A multi-scale risk assessment for tephra fallout and airborne concentration from multiple Icelandic volcanoes - Part I: hazard assessment

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In order to assist the elaboration of proactive measures for the management of future volcanic eruptions in Iceland, we developed a new approach to assess the medium- to long-term hazard related to tephra fallout at various scales and for multiple sources. We coupled field studies with numerical modelling to compile a local ground deposition assessment using the advection-diffusion model TEPHRA2 and a regional atmospheric ash concentration assessment using the numerical model FALL3D.

This study focuses on four volcanoes – Hekla, Katla, Askja and Eyjafjallajökull – selected for their high probability of eruption in a near future or their high potential impacts. Due to their different eruptive behaviours and different degrees of knowledge of past eruptions, separate schemes for the quantification of the hazard were developed. All scenarios are a combination of 1000 runs of each model, varying Eruption Source Parameters (EPS) and/or meteorological conditions (in 10 years of Reanalysis data). EPS (plume height, erupted mass, eruption duration) were defined for each scenario based on field and literature studies.

Two scenarios were considered for Hekla volcano (based on the 1947 and on the 2000 eruptions as references) using the Eruption Range Scenarios approach (ERS), where wind conditions and EPS are stochastically sampled. Eruptions at Katla are numerous and heterogeneous in eruptive styles, including basaltic, silicic and long-lasting eruptions. One ERS was produced for the VEI 2-3 classes to account for the basaltic activity. At Askja, two One Eruption Scenarios were considered to account for both the phreatomagmatic and the magmatic phase of the 1875 eruption, with varying wind conditions and EPS fixed deterministically. We also produced an ERS for VEI 5, based on field evidences of deposits larger than the 1875 eruption. At Eyjafjallajökull, we modelled possible patterns of tephra dispersal associated with a long-lasting eruption similar to 2010. Outputs are produced in a variety of shapes such as probability maps of ground tephra accumulation and airborne concentration, isomass maps for a given probability, hazard curves and atmospheric travel and residence times. At a local scale, results show a strong prevailing pattern of tephra deposition and transportation towards the E and NE part of the island, leaving a very low probability of Reykjavik to be impacted. At regional scale, there is a low to medium probability of having critical ash concentration in Northern Europe and UK airspaces.

This method combines field and numerical approaches and provides a multi-scale hazard assessment to describe both the local hazard associated with ground deposition of tephra and the hazard at a regional scale associated with the long residence time of volcanic particles in the atmosphere, which is the first step to the compilation of comprehensive risk assessments. The vulnerability and impact are presented in Part II.