ID: 101

Tephra fall impacts to buildings: The 2017-2018 Manaro Voui eruption, Ambae, Vanuatu

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Building damage from tephra falls can significantly impact exposed communities around erupting volcanoes. There are limited empirical studies of tephra fall impacts on buildings, with none on tephra falls impacting traditional thatched timber buildings, despite their prevalence across South Pacific island nations and parts of Asia. The 2017/2018 explosive eruption of Manaro Voui, Ambae Island, Vanuatu, resulted in damage to traditional (thatched timber), non-traditional (masonry), and hybrid buildings from tephra falls in March/April and July 2018. Field and photographic surveys were conducted across three separate field studies with building characteristics and damage recorded for a total of 589 buildings. Buildings were classified using a damage state framework customised for this study. Overall, increasing tephra thickness correlated with increasing severity of building damage, corroborating previous damage surveys and vulnerability estimates. Traditional buildings were found to be less resistant to tephra loading than non-traditional buildings. We attribute variation in resistance within each building type to differences in the pre-eruption condition of the building and the implementation of mitigation strategies. Mitigation strategies included covering thatched roofs with tarpaulins, which helped shed tephra and consequently reduced loading, and providing an internal prop to the main roof beam, which aided structural resistance. As is typical of post-event building damage surveys, we were limited in time and access, and we note the limitations this had for our findings. The presented results contribute to the limited empirical data available for tephra fall building damage, improving our evidence base for forecasting future impacts for similar construction types globally.

ID: 126

Are we prepared? The role of legal frameworks in managing the impacts of volcanic emissions.

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A volcanic eruption always has the potential to have a huge impact on its surrounding areas but in an urban centre this risks becoming catastrophic. This is a potential outcome for Tāmaki Makaurau | Auckland, the largest city in New Zealand, built as it is on the Auckland Volcanic Field (AVF). A key part of this will be managing volcanic emissions.

An important (but often overlooked) aspect of disaster risk management is the legal framework in which it operates. In New Zealand, legal frameworks for disasters tend to follow a response-focussed, all-hazard model. Recovery is then managed by bespoke frameworks introduced post-event (e.g., the Canterbury Earthquake Recovery Act 2011). By creating recovery policies and legal frameworks post-event, these frameworks often fail to consider the requirements of long-term recovery, the potential of cascading hazards and ongoing hazards.

A key way to increase societal resilience to volcanic emissions is through testing legal frameworks as part of preparedness and ensuring that they are fit-for-purpose. Creating ad-hoc legal frameworks post-event risks them not properly managing volcanic emissions. This may cause further hazards such as the re-activation of ash.

This paper looks at the role of legal frameworks in managing volcanic emissions stemming from volcanic disasters, using the AVF as a case-study. It advocates that recovery frameworks need to be established and tested as part of preparedness. These frameworks need to acknowledge the additional challenges which volcanic emissions pose and the impact that decisions can have on mitigating or creating future disasters.

ID: 163

Rapid Volcanic Ashfall Impact Assessment for the 2022 Hunga Eruption: a bespoke approach and lessons learned.

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When large, unprecedented disasters occur, rapid impact assessments can be used to release funds, mobilise aid and direct response priorities. The 15 January 2022 eruption of Hunga volcano, Tonga, and the resultant shockwave, ashfall and tsunami, caused substantive impacts across the Kingdom of Tonga. The provision of international aid was complicated by communications disruption, and a need emerged for a rapid, remote volcanic impact assessment and the provision of specialist advice to inform the response of international partners.

This presentation outlines a bespoke rapid, remote volcanic impact assessment approach undertaken in the first 10 days post-eruption, using pre-existing vulnerability models, and progressively updating hazard (e.g. ashfall) and exposed asset (e.g. buildings, farms) data as it became available. There was considerable engagement with expatriate Tongans, and other technical experts, who provided important knowledge, insights, and local context to inform the process. We focused on assessing ashfall impacts to buildings, critical infrastructure, and agriculture, and estimated clean-up requirements on Tongatapu (the main island). These assets and undertakings are vital for community wellbeing and emergency response in the aftermath of ashfall events and had available geospatial datasets.

The methodology employed demonstrates the value of rapid, remote volcanic impact assessment to support international response and aid efforts, particularly considering the severe uncertainties apparent in the days immediately following an eruption. We highlight the challenges and successes of our approach, noting the need for data and tools that support rapid and longitudinal volcanic ashfall impact estimates in tropical and Pacific Island settings.

ID: 165

Understanding ashfall impacts and recovery from the 15 January 2022 eruption of Hunga Tonga-Hunga Ha'apai volcano, Kingdom of Tonga

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The 15 January 2022 Hunga Tonga-Hunga Ha'apai eruption generated a tsunami and ashfall that had widespread impacts to human health, buildings, agriculture, and infrastructure across the Kingdom of Tonga (population ~108,000). Currently, there is limited data on impacts and recovery from ashfall in the South Pacific.

To address this gap, fieldwork was conducted on the island of Tongatapu in June and August 2023, focussing on four main areas: 1) the collection of primary ashfall impact data; 2) what are Tongan partner agencies' interests? 3) how can we collaborate with local existing projects and research directions? and 4) how can we better collaborate on science support? Interviews were conducted with Tongan agencies, including the: National Emergency Management Office; Ministry for Agriculture, Food, Forests, and Fisheries; Ministry of Infrastructure; Ministry of Health; Tonga Water Board; and Tonga Power Ltd. Additionally, a stakeholder workshop was conducted focussing on knowledge transfer and planning preparedness resources. The main lessons identified related to: arrangements for rapid ash hazard characterisation to inform the emergency management response; the requirements for ongoing cleaning of remobilised ash, particularly from electrical transformers and stormwater systems; improving awareness of cascading impacts from areas affected by both ashfall and tsunami; and the need for Tonga-specific ashfall preparedness and response resources.

This presentation highlights the complexities in long-term recovery from ashfall in Tonga, and lessons learned for the wider South Pacific. We discuss the opportunity for continued science collaboration and fostering knowledge exchange mechanisms in future research.

ID: 169

A global analysis of the risk of crops to tephra fallout

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Eruptions regularly highlight the vulnerability of crops to volcanic hazards through destruction, loss of harvests and/or reduction in market value. Beyond physical damages to the plant, reduced photosynthesis caused by fine ash can affect crop yield over widespread areas. Our current understanding of crop vulnerability being limited and often site-specific, a first-order reference of the potential risk caused by tephra fallout is still missing. Such questions as *How much cropland is exposed to* and *How much crop yield loss can be expected from tephra fallout?* remain open. As a first step towards answering these questions, we take a global approach that combines fast semi-analytical tephra dispersal models with available crop production datasets to quantify the monthly exposure of 10 major crops to tephra fallout worldwide. Using the knowledge gained from post-event impact assessments and controlled experiments, we estimate the relationship between tephra accumulation and crop yield loss while accounting for the dependence of crop vulnerability on growth stage. This allows us to estimate crop yield loss from tephra fallout associated with eruptions of VEI 2–5 for all volcanoes in the Volcanoes of the World database. The results indicate that the highest yield losses are expected for sugar cane across all farming practices but are highest for cassava when considering subsistence farming only. Our study provides the foundation for investigating the potential secondary effects of tephra impacts on crop on local to regional economy and food security.

ID: 210

Rapid mapping of tephra fallout building damage: A machine learning approach

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Explosive volcanic eruptions generate tephra fallout that poses a significant threat to buildings in the surrounding area. Following an eruption, the rapid identification of affected structures and the quantification of damage severity are paramount for effective recovery planning. Traditional building damage surveys, typically conducted on the ground by trained personnel, can be labor-intensive and time-consuming. To expedite the assessment of post-eruption building damage, we propose an automated approach leveraging unmanned aerial vehicle (UAV) acquired optical imagery collected after the 2021 eruption of La Soufrière volcano (St Vincent and the Grenadines) and state-of-the-art convolutional neural networks (CNNs). Our comprehensive machine learning framework encompasses all necessary models and pre-processing steps for 1) Building Extraction: our framework accurately extracts buildings from background imagery; 2) Damage Classification: It efficiently distinguishes between undamaged and damaged buildings, achieving a robust F1 score of 95% on the St Vincent test dataset; 3) Severity Assessment: Our framework further categorises damaged buildings into moderate damage and major damage categories, with an F1 score of 74% on the test dataset. The spatial data generated by our framework enables the rapid generation of precise building damage maps which may serve as valuable resources for guiding decision-makers in post-eruption recovery management.

ID: 235

Quantifying the efficiency of tephra clean-up operations to mitigate roof collapse from the 2021 Tajogaite eruption (La Palma, Spain)

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The 2021-Tajogaite eruption in La Palma, one of the youngest islands of the Canarian Archipelago (Spain), showed the challenges that a long-lasting, hybrid eruptive style represents for a society. Several uncertainties regarding the spatio-temporal evolution of volcanic hazards (e.g. tephra fallout, lava and gas) complicated the emergency management. Our study focuses on the impacts of 3 months-long tephra fallout on 764 roofs of primary buildings. We investigated the dynamic relationship between tephra intensity at the time of the impact, vulnerability classes of the roofing stocks, observed damage, and efficiency of clean-up operations in preventing building roof collapses. Our results indicate that tephra clean-up operation during long-lasting eruptions is key to mitigating the risk of building roof collapse. If no clean-up measures had been taken, we estimate that 11% of the surveyed primary buildings would have equaled or surpassed a 75% probability of building roof collapse, while only 10 building roof collapses have been observed (i.e., 1.3% of the total number of analysed buildings). This work contributes to the syn- and post-volcanic event data collection by i) increasing the knowledge about building roof vulnerability to tephra and ii) providing an evidence-based reference for the importance of clean-up operation in emergency plans for future long lasting, hybrid eruptions on roofs, both on La Palma Island and for other monogenetic fields.

ID: 284

Regulating Volcanic Risk: Lessons from Aotearoa New Zealand

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Risk and liability is a key component of the legal landscape around disasters. Such legal frameworks manage, structure and limit the nature of risk that individuals are required (or permitted) to face across all aspects of the disaster cycle, from prevention to response. These frameworks are crucial for reducing the vulnerability and exposure of individuals to hazards, both prior to a potential disaster event and within the context of post event work environments (for example, utilities workers). However, these models tend to be generic and if they apply to disasters at all, such references are minimal. Rarely if ever do they refer to volcanic risk.

This paper provides an overview of these issues in relation to volcanic risk, using the experiences of Aotearoa as a case study. Building upon work being undertaken by the LEAD Institute for Law, Emergencies and Disasters at the University of Canterbury to map legal frameworks around post-disaster recovery (funded by QuakeCoRE, The New Zealand Centre for Earthquake Resilience), it critiques how effective these generic models are in managing risk in the specific case of volcanic hazards. In addition, and drawing upon the litigation around the Whaakari eruption sequence in particular, it examines the difficulties of using generic health and safety systems in the context of volcanic hazards.

The paper concludes by asking how might these legal tools be adapted to effectively manage risk in the specific context of volcanic hazards.

ID: 382

A hundred years of ships and eruptions in Patagonia: addressing the complex interplays between volcanic crises and nautical transport

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In December 1921, an explosive eruption of Cordón Caulle volcano (VEI: 3) generated widespread volcanic ashfalls in Chile and Argentina, causing significant damage to Patagonian ships and ports. Since then, various Andean eruptions have been documented as having an impact on shipping in the region. This includes cases as severe as ships capsizing, the total disappearance of entire ports, and numerous setbacks that remain in force because of the remobilization of tephra deposits.

While the risks posed by volcanic hazards to other modes of transport are a long-standing and fairly well-known issue, our understanding of the effects of explosive eruptions on shipping remains limited. This is particularly critical for situations where water transport may be required for managing volcanic crises (e.g., evacuation). To address these knowledge gaps, we present the results of our multidisciplinary approach to studying the repercussions of four major volcanic eruptions in Patagonia, including those from the Hudson (1991), Chaitén (2008), Cordón Caulle (2011-2012), and Calbuco (2015) volcanoes.

Altogether, we present (1) a systematic catalogue of volcanic ash effects on ships and ports, addressing impacts from primary fallouts and secondary phenomena; (2) a novel volcanic ash impact model for water transport, expanding on available *damage and disruption states* for critical infrastructure; (3) an overview and effectiveness assessment of mitigation strategies observed; (4) a comprehensive feasibility study for managing volcanic emergencies using water transport resources; and (5) our ongoing experiences in communicating lessons learned to all stakeholders to increase societal resilience to volcanic eruptions.

ID: 519

The recent Nyiragongo eruption and its environmental impact: ash fallout and contamination of drinking water

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Nyiragongo (D.R. Congo) is an active volcano known for its impressive persistent lava lake within the crater, and it is recognized as one of the most dangerous volcanoes in the world because more than two million people live on its slopes. On 22 May 2021, unexpectedly, Nyiragongo produced three different lateral lava flows in the lower flanks, and significant amounts of volcanic gas and ash were emitted from the summit crater. For several weeks, the ash fallout impacted the main city of Goma and the numerous villages located in the vicinity of the volcano. 22 samples of volcanic ashes and 135 samples of drinking water (springs, rivers, rainwater, roof runoff) were collected during and after the eruption. From the leaching of the ashes and their direct observation through the electron microscope, large quantities of soluble salts (e.g. sulfates, chlorides) on their surface were identified. The alarming results showed that most of the drinking water were heavily contaminated by volcanic emissions. Fluoride, chloride, sulphur, and many potentially toxic elements (PTEs), including Al, As, Cd, Cr, Cu, Fe, Mn, Mo, Pb, Sb, Se, Te, Tl, and V, exceeded the suggested World Health Organization (WHO) drinking water limits during the eruptive period, exposing the population, often unaware, to high health risks.

ID: 673

Exploring consequences of gas emissions from future eruptions in the Auckland Volcanic Field, New Zealand, for health and the built environment

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Auckland City is built upon the intraplate basaltic Auckland Volcanic Field (AVF). An important component of evaluating and quantifying volcanic risks to Auckland has been the development of credible, detailed AVF eruption scenarios. While hazard footprints for these scenarios have been developed for lava flows, pyroclastic density currents, ballistics and tephra fall, this project is the first to quantitatively assess volcanic gas hazards for an eruption scenario. For basaltic volcanism, sulfur dioxide (SO_2) gas is typically the most consequential volcanic gas emitted. The Māngere Bridge eruption scenario was used as the basis for this study, as preliminary SO_2 emission fluxes have been derived using the petrologic method. The aim of this study was to model SO_2 dispersion from a Māngere Bridge eruption, to derive ground level SO_2 concentrations. Results suggest that under worst-case dispersion conditions, modelled ground-level concentrations of SO_2 would be comparable to those recorded for recent basaltic eruptions in Iceland and Hawaiʻi. Life-threatening concentrations may occur near the vent; this hazard will need to be managed by establishing evacuation zones around the vent, informed by real-time monitoring of SO_2 concentrations. Large areas of the greater Auckland area could be subjected to concentrations exceeding effects thresholds. Public health strategies would include advising the public to remain indoors with doors and windows closed and turning off heat pumps/air conditioning units pulling in outdoor air. Simple risk ratio calculations indicate that some areas of the city may experience a doubling of baseline rates for asthma ED visits and hospitalizations.

ID: 765

Erupción del volcán El Fuego Guatemala del 3 junio 2018: Gas y aerosoles detectados en Costa Rica y el Caribe

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El Fuego de Guatemala eruptó el 3 junio 2018 generando columnas de gas y cenizas entre 6 y 15 km de altura. El colapso de columna produjo los flujos piroclásticos más mortíferos desde 1929. Se estima que unos 1.7 millones de personas fueron afectadas en la parte central de Guatemala y hubo al menos 2900 fatalidades humanas y un número desconocido de desaparecidos. Posterior a la erupción de El Fuego, el 4 y 5 junio, se detectó tanto a nivel del suelo en la región central de Costa Rica como a nivel satelital sobre el istmo de América Central y el Mar Caribe SO_2 y aerosoles. Analizadores de SO_2 y aerosoles detectaron en el aire ambiente a nivel del suelo concentraciones anómalas de SO_2 (record máximo de 32 ppb desde el año 2016) y de PM´s (45 ug/m3 de PM10). Por otra parte, los instrumentos OMI del satélite AURA y OMPS del Suomi detectaron una masa de 4 mil toneladas de SO_2 a 8 km de altura. La detección de SO_2 y aerosoles del Fuego fuera del territorio de Guatemala cerca de la superficie terrestre como en la troposfera media conlleva implicaciones en cuanto a la dinámica de la pluma eruptiva y el transporte en la atmósfera de materiales volcánicos. Los modelos de la NOAA a escala global predicen que los materiales emitidos por El Fuego el 3 de junio, fueron transportados en la atmósfera principalmente en varias direcciones inclusive hasta territorio de Costa Rica.

ID: 462

Assessment of building damage from tephra fall during the 2020-21 eruption of La Soufriere volcano

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Empirical impact data on how the built environment responds to volcanic hazards is vital for improving our understanding of how societal assets may respond during future eruptions and to provide an evidence base for both qualitative and quantitative risk assessments. The explosive eruption of La Soufrière, St Vincent, in April 2021 generated eruption plumes extending 15 km above the volcano, with tephra fallout affecting the whole island of St Vincent as well as nearby islands. The eruption resulted in significant building damage, including collapse, in the northern part of the island. A ground-based impact survey was undertaken in August 2021 with a focus on buildings located in the “red” - very high hazard - zone that sustained the heaviest impacts during the eruption; nearby settlements in the “orange” - high hazard - zone, which were impacted less by tephra deposition, were also incorporated. Over 500 buildings were catalogued in settlements surrounding the volcano, encompassing a wide range of building types and construction materials. A building typology comprising seven categories was developed to characterise each structure, with the majority of assessed buildings having unreinforced concrete block walls and sheet metal roofing. A tailored damage framework was used to categorise each structure and mitigation strategies, both long and short term, were captured. This analysis provides an evidence base for advice on future impacts and mitigation strategies relevant for communities living close to the volcano in St. Vincent and on other volcanic islands in the Caribbean.

ID: 609

Is it possible to identify signs of large volcanic eruptions in tree ring perturbations in southern Mexico?

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Large volcanic eruptions may cause strong anomalies in forests around the globe. These eruptions emit huge amounts of sulfur dioxide gases into the upper-atmosphere, forming sulfate aerosols that remain suspended for several months, reflecting solar radiation and cooling global temperatures in the short-term. However, in many regions, the effect of these eruptions on forests and their environmental implications are not well known. Tree ring approach is an excellent tool to reconstruct the climatological variability since, in many cases, growth tree disturbances are caused by cold and/or dry periods associated with important volcanic eruptions.

In this work, based on dedrogeomorphological methods, we present evidence of disturbances in tree rings from forests in southern Mexico related to large volcanic eruptions around the world. Series of tree rings from the last ~150 years of *Pinus pseudostrobus*, *Pinus rudis* and *Pinus oocarpa* were used. We identified abrupt tree ring growth suppressions in 19th, 20th and 21st centuries in the southern region of Mexico associated with possible volcanic signals such as Krakatau (1883), El Chichón (1982), Pinatubo (1991) and Eyjafjallajökull (2010). Interesting to note that the growth suppression occurred between one to three years after the main volcanic event. These results can be a starting point to identify possible effects on the climate in our study areas and thus better understand their socio-environmental implications.