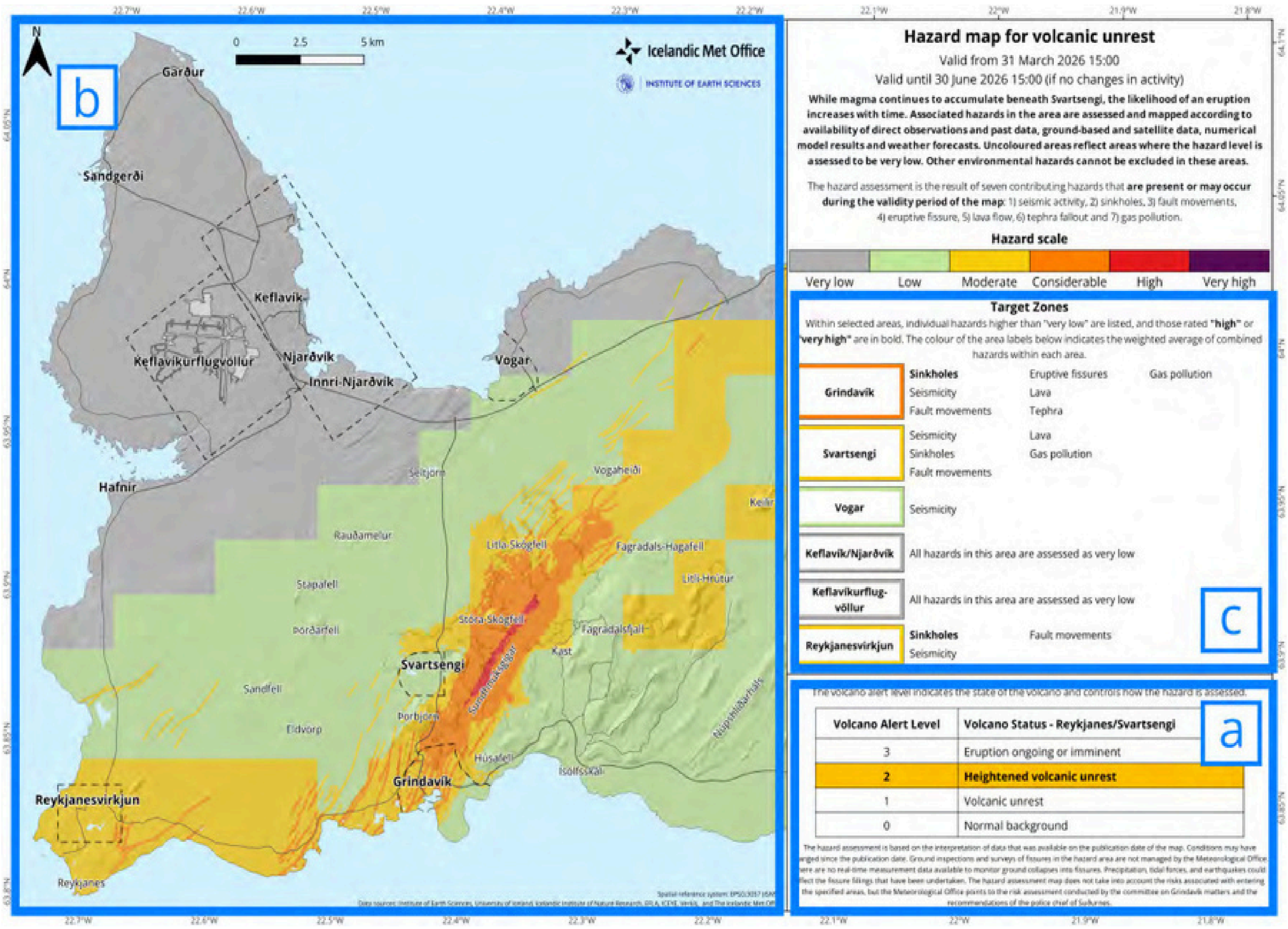

Figure 2 An example of the current hazard map with the three core components: a) the Volcano Alert Level System status (VALS); b) the cumulative hazard map showing the situation across the assessed area; and c) the target zones with hazard lists and hazard level.

The case for effective hazard maps was clear. Hazard maps have been used to communicate volcanic hazards in Iceland since at least Eyjafjallajökull in 2010. In 2021, maps were used to show the extent of hazards around the vents, such as lava, gas, tephra, and ballistics but due to the relatively remote situation of the 2021–2023 Fagradalsfjall eruptions, authorities found it easier to simply close the sites to tourists and visitors when necessary (e.g. in very bad weather conditions, during moss fires or due to expected or observed high level of gas pollution in the area; Barsotti et al. 2023). This changed in November 2023 with the focus of unrest situated immediately adjacent to Svartsengi, a strategically important powerplant, the Blue Lagoon, a major tourist attraction, and Grindavík a population centre.

The aim of the current hazard map (Figure 2) is to communicate the cumulative volcanic hazard at any given location on the Reykjanes peninsula within the map's validity period. The map is composed of three core components: the Volcano Alert Level System (VALS) using a four-tier colour-coded scale reflecting the state of volcanic activity (Figure 2a); a cumulative hazard map (Figure 2b); and details of hazards affecting target zones such as towns or infrastructure (Figure 2c).

Currently, seven separate volcanic hazards are assessed over the area of the map (Figure 3): seismic activity, sinkholes, fault movements, eruptive fissures, lava flow, tephra fallout, and gas pollution. Individually, each component hazard is assessed in terms of geographical extent and significance according to the current level of VALS. The result of this is seven raster layers showing the weight of each hazard across the area. These rasters are summed to give a final cumulative hazard raster shown on the published map. The hazards present or probable within target zones are listed and a weighted average of the cumulative hazard within each zone is provided in the form of a six-tier colour-coded scale (from very low to very high).

A range of input data is used to construct the component hazard rasters. For example, the mapped locations of fractures that have recently moved according to satellite data or direct observations in the field, or the results of MrLavaLoba lava flow simulations. Data, whether vector or raster, is ingested using QGIS, converted to either 100 or 20 metre resolution rasters (dependant on whether modelled or mapped), and aligned to a common grid for the cumulative calculation.

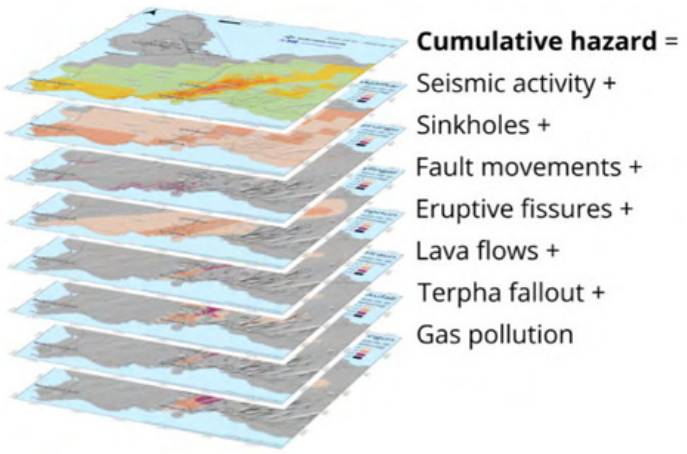

Figure 3 Seven component hazard rasters map the extent and weight of each hazard and are summed to produce the final component hazard map.

The map is re-issued frequently, either to extend the validity period or when new activity necessitates. Typical validity periods range from a month during extended calm periods to hours at the start of eruptions. Since November 2023, 133 maps have been issued.

The final map is published on IMO's website and emailed directly to key stakeholders such as the police, Civil Protection, and local authorities. This hazard assessment is considered by Police and Civil Protection when deciding access to the area and it is used as the basis for risk assessments for the Grindavík area carried out by contractors. It is also distributed by the Grindavík Commission, a temporary independent governmental panel on the situation, and safetravel.is, a website operated by Icelandic Search and Rescue for the benefit of foreign tourists.

The methodology used in the construction of the map is aimed at being as versatile as possible so that the same approach can be used to assess any area of Iceland in a consistent way with any combination of hazards. Future work will involve adaption to a live web map where users can query locations for the presence of specific hazards.

Additional information on the map can be found at:

- https://en.vedur.is/volcanoes/fagradalsfjall-eruption/hazard-map/
- https://en.vedur.is/about-imo/news/important-to-continue-developing-volcanic-hazard-assessment-methodology

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Iceland