Swiss Re

The destructive power of volcanic ash fall

Quantifying volcanic risks will improve insurability and strengthen urban resilience

It goes without saying that volcanoes in close proximity to the world's largest cities pose a serious threat. And this is a risk that in the past has received insufficient attention.

Swiss Re has developed a global probabilistic volcano model to support its clients in assessing volcanic risks and in developing suitable insurance products. The model is the first of its kind in the insurance industry covering the whole world.

Volcanic eruptions – a neglected threat

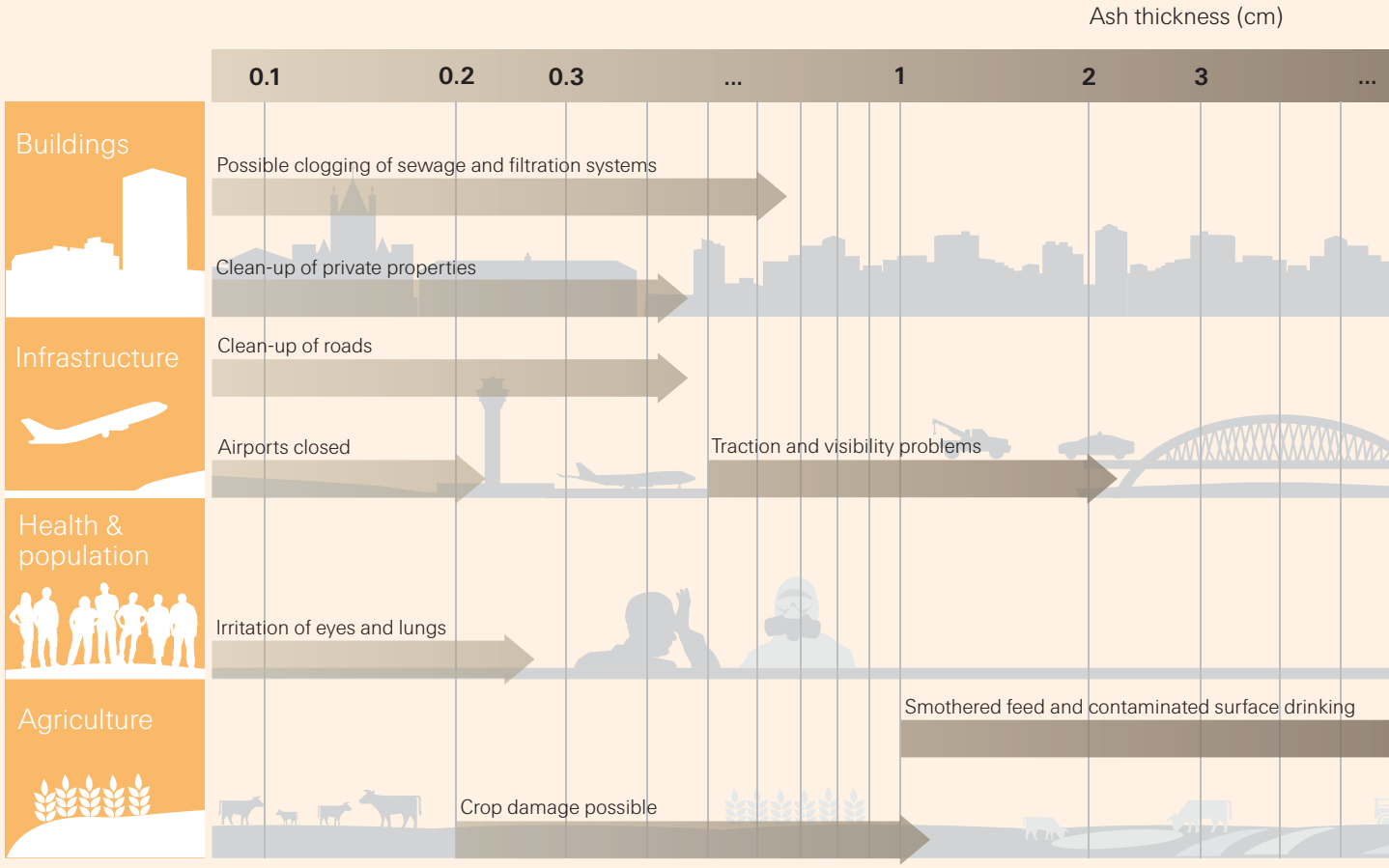
On 15 June 1991, following a drawn-out explosive roar, the sky over the Philippine island of Luzon darkened as a thick grey cloud turned day into night. Ash began falling from the sky, burying villages, people and large areas of land. Covering their mouths with handkerchiefs, the survivors became almost invisible.

After six centuries of dormancy, Mount Pinatubo located 100km north-west of the Philippine capital, Manila, had once again erupted. Shortly after the eruption, the arrival of a rain-laden typhoon added weight to the fallen ash, causing many roofs to collapse.

The second largest eruption of the 20th century had not only spewed an ash column to a height of more than 40km but had also produced avalanches of hot ash, gas and mud. Luckily, the successful forecast of the eruption and subsequent evacuation of thousands of people had minimised the death toll. Nevertheless, the eruption claimed 875 lives and made 250 000 people homeless. The severe damage caused by the eruption, and its after-effects, would disrupt the region's economy for many years to come.

Historically, people have always been attracted by the fertile soil surrounding volcanoes and have hence built major communities in their shadow. In antiquity, the catastrophe that befell Pompeii is testimony to this fact. Today, almost one billion people live within 150km of volcanoes. Eruptions of the recent past, such as that of Mount Pinatubo, have demonstrated that the proximity of people and their homes and belongings to volcanoes threatens both the national and global economy. Since volcanic eruptions are rare events, their attendant risks have not attracted too much attention.

Box 1: Effect of dry ash fall on various sectors



Swiss Re developed first global volcano model in re/insurance industry

Volcanic eruptions have remained a largely unmodelled peril in the re/insurance industry. To enable the insurance industry to quantify this risk, Swiss Re has developed the insurance industry's first exposure-based, probabilistic volcano model. The model covers the entire globe, assessing the risks of 508 active volcanoes.

Since we can mitigate loss of life and injurious health effects by more or less adequate predictions of eruptions and subsequent evacuations of inhabitants around volcanoes, today's largest loss potential of volcanic eruptions is on property. Swiss Re's proprietary global volcano model consequently quantifies the loss potential from volcanic eruptions in the context of property (see Box 2).

The model also focuses on the loss potential from volcanic ash fall because this is the hazard with the most widespread impact. Since autumn 2016, Swiss Re's property underwriters have been using this new model to price reinsurance treaties and single risks.

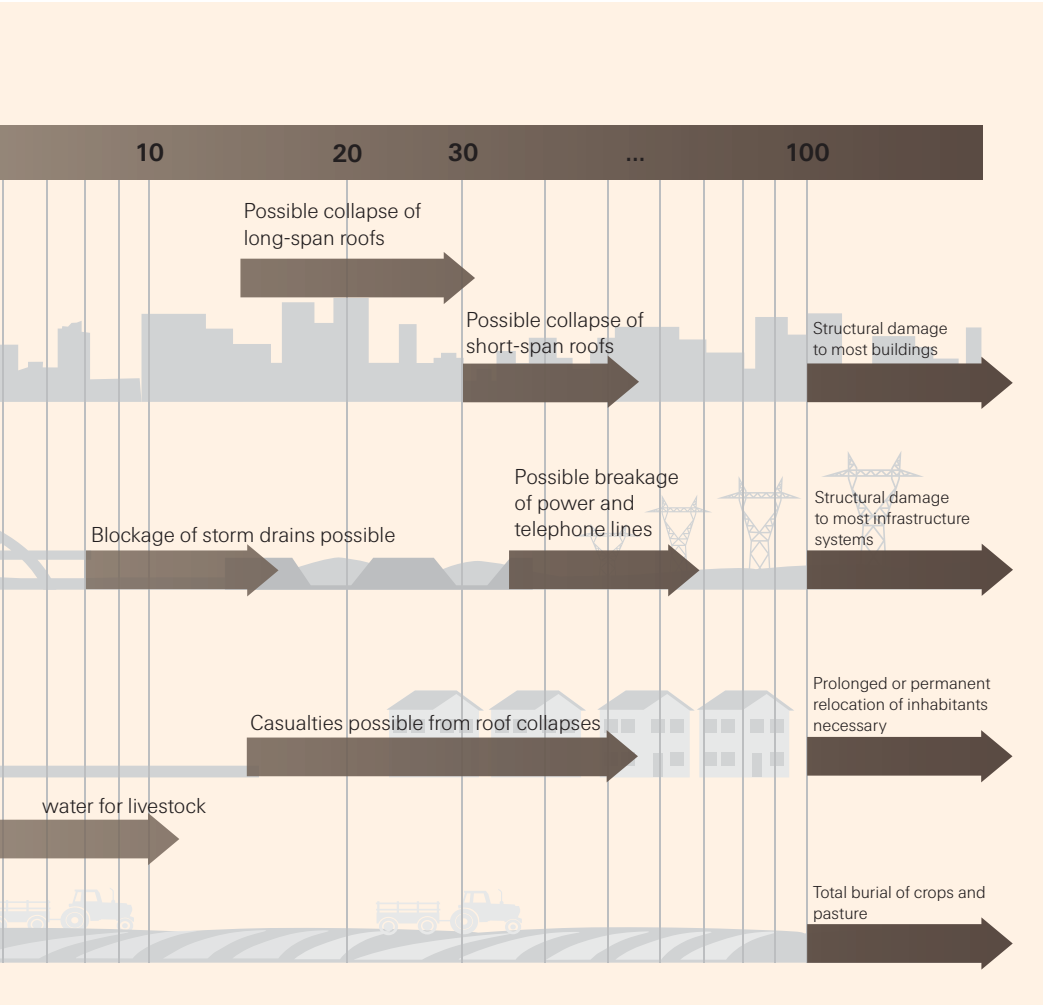


Figure 1: Effects of different intensities of dry ash fall on various sectors. The objects affected are not exhaustive. The length of the arrows indicates the uncertainty of the start of the effect on respective objects. If water was added to the ash – forming wet ash – selected damages would intensify at the same ash thickness.

Box 2: A critical risk assessment tool: Swiss Re's global volcano model

Similar to all state-of-the-art natural catastrophe models, the Swiss Re volcano model is an event-set based probabilistic model. It consists of four distinct components: the hazard, the vulnerability, the value distribution and the insurance conditions.

The hazard component generates a large number of potential volcanic eruption events of different intensities for 508 globally distributed volcanoes of explosive nature. The modelled intensities of volcanic eruptions range from a Volcanic Explosivity Index[1] (VEI) of 3 to 6. Each of the modelled volcanic eruptions is assigned an individual eruption probability, which is based on its past eruption history.

The volcanoes included in the model stem from the Volcanoes of the World (VOTW) database of the Global Volcanism Program (GVP) of the Smithsonian Institution [2]. Thereof, only volcanoes with detailed information on volcano name and type are included in the model. Submarine volcanoes are excluded since they do not distribute ash.

For each of the simulated eruptions, the model calculates the ash distribution pattern around the eruptive volcano according to the semi-empirical approach derived by Gonzalez-Mellado and De la Cruz-Reyna [3] (see Figure 2). This calculation includes the duration and height of the eruption as well as the prevailing wind velocity and direction. The effect of rainfall, which augments the ash deposits' loading, is included in the model by following the approach derived by Macedonio and Costa [4].

In the end, the hazard component of the model estimates the probability of a certain ash thickness from many potential eruptions at a given location. A global ash fall hazard map is accessible to Swiss Re's clients in CatNet®.

The vulnerability component of the model translates the ash thickness at a given location into financial loss to property. It is based on published research [5] and Swiss Re's risk engineering expertise. Vulnerability factors include occupancy type, structure type, number of storeys, year built and geographic region.

Different combinations of these identifiers yield unique vulnerabilities for property. These vulnerabilities not only account for the financial loss caused by direct property damage from ash deposits but also for the ash cleaning and business interruption costs within the affected area. Losses due to damage to agriculture or casualties are excluded. Damage beyond the local economy such as business interruption for aviation and contingent business interruptions is not included either.

The value distribution and insurance conditions components use Swiss Re's internal modelling framework. The value distribution component defines the location and value of insured objects. The insurance conditions component allows a detailed application of both basic and complex insurance conditions.

The global volcano model has two limitations. Firstly, its ash thickness calculation concentrates on a distance of 150km from the volcano. Hence, the global volcano model represents regional effects from volcanic eruptions and is not suitable for modelling widespread ash distribution in the atmosphere, which could impact air traffic or even the global climate. Secondly, the only volcanic hazard included in the model is ash fall. This does not take into account other volcanic perils such as pyroclastic flows or lava flows. These perils are more of a local nature and hence constitute the smaller part of the caused loss.

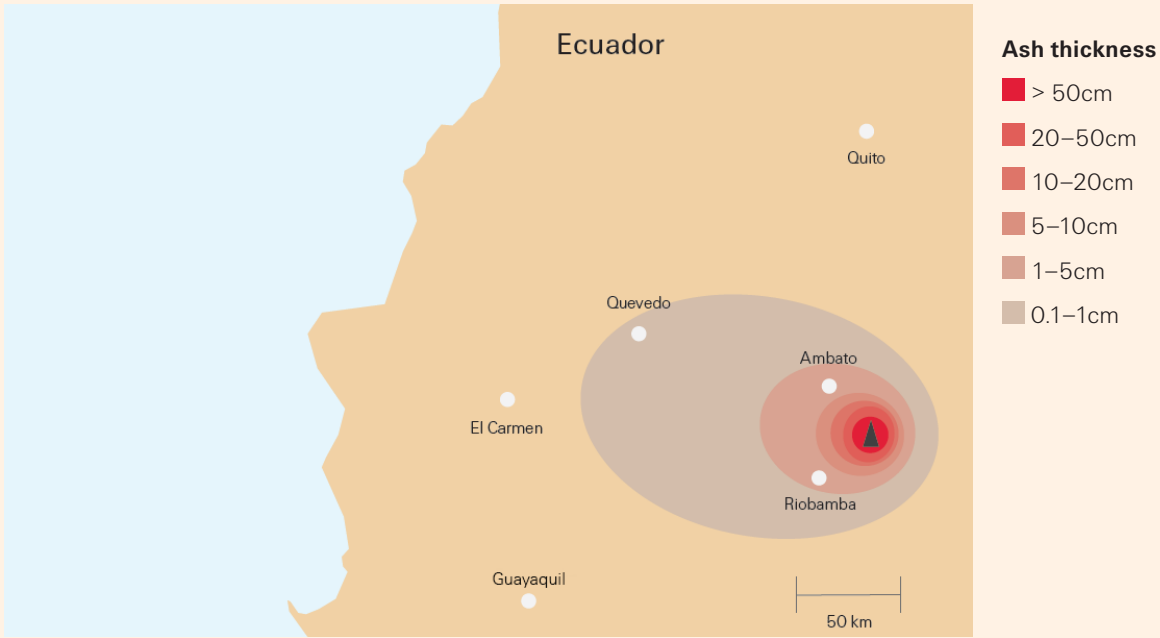


Figure 2: Modelled ash distribution of eruption of volcano Tungurahua in Ecuador on 16–17 August 2006. The event was classified as a VEI-3 eruption.

1 The VEI is the "Volcanic Explosivity Index", a measure of the strength of a volcanic eruption with grading 0 (Effusive) to 8 (Apocalyptic). Rating 3 is "Catastrophic" and rating 6 is "Colossal" [1].

Cities at risk from volcanic ash fall

As centres of population, economic activity and growth, the world's largest cities have a high concentration of assets including infrastructure. Their potential for substantial financial losses caused by natural catastrophes is consequently high. Of the 616 world's largest urban areas ranked in Swiss Re's "Mind the risk" study [6], 90 are located within 150km radius of a volcano.

To quantify the risk posed to the world's largest cities today, we used Swiss Re's proprietary global volcano model and, for each metropolitan area, calculated the frequency of a substantial economic loss caused by volcanic ash fall. A country's economy would definitely be upset with a loss exceeding 0.5% of its GDP. For this reason, we set it as the threshold for a substantial national economic loss. Examples for losses exceeding 0.5% of the country's GDP are:

- Hurricane Sandy 2012, US: Sandy was the second costliest hurricane in the US. It caused USD 72.23bn in damage and destroyed over 650000 homes. Dozens of tunnels and subway stations were inundated. The hurricane had a significant impact on the US economy as many businesses had to close in the aftermath of the storm.
- Queensland Floods 2010/2011, Australia: Prolonged and extensive rainfall affected more than 90 Australian towns in Queensland in December 2010 and January 2011. Three-quarters of the state of Queensland were declared disaster zones. As Queensland accounts for about 20% of Australia's economy, the flooding triggered a negative GDP growth rate of –0.2% in the first quarter of 2011 [7].

The Top 15 world's largest cities at risk of a substantial economic loss from volcanic ash fall are shown in Figure 3. From the Top 15 cities threatened by substantial loss from volcanic ash fall, 12 are located in the ring of fire. As a result of plate tectonics, the ring of fire follows the edges of the Pacific Ocean and has 75% of all active volcanoes on Earth [8].

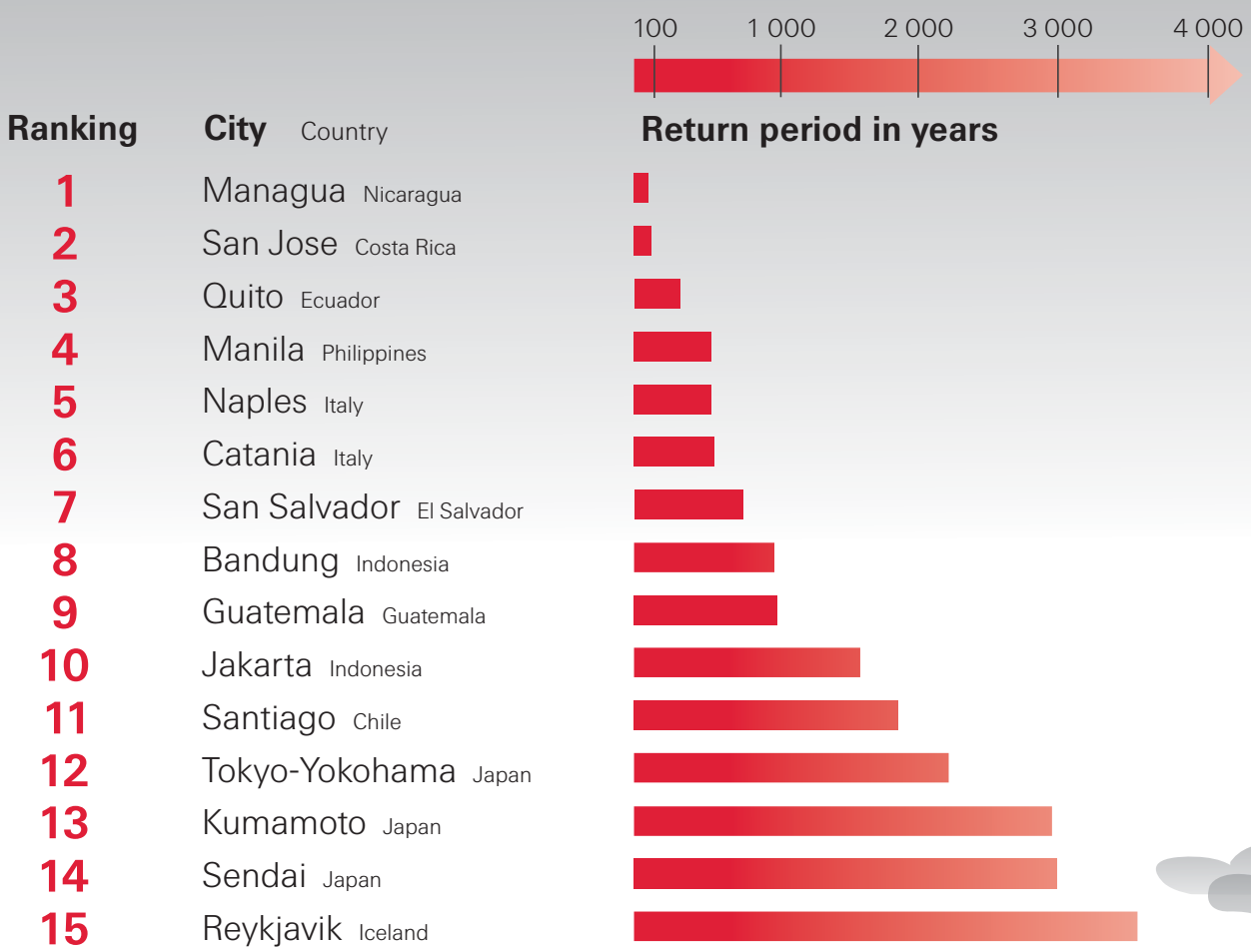


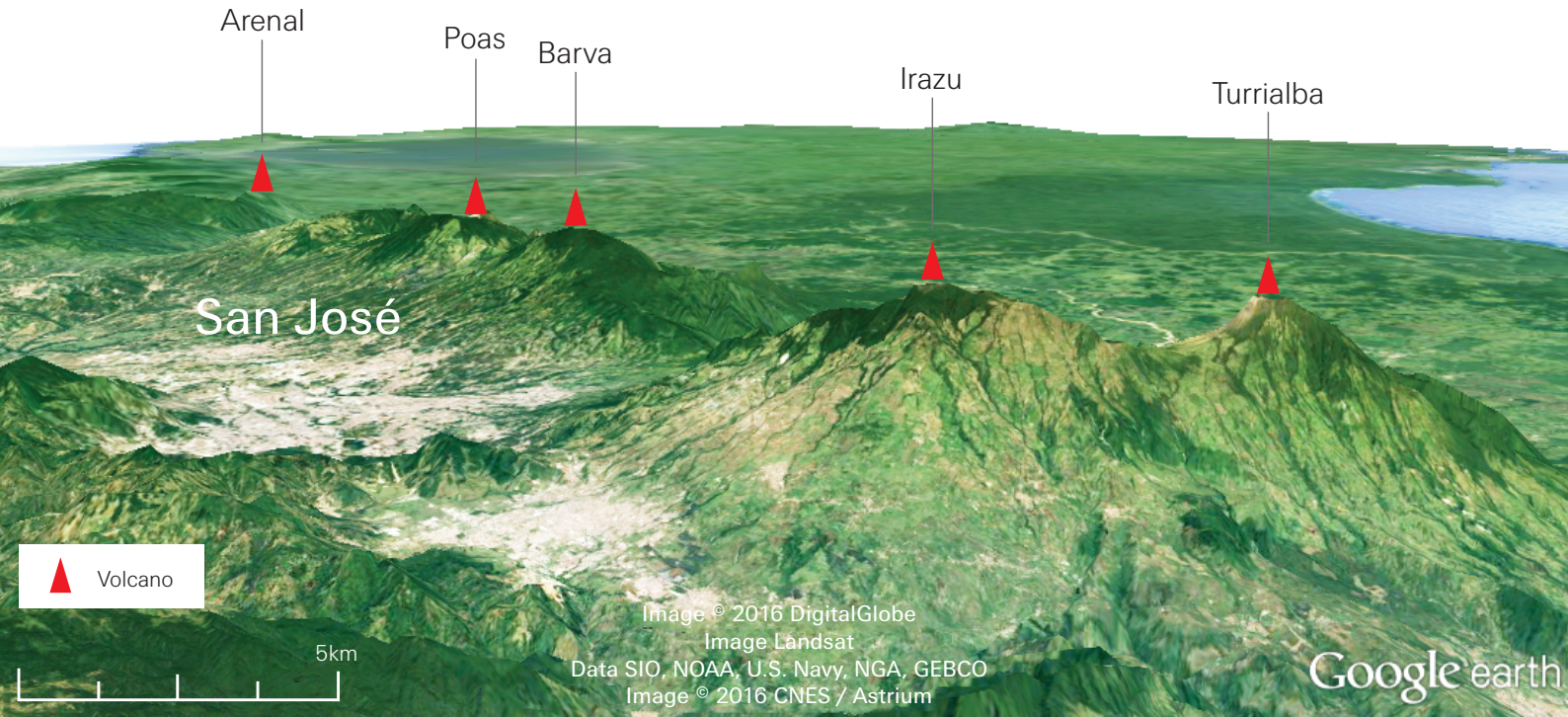
Figure 3: Ranking of the Top 15 world's largest cities at risk from substantial economic loss (exceeding 0.5% of country GDP) caused by volcanic ash fall. Cities are ranked according to the return period of a substantial loss occurrence. The return period (given in years) is an estimate for the likelihood of a loss level being exceeded.

The cities in Figure 3 are ranked according to the predicted frequency of a substantial economic loss caused by volcanic ash fall. From this ranking, we can see that Managua, the capital of Nicaragua, is the city with the highest expected frequency of a substantial loss to its country-wide economy from a volcanic eruption. Its closest volcano, Masaya, poses the greatest threat to the metropolitan area of Managua. The volcano, named "Mouth of Hell" by Spanish conquerors, is one of the country's most active volcanoes.

The frequency for a substantial loss caused by a volcanic eruption in San José, the capital of Costa Rica, is only slightly smaller than the one for Managua. San José is closely surrounded by five volcanoes: Arenal, Poas, Barva, Irazu and Turrialba (see Figure 4). As San José is Costa Rica's economic centre, damages to the city pose a great risk for the whole country. Moreover, the city's inhabitants are often reminded of the volcanic threat. As recently as May 2016, an eruption of Turrialba covered many of the city's buildings with ash and turned the sky grey [9].

The ranking shows that substantial losses from volcanic ash fall are generally rare – with a return period exceeding 100 years. Even though, globally, the threat of volcanic ash fall on property is small, it can be of major importance for individual countries. The cities most at risk from large losses caused by volcanic ash fall are in developing and emerging countries.

Figure 4: San José, the capital of Costa Rica, closely surrounded by five volcanoes: Arenal, Poas, Barva, Irazu and Turrialba.



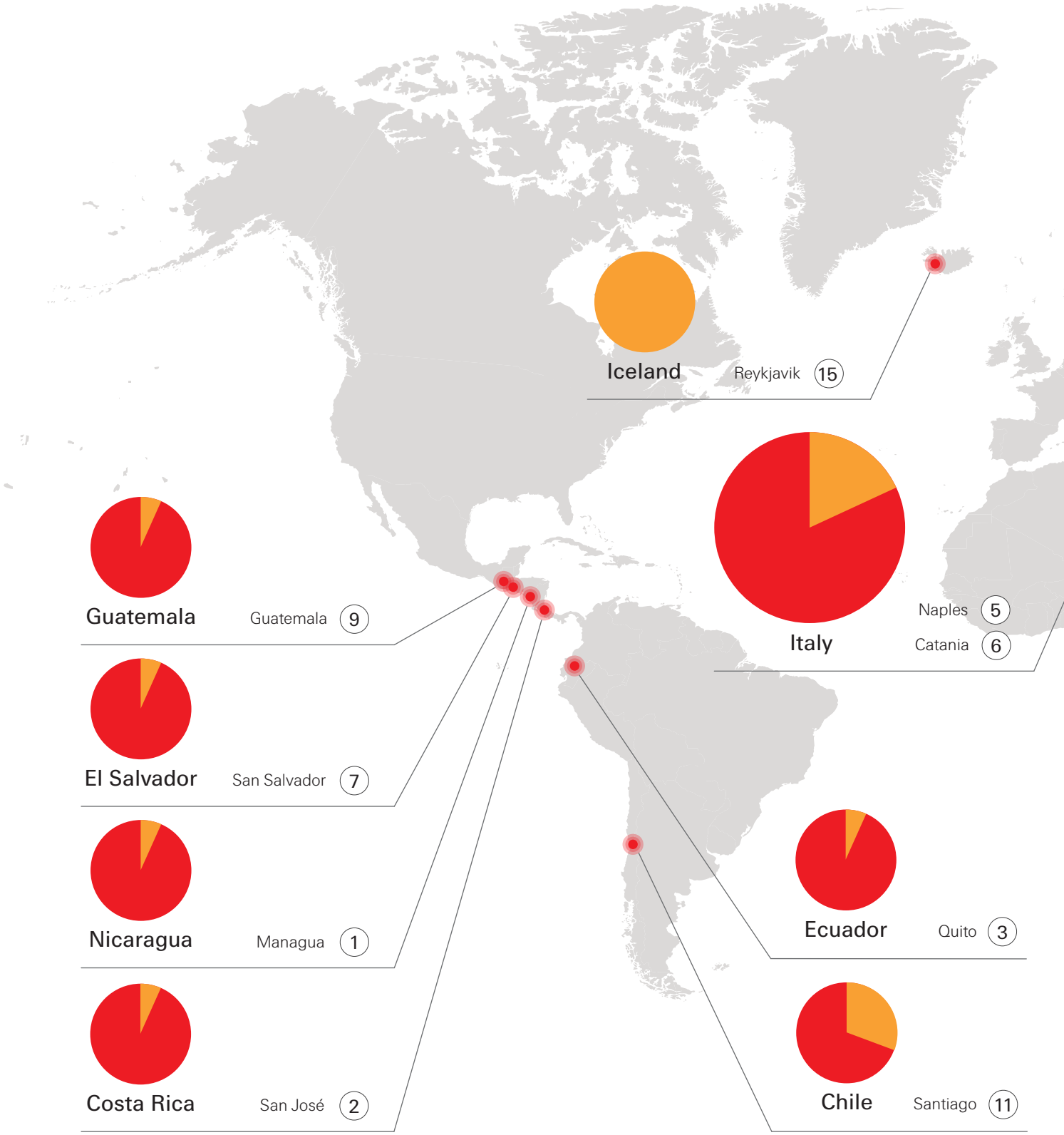
The absolute value of a substantial economic loss differs for different countries (see Figure 5). A substantial loss in a city located in Japan is about nine times larger than the respective loss in a large Indonesian city. A volcanic eruption causing substantial loss in Japan would have an impact on the world economy due to Japan's extensive global interconnectivity. Even though an eruption with a substantial loss in an Indonesian city would probably not impact the global economy as strongly, it would have a detrimental effect on the country itself.

The map further reveals the estimated insured and non-insured fractions of the economic losses within each country. The part of the total economic loss not covered by insurance is referred to as the protection gap. The highest insurance penetration, in other words with the lowest protection gap against volcanic hazards, is in Iceland, where insurance for direct damages caused by a volcanic eruption is compulsory for all real estate and contents. It is offered by the Iceland Catastrophe Insurance, which is a public corporation created in 1975 by the Icelandic Parliament [10].

In contrast to Iceland, the protection gap of other countries whose cities are at risk from volcanic ash fall is large. Eighty to ninety-five percent of the ten most likely losses in large cities are uninsured. This means that individuals, businesses and government would have to shoulder most of the financial burden from a volcanic eruption. The large protection gap can be attributed to the past lack of probabilistic risk assessment tools and to the regional misconceptions about volcanic risk exposure. As volcanic eruptions are rare events, public awareness of the associated risks is low. Volcanic risks are generally insured together with those for earthquakes. The large protection gap, therefore, also stems from only thin earthquake coverage.

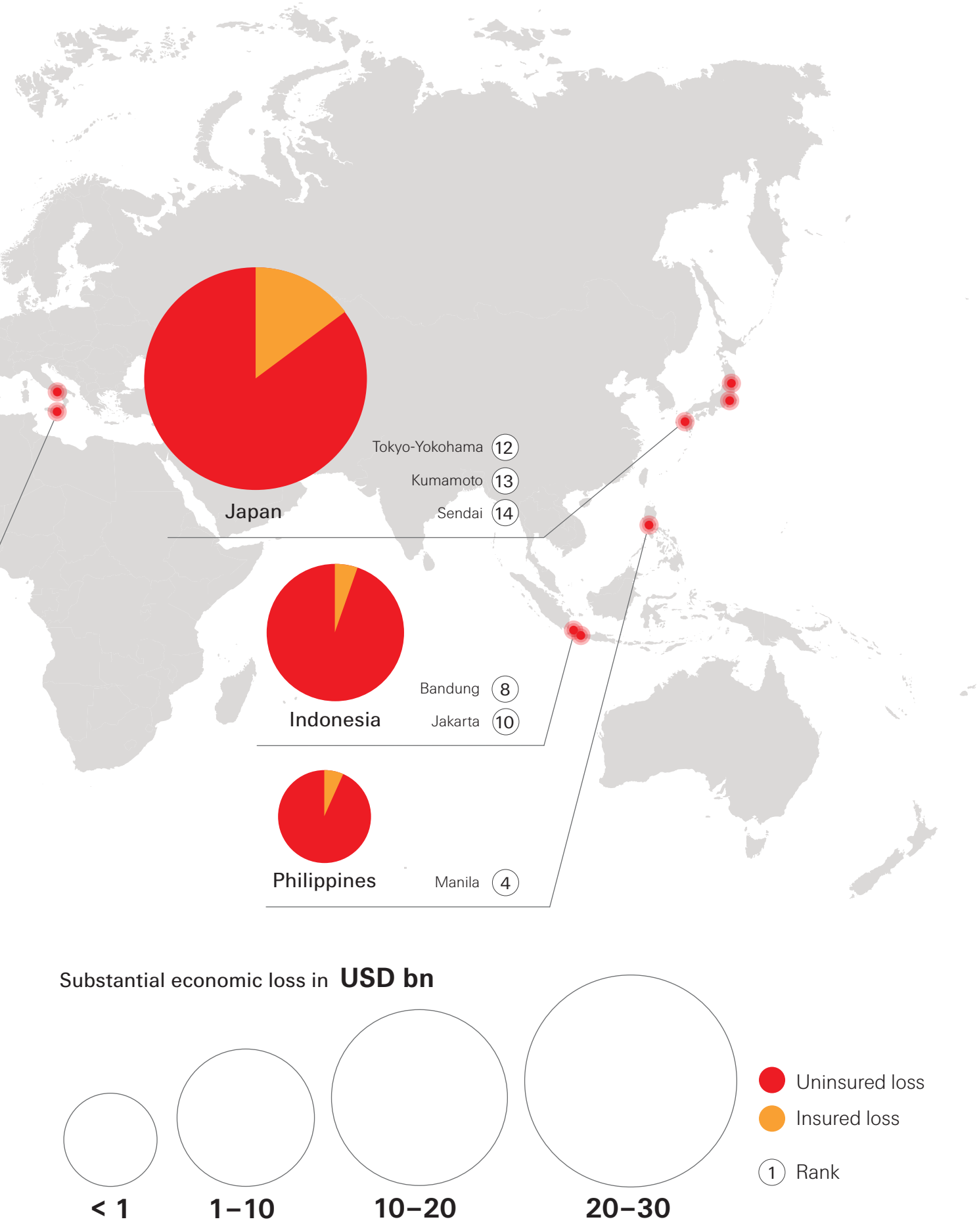
If Mount Pinatubo erupted today with the same intensity as in 1991, it would cause an economic loss of about USD 2bn[2]. This is more than 1% of the country's GDP. As the major part of the loss in the Philippines would not be insured, the cost of damages would impede the country's economy for several years.

2 Loss recorded in 1991 was adjusted for inflation using the US consumer price index to 2015 values. Moreover, the increase in exposure was approximated with the increase in population in the Philippines between 1991 and 2015 [11].



3 Calculated with country GDP-data based on Oxford Economics numbers from 2013.

Figure 5: Global Map of the top 15 cities at risk from substantial economic loss (exceeding 0.5% of country GDP) caused by volcanic eruptions. The map reveals the dimension of the absolute substantial economic loss in each country[3]. Moreover, it shows the fraction of the estimated economic loss that is currently insured and not insured.



Box 3: Volcanic threat in Indonesia

Indonesia is the country where the highest number of people live within 150km of a volcano. More than half its population is highly exposed to volcanic hazards. As shown by our ranking, large cities in Indonesia such as Bandung (rank 8) and Jakarta (rank 10), could experience a substantial economic loss from volcanic ash fall. Despite the large volcanic risk in Indonesia, the major part, namely 95% of its local economy, remains financially unprotected from the impact of volcanic eruptions.

Indonesia offers insurance against volcanic risks in tandem with coverage against earthquakes. To cover losses from volcanic risks, insurance practice has hitherto been to add a small fraction to the earthquake risk. However, according to Swiss Re's global volcano model, the losses from volcanoes can amount to 15% – 25% of the earthquake loss costs in Indonesia. It follows that they can constitute a substantial part of the insurable risk and consequently require a more thorough risk assessment.

Assessment of volcanic risks necessary, feasible and beneficial for all concerned

Up to now, there has been a lack of tools and knowledge to adequately address the risk of volcanic hazards in the insurance market. To account for them, the common practice has been to either exclude volcanic hazards from coverage or to add a small fraction to the earthquake risk. Since in some countries, the volcanic threat constitutes a substantial part of the insurable risks (see Box 3), the ability to assess and price such risks with the necessary precision is crucial. Swiss Re's global volcano model helps in this process.

A few of the underinsured markets are already starting to address volcanic risks concretely. A case in point is Japan. Here, aided by Swiss Re, a major Japanese insurer has begun selling an insurance-like product that helps companies cover losses from volcanic activity. The product embraces business interruption and extra expenses caused by evacuations as a result of volcanic alerts. As the Japan example shows, insurance protection of this nature can help small and medium-sized companies stay in business in the short to medium term and potentially also assist individual households in dealing with the financial consequences of a volcanic eruption.

As global urbanisation gathers pace and new technologies emerge, the protection gap for volcanic hazards widens. And it is only the precise quantification of volcanic risk that will enable adequate insurance coverage. Moreover, accurate volcanic risk assessment can help urban authorities devote proper attention to this risk. This way, they can reduce the misconceptions about volcanic risk exposure, increase public risk awareness and draw up appropriate emergency response plans in a timely fashion. Such proactive measures are effective and efficient since they constitute pre-disaster resilience building rather than reactive, post-disaster management.

Volcano insurance can be a potentially sustainable growth area for our insurance clients since in many of the world's regions exposed to volcanic risk much of the property remains without coverage. Taking advantage of such protection would strengthen the resilience of urban areas and further diversify the potential liabilities of Swiss Re's insurance clients. Ideally, volcanic risk should be bundled with that for earthquakes, with the two combined risks being adequately priced, instead of merely adding a small fraction of the former to the latter.

What can we do for you?

Swiss Re collaborates with insurers and governmental agencies to improve the assessment of volcanic risks and find adequate measures to strengthen the resilience of specific regions against volcanic hazards. Our innovative volcano model is a powerful tool in this effort.

It allows you to:

- quantify the volcanic risks of insurance portfolios for personal and/or commercial lines;
- assess the risks for single large facilities in close proximity to volcanoes;
- calculate the expected losses in order to design an insurance product; and
- identify exposure clusters in an insured portfolio in critical proximity to a volcano.

If you're interested in talking with us about the extent of volcanic risks in your market, please reach out to your client manager.

Eruption of Mount Etna in November 2013.

References

[1] Wikipedia, (2016). Volcanic Explosivity Index. [online] Available at: http://en.wikipedia.org/wiki/Volcanic_explosivity_index [Accessed 27 Sep. 2016].

[2] Global Volcanism Program, (2013). Volcanoes of the World, v. 4.4.1. Venzke, E (ed.). Smithsonian Institution. Downloaded 29 Sep 2015. Available at: http://dx.doi.org/10.5479/si.GVP.VOTW4-2013.

[3] Gonzalez-Mellado, A. O. and De la Cruz-Reyna, S. (2010). A simple semi-empirical approach to model thickness of ash-deposits for different eruption scenarios. Natural Hazards and Earth System Sciences, 10(11), 2241-2257.

[4] Macedonio, G. and Costa, A. (2012). Brief Communication "Rain effect on the load of tephra deposits". Natural Hazards and Earth System Sciences, 12(4), 1229-1233.

[5] Spence, R. J. S., Kelmann, I., Baxter, P. J., Zuccaro, G. and Petrazzuoli, S. (2005). Residential building and occupant vulnerability to tephra fall. Natural Hazards and Earth System Sciences, 5(4), 477-494.

[6] Swiss Re. (2014). Mind the risk – A global ranking of cities under threat from natural disasters. Available at: http://media.swissre.com/documents/Swiss_Re_Mind_the_risk.pdf [Accessed 22 Aug. 2016].

[7] Organization for Economic Co-operation and Development (OECD), (2016). Available at: http://www.oecd.org/ [Accessed 29 Sep. 2016].

[8] National Geographic Society (2016). Encyclopedic Entry – Ring of Fire. [online] Available at: http://nationalgeographic.org/encyclopedia/ring-fire/ [Accessed 12 Sep. 2016].

[9] Bale, R. (2016). This Volcano is Spewing Ash Nearly Two Miles High. National Geographic. [online] Available at: http://news.nationalgeographic.com/2016/05/160521-turrialba-volcano-erupts-costa-rica-flights-ash/ [Accessed 16 Sep. 2016].

[10] Iceland Catastrophe Insurance (ICI), Available at: https://www.vidlagatrygging.is/en/about-the-ici/ [Accessed 15 Sep. 2016].

[11] The World Bank Group. (2016). Total Population. [online] Available at: http://data.worldbank.org/indicator/SP.POP.TOTL?locations=PH&start=1991 [Accessed 29 Sep. 2016].

Title
The destructive power of volcanic ash fall
Quantifying volcanic risks will improve insurability and strengthen urban resilience

Authors
Anja Adamov, Vipin K S

Contributors
Patrice Tscherrig, Nina Köhler, Peter Hausmann, Balz Grollimund

Concept and Realisation
Stephan Schreckenberg, Oliver Schelske

Editing
Richard Heard

Managing Editor
Urs Leimbacher

Graphic design and production
Swiss Re Corporate Real Estate & Logistics / Media production Zurich

Infographics
Annie Wu

Photographs
Getty images

Swiss Reinsurance Company Ltd
Mythenquai 50/60
P.O. Box
8022 Zurich
Switzerland

Telephone +41 43 285 2121
Fax +41 43 285 2999
www.swissre.com