Evolution, Causes and Influence Factors of Taal Volcanic Activities

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Abstract—Volcanoes are a kind of geological feature which can bring both destruction and wealth to human beings. This study takes the eruption of Taal Volcano on January 12, 2020 as an example to analyze its eruption evolution, causes and influence factors via QGIS software. Taal Volcano lies at the southwestern end of a convergent boundary between the Eurasian and Philippine Sea tectonic plates where volcanic activities are frequent. Results show that the evolution of the eruption consists of increased CO₂ flux, seismic swarms, phreatic explosion chronically. The origin of the volcano is the subduction of the oceanic plate and terrestrial plate. Volcanic eruptions are mostly due to pressurization by active convergent plates activities. The eruption emitted tephra and gas, which exerted impacts on the atmosphere, the nearby vegetation and the water body, and was predicted to result in an El Nino. High concentration of particles, dispersed tephra output, a sharp increase in SO₂ and CO content, variation in atmospheric ozone, and rise in humidity were observed in the atmosphere following the eruption. The volcanic output wiped out the plant cover on the volcano island, and covered the vegetation outside of the volcano island, as shown in the RGB band composite and land cover change monitoring images generated using QGIS from Sentinel-2 data. The volcanic output’s influences on nearby water bodies were shown through drops in ocean salinity and Taal lake’s PH, variation in ocean temperature, and increased ocean’s surface latent heat flux.

1. Introduction

Humans and volcanoes have always been closely interrelated. Approximately 800 million people in the world live near active volcanoes (within 100 kilometers of volcanoes), composing more than 10% of the entire population [1]. Volcanic eruptions can exert a tremendous impact on human lives, leading to a wide variety of both short- and long-term natural disasters, including air pollution due to volcanic gas emission, climate change due to CO₂ emission, and casualties caused by flowing high-temperature lava. What is perhaps the most terrifying aspect of a volcanic eruption is that human beings have no power to control it or prevent it. However, there is also a lot of wealth that volcanic eruptions can bring to people. The sprayed water vapor would bring abundant precipitation, the volcanic ash would fertilize the land, and geothermal resources can be a source of energy for nearby populated areas. In addition, many minerals are related to volcanic activity, including metal minerals such as gold, silver, and copper, as
well as non-metallic minerals such as sulfur and diatomite. Therefore, although volcanic eruptions can be somewhat disastrous to humans, it is far from devastating.

Unlike other natural disasters, such as fire and earthquakes, that occur rather suddenly, volcanic eruptions can be predicted quite accurately. Before a volcano erupts, there are usually signs of unrest around the volcano, including an increase in the amount of lava at the peak, a change in the slope of the volcano, etc. Therefore, these signs can be indicators of a volcanic eruption shortly. In order to mitigate the damage done to humans by an eruption, continuous monitoring of volcanoes and orderly evacuation can greatly reduce the risk of volcanic eruptions.

This study takes the Taal volcano as an example to offer a clearer and more visual approach to monitoring volcanoes. The Philippines is an archipelago country at the junction of multiple geological plates with frequent volcanic eruptions, and South Asia is one of the most densely populated regions in the world. In the eruption on January 12, 2020, over 390,000 people ultimately had to move into evacuation centers [2]. Regarding the eruption’s huge impacts on humans and the environment, this research discusses the evolution of the volcano, the cause of the eruption and the influencing factors using QGIS to analyze land surface changes after Taal volcanic eruption from Sentinel-2 data sets.

2. Site background
Taal volcano is a caldera located in southwestern Luzon Island in the Philippines (Fig.1). It is one of the frequently erupting volcanoes in the country, having at least 33 known historical eruptions. The volcano is part of the Macolod Corridor, a complex NE-SW trending 50–60 km-wide rift zone, characterized by active volcanism, crustal thinning, extensive faulting, and block rotation [3].

![Fig. 1 (left) A map of Maynila and Mindoro region in the Philippines. The red box is the study area. (right) A satellite map of the study area taken on December 6, 2019, approximately a month before the eruption, using the Operational Land Imager on Landsat 8](image)

The reason why this study chose to study the eruption at Taal volcano on 12th January of the year 2020 is that this was the most hazardous volcano that erupted in 2020 and took the lives of 39 individuals. Normally when without remote sensing techniques a lot of remote volcanoes will have their eruptions ignored by scientists and remain uninvestigated. More than 1,500 potentially active volcanoes dot the Earth’s landscape, of which approximately 500 are active at any given time. Although scientists keep
watch over many of the Earth’s volcanoes using traditional ground observation methods, satellite-based remote sensing is quickly becoming a crucial tool for understanding where, when, and why the Earth’s volcanoes periodically boil over. To analyze the satellite data, QGIS is a useful and free tool for better observation of volcanoes. This essay is about taking Taal volcano as an instance, using QGIS to analyze satellite data from USGS and discuss the eruption process, the reason behind eruption and the effect of eruption [4].

3. Data and Methods

3.1. Data
Satellite images of four different dates from Sentinel-2 were acquired. One of the images was taken one month before the volcanic eruption at Taal volcano, on December 12, 2019. Another image taken on January 28, 2020, 16 days after the eruption, was also acquired. These specific images were used to understand the scale of the impact of the volcanic eruption by comparing pre- and post-eruption images. Additionally, two other images were acquired, taken on April 7, 2020 and September 24, 2020 respectively, each a few months after the previous image, in order to demonstrate the gradual recovery of the local ecosystem, especially local vegetation.

3.2. Methods
This study used the software QGIS to analyze the satellite images.

3.2.1. RGB band composite
The plant health monitoring RGB band composite was utilized in this study. In this band composite, the color red was assigned to band 8 of sentinel-2, green was assigned to band 4, and blue was assigned to band 3. Band 8 is the band for visible and near-infrared (VNIR), with a central wavelength of 842 nm; band 4 is the band for the color red, with a central wavelength 665 nm; band 3 is the band for green, with a central wavelength 560 nm. Specifically, band 8, the VNIR band, reflects chlorophyll, the green substance in plants, particularly well. Therefore, more chlorophyll would make the value in band 8 stronger, thus making that specific part of the image redder in this band composite. In this case, chlorophyll would represent the amount of vegetation in an area. As a result, the redder the image, the denser the plant cover.

3.2.2. Land cover change images
This study also used land cover change monitoring to showcase the change in vegetation before and after the eruption, as well as the recovery of the plant cover in nearby regions 9 months after the eruption. First, the classification images were created for all four images using Semi-Automatic Classification Plugin (SCP-Plugin). The land cover was divided into five master classes. The first master class is vegetation, second built-ups, third cloud, to minimize the effect of cloud cover on the classification of land cover, fourth volcanic output, and fifth water body. Under each master class, multiple classes were created using samples on various parts of the image with the same type of land cover, in order to classify each type of land cover more accurately. The classification images were then generated based on master classes using the classification tool. Second, after the classification images were generated, the classification images of December 29, 2019 and January 28, 2020 were used to generate the pre- and post-eruption land cover change image using SCP-Plugin. This image can be used to showcase the scale of the destruction of nearby vegetation due to the volcanic eruption. Red was assigned to the parts that were classified as vegetation in 2019, but was classified as volcanic outputs after the eruption; yellow was assigned to parts that were built-up areas pre-eruption, but were classified as volcanic outputs post-eruption; black was assigned to other parts. It means that vegetation covered by volcanic outputs was shown in red, while built-ups covered by volcanic outputs were shown in yellow. The other land cover change image was created using the classification outputs of the satellite data taken on January 28, 2020 and September 24, 2020. This specific image can be used to demonstrate the vegetation cover that has
recovered approximately nine months since the eruption. Green was assigned to parts that were classified as volcanic outputs in the January image, but was classified as vegetation in the September image; purple was assigned to locations that were classified as volcanic outputs in the January image, but was classified as built-up nine months after. To sum, the green parts on the image are the restored vegetation, whereas the purple parts are the restored built-ups.

4. Results

4.1. RGB Band Composite

The resulting red and grey images showcase the differences in vegetation density of the four dates. In these four images, some seem to have a generally lighter color, while some are darker. In the pre-eruption image taken in December 2019, almost all land areas are red. After the eruption in January 2020, however, the whole volcano island, as well as nearby land, especially to the north of the volcano, turned grey. The images taken in April and September 2020 illustrate that the areas outside of the volcano island have turned red again, but the volcano island area remains grey nine months after the eruption (Fig. 2).

![RGB Band Composite Images](image)

Fig. 2 RGB band composite images of Taal volcano and areas surrounding Taal volcano generated using QGIS taken at (upper left) December 29, 2019; (upper right) January 28, 2020; (lower left) April 7, 2020; and (lower right) September 24, 2020. The color red indicates plant cover, the white parts are cloud cover, the grey areas are neither vegetation nor cloud.

4.2. Land Cover Change Monitoring

The land cover change images show the changes in vegetation and built-ups due to the eruption and the recovery of vegetation and built-ups 9 months after the eruption. In the image of the land cover change generated through comparing the data taken on December 2019 and January 2020, approximately the entire volcano island is displayed in red, with some yellow parts. On the nearby land areas outside of the volcano island, there are also large areas of red and yellow, with yellow concentrated on the north and west side. In the image of the land cover change generated through comparing the data taken on January and September 2020, most of the areas that are displayed in red and yellow in the last image are shown in green, except for the volcano island, where there are only small patches of green. The color
purple is seen dotted throughout the image, especially on the volcano island and to the north of the volcano island (Fig. 3).

Fig. 3 The land cover change image generated using QGIS. (left) The land cover change between December 29, 2019, and January 28, 2020. The former vegetation areas covered in volcanic outputs after the eruption are highlighted in red, while former built-up areas covered in volcanic outputs after the eruption are highlighted in yellow; (right) The land cover change between January 28 and September 24, 2020. The plant cover areas recovered from the volcanic output are highlighted in green, while the built-ups restored from the volcanic output are highlighted in purple

5. Discussion

5.1. Evolution of Taal volcanic eruption

The whole process of the eruption from 2019 to 2020 was summarized chronically combining data from this study (Fig. 2) and previous researches.

The signal of the eruption can trace back to more than nine months ago. On March 28th, 2019, elevated seismicity was detected together with slight inflation and increased CO$_2$ flux. Later, at the first of December 2019, a series of seismic swarms took place. On the 12th of January, the day the eruption actually took place, seismic swarms occurred at 3:00 UTC time. Two hours later, a phreatic explosion occurred at around 100 meters deep. At 6:30 UTC time, a phreatic eruption took place. Shortly after, a phreatomagmatic eruption happened, causing the alert level to rise from level 1 to level 2. Precautionary evacuation has been issued. Another one and a half hours later, the alert level increased from 2, which is increasing unrest, to magmatic unrest, and evacuation of high-risk barangays and towns was conducted due to phreatomagmatic eruption together with 1 km eruption plume and volcanic tremors with earthquakes and ashfall. At 9:30 UTC time, eruptive activity intensified, and roughly 10-15 km tephra column was produced with volcanic lightning and wet ashfall. Two hours later, the alert level was intensified to level 4, which is a hazardous eruption imminent. As a result, a total evacuation of the volcano island and areas within the 14-km radius from the main crater was implemented, and civil authorities were advised to avoid the airspace around Taal due to more phreatomagmatic eruption and two volcanic earthquakes around a magnitude of 3. At exactly 18:49 UTC time, lava finally fountained and activity waned then resumed immediately as evidenced by lava fountaining and hydrovolcanic activities. Not until two weeks later, on the 26th of January, the alert level was lowered from level 4 to level 3 due to decreased tendency toward magmatic eruption. Furthermore, on the 14th of February, the
alert level was decreased to level 2 which is decreased unrest, and finally on the 19th of March alert level declined to level 1, or abnormal [3].

5.2. Origin of volcanic eruption

The Earth’s Plate movement has three main types-divergent, convergent and transform. Volcanic activities are mainly caused by subduction from convergent plates (Fig. 4).

![Fig. 4 A schematic diagram of a convergent plate boundary, where the oceanic plate sinks under the continental plate as they approach each other [4]](image)

Taal Volcano is located at the southwestern end of a convergence boundary between the Eurasian and Philippine tectonic plates, so there are frequent earthquakes and volcanic eruptions. During the volcanic eruption process, the most dominative driving force is the movement of magma. Magma in the mantle can be stored at magma reservoirs formed at shallower zones through accumulation in the form of dike risen and melt-pocket injections before erupting.

The initial gas content and melt and magma viscosity become decisive factors of the explosive eruption when the magma reservoirs approach the land surface. When the plates move creates some turbulence, the turbulence can cause decompression. Then, magma will be rising rapidly and pressurization in the shallow reservoir. These steps lead to the volcanic eruption [3].

For the 2020 eruption of the Taal volcano, the magma reservoir at a depth of around 5 to 6 km turned to an unstable state and ruptured as a result of the continued injection of magma into the shallow reservoir in a relatively short period of time. This zone of Taal has a history of frequent seismic volcanic activities. The pressure imbalance of shallow reservoirs due to diffuse degassing for a long period led to the abrupt magma injection in 2019. This was illustrated by long-term deflation and short-term inflation detected using InSAR, as well as the drop in CO₂ flux in the period from 2015 to 2017, followed by a rapid increase from 700 T per day to 2400 T per day from February 2019 to the day of the eruption [3].

Before the eruption, volcanic magma and magmatic gases have flowed from the shallow magma reservoir to the hydrothermal system. Then, the hydrothermal system might have been heated, sealed, pressurized, and filled by magmatic gases and volcanic magma, either as small flows or interactions from a large dike, paving the way for the explosive eruption of Taal.

5.3. Influence factors

5.3.1. Atmospheric Parameters

Volcanic gases and ash particles are one of the main products after the volcanic eruption, and it is a significant factor to influence the atmosphere around that area in January 2020.

(1) Volcanic ash

The eruption exploded volcanic ash upward to above fifteen kilometers. The volcanic plume’s influence extended to cities as far as 70 kilometers away from the volcano island. Volcanic aerosols have been observed to increase after the eruption. According to measurements taken at the Manila AERONET
station, the concentration of fine particles reached a maximum amount on January 16 and 19, 2020, a few days after the eruption. High aerosol optical depth (AOD) and angstrom exponent (AE) were detected on 29 January 2020, both indicating a high concentration of particles in the atmosphere. These changes can be attributed to volcanic ash emission because the measurements increased after the eruption in comparison to other days.

A large amount of volcanic ash was dispersed by winds in a different direction. The north-east wind at 500 meters altitude and the south-to-south-westerly wind at 5000 and 10,000 meters bring the volcanic ash towards different directions [6].

(2) Volcanic gases

Apart from volcanic ash, volcanic gases, including SO$_2$, Ozone and CO, have shown to impact the air quality surrounding the region after the eruption according to satellite images. The gas output at higher altitudes was dispersed and greatly impacted the northeast oceanic area in the Philippines. On 14 January 2020, volcanic gases were transported to the southern Philippines at a 10-degree latitude.

The explosive eruption has emitted a large amount of SO$_2$ into the atmosphere. On 13 January, the highest total vertical column of SO$_2$ and the strongest SO$_2$ emission have been observed around the Taal volcano. On the following day, SO$_2$ was transferred to the southwest of the volcano and spread to the ocean, becoming less intense along the way. Lower emission of SO$_2$ is apparent after the eruption ended two days after the eruption started. The attribution of SO$_2$ increase to volcanic eruption is further confirmed by comparing the pre- and post-eruption data as well as the measurements on those days in the past years. Specifically, in one of the measurement boxes which monitored the surrounding areas of the Taal volcano, the average OMI SO$_2$ is 0.27 Dobson Unit (DU), while on January 14, 2020, two days after the Taal eruption, the OMI SO$_2$ rose dramatically to 1.39 DU. Around the same time in 2018 and 2019, both of the measurements have been averaged 0.12 DU, which is significantly lower than the statistics after the 2020 Taal eruption [6] (Fig. 5). These statistics demonstrate the intense emission of SO$_2$ as a result of the volcanic eruption.

![Fig. 5 Changes of OMI SO$_2$ measured around Taal volcano over time. The black arrow indicates the start time of the volcanic eruption on January 12, 2020 [6]](image)

The variation in ozone concentration largely corresponds to the changes in SO$_2$ concentration due to the eruption. The SO$_2$ emitted by the eruption, when reacting with chlorine distributed throughout the atmosphere, created ozone-depleting chemicals. This reaction is responsible for the drop in the total column zone (TCO) right after the eruption. However, TCO then went on to show a trend in which the concentration increases despite the strong variability, which roughly matched the emission of SO$_2$ from the Taal volcano [6] (Fig. 6).
Fig. 6 Changes in TCO and SO$_2$ measured in January 2020. The black arrow indicates the start time of the volcanic eruption on January 12, 2020 [6].

The explosive volcanic eruption event also emitted a large amount of CO into the atmosphere. The increase is shown through satellite imaging, Sentinel-5P TROPOMI CO data to be more specific. Following the eruption from 13 to 17 January, a significant rise in CO mole fraction is detected at pressure levels 500 to 1000 hPa. It is apparent in the graph that CO concentration increased after January 12, 2020, when the eruption occurred [6] (Fig. 7).

Fig. 7 CO mole fraction measured at different dates in January 2020 [6].

Water vapor is another component of volcanic output injected into the atmosphere. On 12 and 13 January, the water vapor mixing ratio and relative humidity demonstrated a clear rise at pressure levels from 200 to 400 hPa, in the upper troposphere, in comparison to surrounding days. On January 13, 2020, at 850 to 1000 hPa, as a result of continued eruption at Taal volcano, both relative humidity and water vapor increased pronouncedly relative to the previous day, when the eruption initiated. It is also worth mentioning that water vapor could potentially cause ozone decrease, which could partly account for the decrease in ozone concentration immediately after the eruption [6].

5.3.2. Vegetation

The explosive eruption of the Taal volcano in 2020 exerted a great impact on the vegetation of nearby regions. The volcanic ash and lava outpour destroyed the plant cover on the surface of the volcano island, and the volcanic ash covered large areas of land outside of the volcano island.
RGB band composite images can be used to demonstrate the impact of the volcanic eruption on vegetation. The four images display different shades of red and grey. This variation is most likely caused by the different amount of light reaching the ground due to the different cloud covers, therefore this study ignores the varying shades of red within each image, and instead focus on the areas in the images that display the color red and grey, which would indicate vegetation cover and non-vegetation cover, respectively. As shown in the figure, the vegetation on the volcano island almost nine months after the eruption, taken in September 2020, remained scarce. The plant cover outside of the volcano island, on the other hand, recovered fairly quickly. The lava outpour was stopped by the lake around the volcano island. only volcanic ash was able to expand its influence outside of the volcano island. Due to various nutritious components of the tephra, including elements such as sulfur and carbon, volcanic ash is, in fact, efficient fertilizer. As a consequence, the large amount of volcanic ash covers potentially aided the recovery of plants outside of the volcano island. As the RGB band composite suggests, the vegetation in regions outside of the volcano island, especially to the north of the island, were detected to be covered by volcanic ash on January 28, 2020, 16 days after the eruption. On April 7, it is apparent that most of the damages have been recovered for the vegetation cover outside of the volcano island. The volcanic eruption is shown to have a limited impact on vegetation outside of the volcano island (Fig. 2).

The land cover change images were used to further confirm the changes in vegetation near the Taal volcano due to the eruption. Although the classification of different land covers was somewhat interfered with by the cloud cover, the images still largely correspond to the changes demonstrated through comparing the RGB band composite images. The red parts in the figure on the left show the damage the eruption exerts on the nearby vegetation, specifically wiping out all the vegetation on the volcano island. The yellow parts demonstrate how the volcanic output has covered the nearby built-ups. The figure on the right highlights the recovery of vegetation and built-ups. The purple parts indicate the restored built-ups, and the green parts indicate the restored vegetation. Most of the areas in the image on the left that has been marked as damaged vegetation has recovered, except for the volcano island, and the built-ups have largely been rebuilt as well (Fig. 3).

5.3.3. Water Body
Significant deposition of volcanic ash resulted in a decrease in ocean salinity at depth 0-20 meters after January 14, 2020, in one of the stations near Taal volcano that is in the way of aerosols displacement.

The volcanic eruption has decreased the PH of Taal lake, due to the output of volcanic gas. Taal volcano is located in the middle of Lake Taal. From February 2019, the CO₂ flux was rising up from background values of 700t per day to over 1000t per day by the end of March. In mid-August 2019, the flux values increased to the peak of 2000t/day. When the Taal volcano erupted, the flux of CO₂ rose to more than 2400t per day. The CO₂ dissolved in the water of Lake Taal and formed the acidic H₂CO₃. Consequently, the PH of Taal lake dramatically decreased.

Ocean temperature has also shown variation that can be attributed to the volcanic eruption. In deeper water, as detected by one of the Argo stations, the temperature has shown a gradual increase up until the end of January. While in shallower water, on January 13 and 14, one to two days after the eruption, a drop in temperature is observed. In the following days, the temperature started to rise gradually. For the station that is in the way of volcanic aerosols transportation, the temperature is most obviously impacted due to particle deposition in the ocean. In general, a decrease in water temperature a few days after the eruption is most likely due to volcanic ash deposition, as tephra spread to cover the surface of the ocean[6] (Fig. 8).
The explosive eruption exerted an impact on the ocean’s surface latent heat flux (SLHF), an indicator of the energy, in this specific case heat, transferring between the atmosphere and ocean. Particularly, the eruption is shown to increase the SLHF over the ocean near the Taal volcano. Following the eruption, according to satellite images acquired from National Centers for Environmental Prediction/National Center for Atmospheric Research, SLHF is shown to rise between January 12 and 14, 2020, with its peak appearing at January 13, 2020. The change in SLHF is more pronounced for regions of the ocean which is in the path of volcanic ash. The variation in SLHF stopped on January 15, recovering from the effect of volcanic ash [6].

5.3.4. El Nino
The volcanic eruption would likely lead to an El Nino in the following winter. Aerosols emitted by the volcano scatter and block sunlight from reaching the Earth’s surface, and absorb terrestrial radiation. A group of researchers points out that if Taal volcano’s activities were more violent, El Nino could have occurred during the 2020-2021 winter and caused a change in the global climate. As the volcanic ash and sulfur dioxide gas released into the atmosphere by the eruption was blocking the solar radiation, the temperature at Earth’s surface is decreased. However, warming might also occur when the temperature starts to rebound. Researchers were able to predict the effect of volcanic eruptions on climate through computer simulations. Researchers inputted data from volcanic eruptions around the globe over the past 1,100 years into climate models, which indicates that there is an 83% chance of an El Nino warming incident if the Taal eruption gets more severe. All the past massive tropical volcanic eruptions, except for the one in 1883, also suggest that El Nino could occur during the first winter after the eruption. A weak La Nina is observed in winter 2020-2021 [7].

6. Conclusion
This study analyzed the evolution, contributing factors and impacts of the Taal volcano’s eruption in 2020.

Generally, the evolution of the eruption of the Taal volcano in 2020 was a long-term process that exerted profound effects on the surrounding areas. It all started with slight inflation and increased CO2 flux in March 2019. Later, a series of seismic swarms took place. Then, the actual eruption occurred on the 12th of January with a phreatic explosion 100m deep. Finally, 2 months later, the alert level decreased to level 1 and most volcanic activities ceased.

The fundamental reason for the eruption is the fact that Taal Volcano is located in the convergent area between the Eurasian Plate and the Philippine Sea plate. It is formed by the subduction of the Philippine
Sea plate underneath the Eurasian Plate. This eruption in 2020 was due to the shallow reservoir injecting new magma by active crustal plates’ activities in a short time which led to pressurization.

The eruption emitted volcanic ash (tephra) which exerted impacts on the atmosphere, water body, vegetation, and El Nino. (1) A high concentration of particles was observed in the atmosphere after the eruption. The ash output was dispersed by wind at different altitudes. The eruption also emitted gases. The eruption accounts for the sharp increase in SO$_2$. The ozone measurement showed strong variability after the eruption, which matched with the changes in SO$_2$ content in the same area. CO was also a product of the volcanic eruption. (2) Water in the gas phase was injected into the atmosphere due to the eruption. Following the eruption, the water vapor mixing ratio and relative humidity experienced a sharp rise. (3) The volcanic eruption impacted the nearby vegetation. The volcanic output had a detrimental long-term effect on the plant cover on the volcano island, whereas the vegetation outside of the volcano island surrounding the Lake Taal, though covered in tephra immediately after the eruption, recovered fairly quickly. The volcanic aerosols had led to a decrease in ocean salinity in shallow water. The volcanic gas caused a drop in Taal lake’s PH. Specifically, the CO$_2$ content in the volcanic gas dissolved in water and formed acidic substances. The Ocean temperature saw variations after the eruption. The temperature changes were most likely due to tephra deposition. Ocean’s surface latent heat flux was increased around the volcano following the eruption, which could also be attributed to the tephra emitted. (4) An El Nino was predicted to occur if the eruption got more intense.

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