Introduction to the Assessing Volcanic Hazards and Risks with Code Module

In 1992, the Cerro Negro volcano in Nicaragua erupted, depositing more than 80 cm of tephra in the region and destroying buildings, farms, and forest in just a few days. Tephra eruptions, like those from the Cerro Negro volcano, can alter human activity by impacting agriculture, health, infrastructure and human lives. The Assessing Volcanic Hazard and Risks with Code module engages students in exploring the hazards of living near an active volcano and determining how great a risk a future eruption might be for people and ecosystems nearby. To do this, students integrate science practices with computational thinking to produce simulation outputs of tephra distribution and future risks for specific locations.

This approach helps students develop a deep understanding of how geoscientists assess geohazards and risks. In this module, students consider the following framing question:

Based on historical data of a volcano and local weather conditions, what are the risks for people living nearby?

To do this, students use a block-based programming tool to set up simulations and investigate how variables such as wind conditions and volcanic explosivity affect tephra eruptions and the distribution of tephra. Students translate their understanding of the variables into code and then analyze the output of their code represented in a visualization of tephra distribution.

This is a novel approach to teaching about volcanic eruptions, hazards, and risk assessment as computer programming and computational thinking are rarely integrated into science classrooms. However, with the new coding and simulation tools embedded in this module, it is now possible to engage students in scientific investigations much in the same way volcanologists do. The module is carefully structured to scaffold student experiences by familiarizing students with volcano eruption phenomena, introducing science concepts and then computer programming to systematically investigate various variables affecting tephra distribution. All of the steps in the module are necessary for students to computationally estimate risks posed by tephra across a region. Questions embedded in the module guide students' simulation-based investigations.

There are six activities in this module.

- In **Activity 1,** students are introduced to basic hazards and risks of volcanoes, such as tephra, and real-world examples of past volcanic eruptions. Students learn why some hazards pose risk to people and others do not. Students also consider why studying past eruptions could help people prepare for future eruptions.
- In **Activity 2,** students investigate variables that influence where tephra is distributed as a volcano erupts. While scientists cannot predict exactly what the distribution of tephra will look like, understanding how wind speed and wind direction affect where tephra will travel can help students understand why tephra distributions look the way they do. Students are introduced to the GeoCode Explorer – the coding and visualization tool designed as the workspace for students' investigations.
- The goal of **Activity 3** is to learn about two more variables that affect tephra distribution: column height and ejected volume. These two variables are characteristics of the volcano

rather than the surrounding environment. These two variables are connected (you can't have a very high column if you don't have a lot of material being erupted). Students learn how volcanologists combine these variables into what is known as Volcanic Explosivity Index (VEI) to characterize eruptions into several numerical categories such as VEI=0, VEI=1, etc. As part of continued development of computational thinking practices, students use core programming concepts such as loops, variables and functions to systematically investigate how VEI affects tephra distribution.

- In **Activity 4,** students begin to include real-world historical wind and VEI data collected by scientists to explore risks near the Cerro Negro volcano. Students consider the following question "What if an eruption happened on a particular day in the past?" Students use real-world data to determine whether tephra might have impacted a town near the volcano.
- The goal of **Activity 5** is to begin grappling with what it means to predict hazards and risks when scientists can't know how big an eruption might be and what the weather will be when it erupts. Students use code to explore 11 years of wind speed and direction data collected near Cerro Negro. Students investigate patterns in the data and consider the idea of running the tephra distribution model many times – each time using a set of wind speed and direction data points randomly sampled from the historical data. Finally, students explore how sample size influences the sample's ability to capture patterns in the entire data set.
- In **Activity 6,** students investigate the probability of tephra hazard events occurring for several different volcano eruption scenarios. In order to do this using real-world data, students learn how to use a Monte Carlo simulation to randomly sample from wind data. Students then investigate the probability of exceeding a threshold tephra thickness for different VEI values, locations, wind speeds and directions, and times of year.