Volcanoes

GLOBE		*Related SDGs:*	*Type of activity*
Sphere	**Protocols**		
Atmosphere	Wind direction and speed. Aerosols. Rainfall. Relative humidity	13 (Climate action) 15 (Life on land)	Exploratory
Biosphere	Land cover. Biometrics. Phenology		
Pedosphere	Soil characterization. Fertility. Humidity. pH. Temperature		
Package	Soil Agriculture Air Quality Soils		

Overview

Satellite images and maps are analyzed to understand volcanic activity's negative and positive impacts, especially the effect of increased soil fertility. Students analyze cases of different volcanic eruptions in Latin America and the Caribbean. Extensions of activity are suggested by making field measurements to complement satellite information.

Time

3 or 4 classes

Prerequisites

Basic knowledge of volcanoes, location of volcanoes, types of eruptions. ICT management. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

Final years of elementary, secondary, and university students

Purpose

Understand the negative impacts of volcanic eruptions and the long-term positive effects on increasing soil fertility and developing commercially essential crops.

Student Outcomes

- Identify the significant impacts of volcanic eruptions in nearby areas and at great distances.
- Know the changes caused by volcanic ash deposits in soils.

- Analyze the predominant soil type around volcanoes and changes in natural vegetation and crops following weathering of volcanic ash.

Introduction

Volcanoes are openings in the surface crust of a planet or moon where lava or other materials that are hotter than their surroundings (ash, rocks) come out, causing an eruption. In addition to the numerous volcanoes on Earth, volcanoes have been found on other planets (e.g., Mars has the largest volcano in the solar system, called Olympus Mons, almost three times higher than Mount Everest) and also on moons (e.g., Mars has the largest volcano in the solar system, called Olympus Mons, nearly three times higher than Mount Everest) and also on moons (e.g., Mars has the largest volcano in the solar system, called Olympus Mons, almost three times higher than Mount Everest) and also on moons (e.g., On Io, one of Jupiter's moons, volcanic eruptions have been detected)

According to the Global Volcanism Program, there are currently approximately 1,350 active volcanoes in the world, and about 500 erupted in the last , years. Volcanoes that have shown activity in the last 10,000 years are considered active. The Smithsonian Institution's map of active volcanoes shows that most are in the Pacific Ring of Fire and associated with seismic zones. Most of these volcanoes are located in Latin America and the Caribbean.

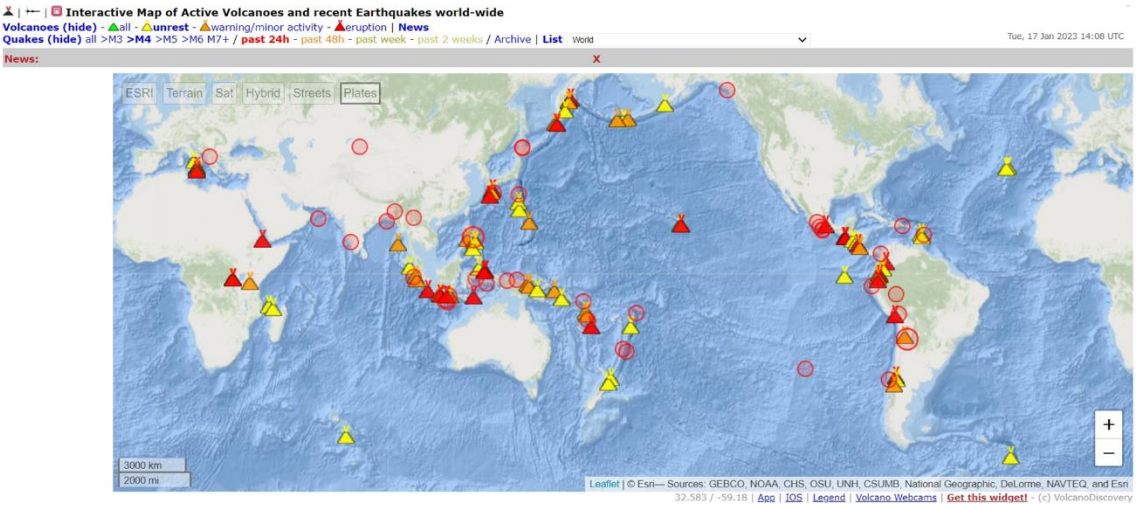

Fig. 1. Location of active volcanoes and recent earthquakes.
https://earthquakes.volcanodiscovery.com/

It is now possible to monitor volcanic and seismic activity in near real-time worldwide (Fig. 1). Volcanic activity is highly variable. The Smithsonian Institution reported that 54 volcanoes erupted in 2022 and 75 in 2021. Some volcanoes have near-permanent activity, while others erupt after prolonged periods of inactivity. For example, in the case of the Chaitén volcano, it is estimated that the last eruption would have occurred 9,000 years ago before erupting in 2008. Latin America and the Caribbean are home to some of the world's most active Volcanoes. (See map). This variability makes it challenging to investigate, especially when no volcano exists, as happened in Mexico when the Paricutín volcano was formed in 1943. This event was surprising; a fissure appeared in the ground in the middle of a corn plantation (according to the accounts of villagers, the owner of the field noticed an area where the corn dried, the soil had a higher temperature and heard a sound coming from the ground that looked like a stream of water). From the fissure in the field, volcanic material began to emerge for nine years and 11 months,

forming a cone 240 meters high and a lava field of 25 km2 that buried the cities of Paricutín and San Juan Parangaricutiro. Table 1 shows more examples, with satellite images, of some of the latest volcanic eruptions in Latin America and the Caribbean.

Volcanoes are formed (Fig. 2) when tectonic plates separate (at divergent edges), as occurs on the seafloor. Magma rises and rises, filling space and forming submarine volcanoes. Also, when tectonic plates move over each other, forcing one to penetrate the interior (convergent plate edges), pressure, friction, and heat melt the crust and can form volcanoes. For example, the Nazca plate in the Pacific Ocean, which enters below the South American plate, has formed numerous volcanoes in the Andes Mountains. Other volcanoes form far from the edges of plates in volcanic hot spots resulting from magma plumes rising to the surface, as underwater volcanoes can form islands. For example, the Galapagos Islands.

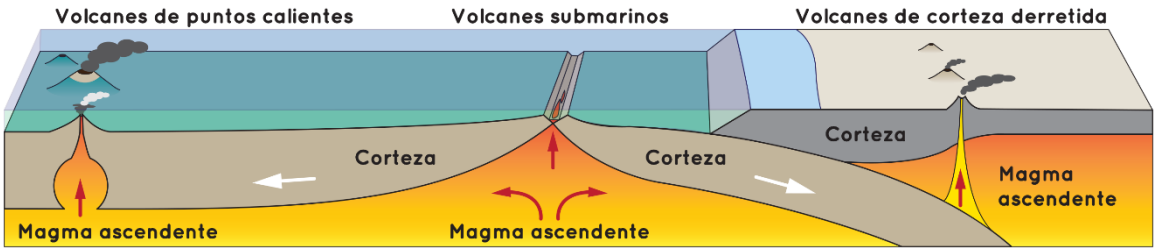

Fig. 2. Formation of volcanoes on the earth's surface: a) Hot spot volcanoes, b) Submarine volcanoes, and c) Melted crust volcanoes. Source: https://spaceplace.nasa.gov/volcanoes2/sp/

Volcanic eruptions are shocking natural phenomena. During eruptions, lava flows, pyroclastic flows, and lahars are released, posing a risk to nearby people. Large explosive eruptions can cause long-term effects by filling the atmosphere with volcanic ash and gases, disrupting air transport. E.g., the 2011 eruption of the Puyehue Cordón Caulle Volcanic Complex released a large amount of ash, which was dispersed by the wind (See Table 1). Ash from the Calbuco volcano reached Uruguay, Brazil, and Australia. To alert the population and reduce risks, earthquakes generated in volcanoes are monitored, webcams are used (to monitor the volcano on the ground), satellite images (to study the deformation or release of volcanic material), and other technologies.

But volcanic eruptions also bring benefits, from creating new land areas on coasts to entire islands in the middle of the oceans. Andisols are soils derived from volcanic ash, pumice, or other volcanic material. According to the Soil atlas of Latin America and the Caribbean, this soil type is widely distributed in the region, particularly in the Andean area. These soils are very productive for coffee cultivation. Another property of volcanic ash is that chemical weathering absorbs carbon dioxide from the atmosphere and incorporates it into the ground. For this reason, several scientists recommend using volcanic ash in crop areas to store more carbon in soils and mitigate the climate crisis. However, they warn that more research is required to optimize the process. Weathering of volcanic ash releases nutrients that have positive effects on plant growth. Volcanic ash also retains moisture in the soil. Positive impacts of volcanic ash have been documented in many cases: a) after the eruption of the Puyehue Cordón Caulle Volcano in 2011, scientists found that *Nothofagus plumillo* trees located near the volcano had significantly higher than average growth because the ash layers increased water retention in the soil, The ash facilitated the plants' access to nutrients and reduced the attack of herbivores. (b) after the eruption of the Hudson volcano in 1991, in the long term, the soil in the orchard and cherry production area that had received volcanic ash increased its fertility (chemical and physical changes were recorded), especially in those

using irrigation. Knowing the type of soil in your environment, if you have had volcanic ash deposits in the past, the type of use of that soil, if it is soil with tillage for crops, the variation in the number of nutrients and humidity throughout the year, the pH, is important for proper management.

Guiding Research Questions

- Has my locality received volcanic ash in the past? When? What volcano did they come from?
- How do aerosols and ash produced by volcanoes influence natural ecosystems, crops, and human activities?
- How are ash and aerosols dispersed? Why does the direction of ash rain change on different days?
- How far is my town from the nearest volcanoes? If any of them erupt, could the winds deposit the volcanic ash in my locality? What wind direction prevails in my locality?
- What factors affect plant growth in my locality? Is the soil of volcanic origin? Do you have volcanic ash deposits?
- Why is coffee grown very close to volcanoes?
- What crops are important in my area? Does it have any relation to volcanic activity?

Scientific Concepts

- Ecosystems: Tropical, subtropical, and temperate forests
- Land cover
- Soils
- Carbon cycle
- Satellite images

Scientific concepts

1. ArcGIS StoryMaps https://storymaps.arcgis.com/
2. Satellite information data from some recent volcanic eruptions:

Table 1. Recent eruptions in Latin America and the Caribbean

Volcanoes	Eruptions
Chaitén Volcano Chile	*Eruption 2 May 2008* Satellite images: 03/05/08 – 05/05/08 - 06/05/08 – 26/05/08 (city of Chaitén) – 26/05/08 - 28/05/08 – 31/05/08 – 31/05/08 (caldera) – 18/06/08 - 01/07/08 – 07/09/09 - 03/03/10 (Lava dome) – 18/01/22 Ashes: 02 y 03/05/08 Aerosols and gases: 03/05/08

Llaima Volcano Chile	*Eruption 4 April 2009* Satellite images: 04/04/09 – 08/04/09 – 16/04/09 - 15/01/23
Puyehue-Cordón Caulle volcanic complex Chile	*Eruption June 4, 2011* Satellite images: 04/06/11 – 06/06/11 – 04-06/06/11 – 11/06/11 – 13/06/11 - 13/06/11 (ash in Australia and New Zealand) – 14/06/11 – 20/06/11 – 02/07/11 – 31/07/11 – 14/08/11 – 18/08/11 - 21/08/11 – 30/08/11 – 17/09/11 – 09/10/11 – 22/10/11 – 4/11/11 – 16/11/11 – 23/12/11 – 26/01/12 – 10/02 y 07/03/12 - 08/01/23 Aerosols: 05/06/11 – 5-13/06/11 (ash in Australia and New Zealand)
Calbuco Volcano Chile	*Eruption April 22, 2015* Satellite images: 23/04/15 – 03/05/15 (ash in suspension) – 24/04/15 - 08/01/23 Gases: 23-26/04/15
Villarrica Volcano Chile	*Eruption March 3, 2015* Satellite images: 05/03/15 – 18/03/15 - 13/01/23
Tungurahua Volcano Ecuador	*Eruption August 2006* Satellite images: 17/07/06 - 24/07/06 – 17/08/06 – 25/10/06 - 20/02/22 Aerosols: 17/08/06
La Cumbre Volcano Ecuador (Galápagos)	*Eruption 11 April 2009* Satellite images: 11/04/09 – 14/04/09 – 27/04/09 - 07/12/22 Gases: 14/04/09
Wolf Volcano Ecuador (Galápagos)	*Eruption May 25, 2015* Satellite images: 28/05/15 – 11/05/15 Eruption January 7, 2022 Satellite images: 07/01/22 (night and day) – 14/01/22
Montserrat Volcano Isla Monserrat	*Eruption 29 August 2006* Imágenes satelitales: 29/08/06 – 01/09/06 – 12/09/06 – 14/02/07 - 27/12/22
Colima Volcano México	*Several eruptions in February 2003 and June 2005* Satellite images: 21/05/05 – 07/06/05 – 22/01/11 – 12/01/23
Momotombo Volcano - Nicaragua	*Eruption December 2015* Satellite images: 04/12/15 - 02/03/16 - 04/12/22

Case 1. Puyehue-Cordón Caulle volcanic complex - Chile:

- Google Map - Localization
- WorldView – Comparison Eruption vs. image after several years
- NDVI and False Color during the eruption – NDVI and False color after several years.
- Current state of the volcano

- Soil atlas of Latin America and the Caribbean: Andosols near the volcano (pages 67-110 and legend page 59) and organic carbon in the soil (page 138)

Case 2. Calbuco Volcano - Chile:

- Google Map - Location
- WorldView – Comparison Eruption vs. image after several years
- NDVI and False Color during the eruption – NDVI and False color after several years.
- Current state of the volcano
- Soil atlas of Latin America and the Caribbean: Andosols near the volcano (pages 67-110 and legend page 59) and organic carbon in the soil (page 138)

Case 3. Cotopaxi Volcano - Ecuador:

- Google Map - Location
- WorldView – Comparison Eruption vs. image after several years
- NDVI and False Color during the eruption – NDVI and False color after several years.
- Current state of the volcano
- Soil atlas of Latin America and the Caribbean: Andosols near the volcano (pages 67-110 and legend page 59) and organic carbon in the soil (page 138)

Case 4. Volcán de Fuego - Guatemala:

- Google Map - Location
- WorldView – Comparison Eruption vs. image after several years
- NDVI and False Color during the eruption – NDVI and False color after several days.
- Current state of the volcano
- Soil atlas of Latin America and the Caribbean: Andosols near the volcano (pages 67-110 and legend page 59) and organic carbon in the soil (page 138)

Note: The false color highlights vegetation in red. NDVI (Normalized Difference Vegetation Index) indicates the state of health of the vegetation; it is good when the green is more intense.

What to do and how to do it

- ***Beginning***

- Show your students the location of volcanoes in Latin America and the Caribbean, the following videos: a) Volcanoes 101 b) How the Paricutín volcano buried two villages in Mexico c) Paricutín Volcano, destruction and rebirth and d) Tracking Volcanic Ash with Satellites.

  Discuss the impact of volcanoes in nearby areas and at great distances. Ask if they know of any eruptions that have caused significant impacts.

- ***Development***

1. Ask students to read the introduction to this activity, consult the links and make a concept map with the information.

2. Divide the class into groups and assign a case to each group for analysis.
    a. Look at the current satellite image on Google Maps. What do you see in that image (volcano, forest, crops, roads, cities, etc.)?
    b. Considering the concept map, what cities and economic activities would it affect if that volcano were to erupt again?
    c. Compare Worldview images during and after the eruption.
    d. After an eruption, several scientists reported that after a while, the soils have greater fertility and favor the growth of plants. One way to detect it is to measure the intensity of green with the NDVI index or red with the false color combination. Analyze this volcano if changes are observed.
    e. What is the state of this volcano today? Have alerts been issued to the population? See the monitoring report.
    f. Consult the Soil Atlas on the indicated pages and analyze the soil type around the volcano and the organic carbon stored.
3. Ask your students to give a presentation about the case under discussion. They can make a story with maps (ArcGIS StoryMaps), a slide show, or a video.
4. Gather all the groups and ask them to explain the cases analyzed.
5. Compare eruption intensity between volcanoes analyzed and impacts on soil and carbon sequestration. (In this case, consider that there are other volcanoes near the one you are analyzing, which also influence the variables analyzed)
6. Complete the concept map with the main characteristics of each case analyzed
7. If volcanoes are nearby in your locality or you are in the direction of the prevailing winds and volcanic ash could arrive, you can use the same tools to study it

- ***Closing***
- Because of the relevance of this problem, it is important to develop dissemination materials. Students can create a story with maps (Story Map), a video, or flyers to post on social networks summarizing the cases analyzed and highlighting the importance of volcanoes in soil formation and plant growth.

Frequently asked questions

Where do I find satellite images? – Worldview – Google Earth – Google Map

Where do I find information about volcanoes? Global Volcanism Program gathers all the information about volcanoes and has a map of active volcanoes. Volcano Discovery has an interactive map with a report of the latest eruptions in the world. The websites listed in the materials are also recommended.

Suggested Resources

As an extension of this activity, students can consult the list of recent eruptions in the region and satellite images of different dates and places to explore other sites of interest. Complement this analysis with the Soil Atlas and seek information on the type of crops

in the region they are analyzing. Guiding research questions can help analyze volcanic activity at other sites not covered by this activity.

You can use GLOBE Program protocols to make measurements in your environment and query program data to compare volcanic data. If your locality is far from volcanic areas, you can analyze satellite imagery and search for field measurement data in the GLOBE Program database.

Websites

- Centro de Investigación en Suelos Volcánicos CISVO https://www.cisvo.cl/
- Global Volcanism Program. Smithsonian Institution. NMNH. https://volcano.si.edu/ (Volcano Information Sources, Eruption Reports, Monitoring, etc.) - Volcano Information Sources by Country. https://volcano.si.edu/resource_infosources.cfm
- My NASA Data. Volcanic Eruptions Story Map. https://tinyurl.com/43hwsjnv
- NASA. ACDL (2023) Global Sulfur Dioxide Monitoring. https://so2.gsfc.nasa.gov/
- Volcanic Magazine https://www.jvolcanica.org/ojs/index.php/volcanica/issue/view/9
- SegemAR https://oavv.segemar.gob.ar/monitoreo-volcanico/ - Questions about volcanoes
- Seismic Monitor (global earthquake monitoring) http://ds.iris.edu/seismon/index.phtml
- Sernageomin https://rnvv.sernageomin.cl/
- The Caribbean GeoPortal https://www.caribbeangeoportal.com/
- Volcano Active Foundation https://volcanofoundation.org/es/
- Volcano discovery https://earthquakes.volcanodiscovery.com/

Videos:

- BBC News Mundo (2019) Cómo el volcán Paricutín sepultó dos pueblos en México. Youtube: https://youtu.be/-TYXiD7U_tg
- Conexión Milenio (2022) *Volcán Paricutín, destrucción y renacimiento*. Dailymotion: https://www.dailymotion.com/video/x89pokr
- IRIS Ciencias de la Tierra: Terremotos (2021) *Hotspot Volcanism: Thermal Plume*. Youtube: https://youtu.be/KHsR_hmfcp8
- IRIS Earthquake Science (2017) *Sismicidad Volcánica*. Youtube: https://youtu.be/ojPRNomTI6I
- National Geographic (2018) Explosiones Volcánicas ¿De dónde proviene toda esa fuerza destructiva? https://tinyurl.com/bdd3z3kf
- NASA SVS (2016) Tracking Volcanic Ash with Satellites. Calbuco. Youtube: https://youtu.be/Imyjh3t3c7g News: https://svs.gsfc.nasa.gov/12221

Articles

- National Geographic. (2022) *Volcanes: qué son y cómo se forman.* *https://bit.ly/3iEKNqt* - *Erupciones volcánicas* *https://tinyurl.com/5bupjw3x*
- Perfect Daily Grind (2020) *¿Por Qué se Cultiva Café Cerca de Volcanes Activos?* [En español] *Why Do Some Producers Grow Coffee Near Active Volcanoes?* [En Inglés]

Other Resources:

Tutoriales de: Worldview, Story Map, Copernicus Browser

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