Dark Skies: Volcanic Contribution to Climate Change

Unit: Little Ice Age
Lesson: 10

Materials & Preparation

Time:
- Preparation: 30 minutes
- Teaching: Two, 45-minute, class periods

Materials for the Teacher:
- Overhead projector or computer adapted projector
- Dark Skies PowerPoint presentation (or overhead transparencies)
- (optional) additional images of volcanic eruptions

Materials for the Class:
- Overhead projector or computer adapted projector
- Dark Skies PowerPoint presentation (or overhead transparencies)
- (optional) additional images of volcanic eruptions

Materials for Individual Students:
- Pencil
- Student Page: Changes in the Landscape, Changes in the atmosphere

National Science Standards
- Science as Inquiry: Content Standard A
- Earth and Space Science: Content Standard D
- Science in Personal and Social Perspectives: Content Standard F
- History and Nature of Science: Content Standard G

Colorado Science Standards
- Science: 1, 4.1c, 4.2a, 4.3b 5, 6e, 6f

Learning Goals
Students will
- Understand that climate change can result from natural events
- Understand that volcanic eruptions contribute to the chemical composition of the atmosphere
- Understand that large volcanic events impact local AND global environments and climate
- Illustrate the effects of a volcanic eruption on the appearance and composition of the atmosphere

What Students Do in this Lesson
In this activity students learn how volcanic eruptions affect t global climate. To begin, students illustrate their understanding of the effects of a volcanic eruption upon the landscape and the atmosphere. Next, students are introduced to the effects a major eruption has on the atmosphere through the use of recent and historical images. Students model the reduction in light to Earth's surface using simple tools. Students complete the activity by revising their initial drawings to summarize their learning.

Key Concepts
- Natural events can change the climate
- Debris from volcanic large eruptions collects in the atmosphere
- Debris from large volcanic eruptions is distributed globally and remains in the atmosphere for up to several years
- Volcanic debris forms a layer in the atmosphere that reduces the amount of sunlight reaching the surface of Earth
- The reduction in light reaching Earth's surface results in lower annual temperatures
- Low annual temperatures persist as long as the aerosol layer remains in the atmosphere

Advanced Preparation

- Read and review the lesson plan
- Review and practice the PowerPoint presentation
- Copy, 1 per student, Changes in the Landscape, Changes in the Atmosphere.
- Arrange drawing materials such as colored pencils and extra paper.

Introducing the Lesson

- Explain to students that in order to understand the changes in the climate of Earth, one must also understand the interactions between various natural systems.
- Explain that in this lesson, students will explore the relationship between the atmosphere and volcanoes.
- Show an image of a massive volcanic eruption. Ask students to identify the image. (Some students confused the eruption with a nuclear explosion.)
- Ask students to describe what occurs during a volcanic eruption and what materials are forced out of the volcano. Student's answers may include but are not limited to the following:
    - Rocks
    - Ash
    - Smoke
- Draw student attention to the vast amounts of ash and gas that are forced into the atmosphere. Ask students to consider where that material goes and what effects it might have upon the planet.
- Use student sharing to discuss the various predictions they made about the changes to the landscape and the distribution of volcanic material throughout the atmosphere.
- Create a list of the various changes students predict for the landscape and atmosphere over time

Facilitating the Lesson

1. Distribute and review the student page, Changes in the Landscape, Changes in the Atmosphere.
2. Ask students to draw what they think the landscape around a volcano looks like during and after an eruption
3. Explain to students that they should use their imaginations to draw what the atmosphere surrounding the Earth looks like before, during, and after an eruption.
4. Allow students to brainstorm their ideas at this stage of the lesson.
5. Circulate around the room as students work to support their efforts. If necessary, ask students to label the parts of their drawings so that the details are clear to any viewer.
6. Ask volunteers to share their drawings with the class and explain what they believe happens to the landscape and atmosphere during and following a volcanic eruption. (Alternatively, have each student tape her/his drawing to the wall and allow students to circulate around the room to view each picture as if in a museum of art.
7. Use student sharing to discuss the various predictions they made about the changes to the landscape and the distribution of volcanic material throughout the atmosphere.
8. Create a list of the various changes students predict for the landscape and atmosphere over time.

Teacher tip

Provide students with access to the chalkboard, whiteboard, poster paper, and/or the overhead when they share their drawings.

Presenting the PowerPoint (slide show)

- The PowerPoint presentation provides images, information, and anecdotes about changes in the landscape and atmosphere that can result from a massive volcanic eruption. While volcanic eruptions drastically change the local environment, the far reaching effects on the atmosphere and climate should be emphasized. The PowerPoint presentation includes images, image explanations, and questions for students.
- Facilitate the PowerPoint presentation and encourage student questions and observations.
- Following the presentation, ask students what they would change if they were to revise their original drawings on Changes in the Landscape, Changes in the Atmosphere.

Modeling the Reduction of Light

Explain to students that they will try to model the reduction of light reaching Earth following a volcanic eruption. Explain that the flashlight represents the Sun, the white surface represents the surface of the Earth, and the translucent sheet of paper represents the cloud layer produced by a volcanic eruption that blocks incoming light. Alternatively, you may want to do this as a demonstration.

- Using the overhead projector or a flashlight, project a beam of light onto a white surface.
- Using a light meter (or visual assessment) record the amount of light reaching the surface.
- Next, place a sheet of translucent (tracing paper) between the light and the surface.
- Measure or note the change in the intensity of light reaching the white surface.

Summarizing and Reflecting

Following the PowerPoint presentation, the discussion, and the activity described above, ask students to revise the drawings they made on, Changes in the Landscape, Changes in the Atmosphere.

Extensions or Homework

Create a set of images that show the sequence of events, in the Earth's atmosphere, during and after a volcanic eruption. Randomize the images and have students organize them into a correct sequence.

Science Background Information

Scientists who specialize in the study of climate (climatologists) have identified three major contributors to climate change: the solar cycle, extreme or persistent volcanic eruptions, and the release of gases into the atmosphere as byproducts of human energy consumption. In this lesson, students learn about volcanic contributions to climate change.

Volcanoes have a significant long and short term effect on the global climate and environment. Over time, they affect the chemical composition of the atmosphere. Short term effects include local devastation and a measurable decrease in the global temperature. Ash and gas produced by volcanic eruptions may spread throughout the globe in a matter of weeks. Gases rich in sulfur combine with water vapor to form sulfuric aerosols that remain in the atmosphere for up to several years following an eruption. These small droplets form a cloud layer that blocks light from the Sun, reducing the amount of energy reaching Earth. In addition, the aerosols absorb energy radiated from the surface of Earth. This process, known as "radiative forcing," persists for several years and results in surface temperatures that are cooler in the summer and warmer in the winter.

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Once aerosols enter the stratosphere, they absorb energy radiating from the Earth, causing this layer of the atmosphere to warm. A warmer stratosphere leads to changes in winter conditions across the northern hemisphere. High pressure systems that form over the North Pole send cold air and storms to lower latitudes. This weather pattern is known as the "negative phase" of the Arctic Oscillation. From the early 1900's through the 1970's the Arctic Oscillation alternated between a negative and a positive phase; the positive phase having characteristics opposite of the negative phase. However, since approximately 1970, the positive phase has dominated, leading scientists to believe that human emissions of gases have changed the natural pattern of atmospheric circulation, and thus, the weather for the northern hemisphere.

Massive volcanic eruptions capable of changing global climate occur infrequently. In order to assess the relative size of eruptions, the Volcanic Eruptive Index was developed in the early 1980's. The scale, like the Richter scale used to measure earthquakes, is logarithmic. Thus, a volcanic event that measures 3 on the scale is ten times more explosive than an event measuring 2. Single volcanic explosions that change global climate generally measure greater than 5 on the VEI scale. These explosions generate millions of tons of debris that catapulted into the upper tropopause and lower stratosphere. According to the USGS, "the record of volcanic eruptions in the past 10,000 years maintained by the Global Volcanism Program of the Smithsonian Institution shows that there have been 4 eruptions with a VEI of 7, 39 of VEI 6, and 84 of VEI 5..." More important to climate change than the ash and particulates produced by an explosion, is the amount of sulfur dioxide that is generated. Scientists have yet to determine the primary source of this sulfur. Also, each eruption releases varying amounts of sulfur depending upon the chemical composition of the magma.

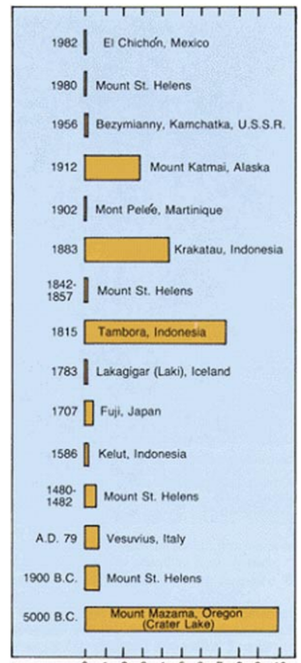
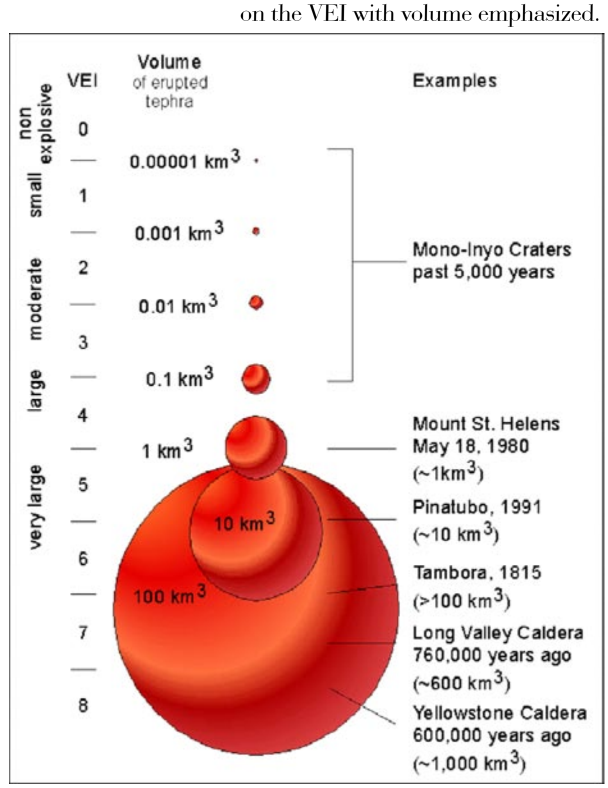


Figure 1: (above) Size of volcanic eruptions on a VEI scale of 0 to 10. Figure 2 (below) Volcanic eruptions on the VEI with volume emphasized.



The two figures below compare the relative sizes of several recent and historical eruptions. From these figures we learn that the 1980 eruption of Mt. St. Helen's was quite small in comparison to the massive eruptions of Krakatau in 1883 and Tambora in 1815. To estimate the size of historical explosions, geologists measure the depth of ash layers produced and their global distribution. Understanding and predicting the effects of eruptions helps us to anticipate changes to the atmosphere, climate change, and the effects of human energy consumption which releases similar gas byproducts into the atmosphere.

Additional Resources

- NASA Earth Observatory: http://earthobservatory.nasa.gov/
- Earth Observatory: Volcanoes & Climate Change: http://earthobservatory.nasa.gov/Study/Volcano/
- Mt. Pinatubo Eruption: http://www.gsfc.nasa.gov/gsfc/earth/pinatuboimages.htm
- Volcanoes and Climate Effects of Aerosols: http://eospso.gsfc.nasa.gov/science_plan/Ch8.pdf
- USGS Cascade Volcano Observatory: http://vulcan.wr.usgs.gov/
- National Snow and Ice Data Center, The Artic Oscillation
- http://nsidc.org/arcticmet/patterns/arctic_oscillation.html

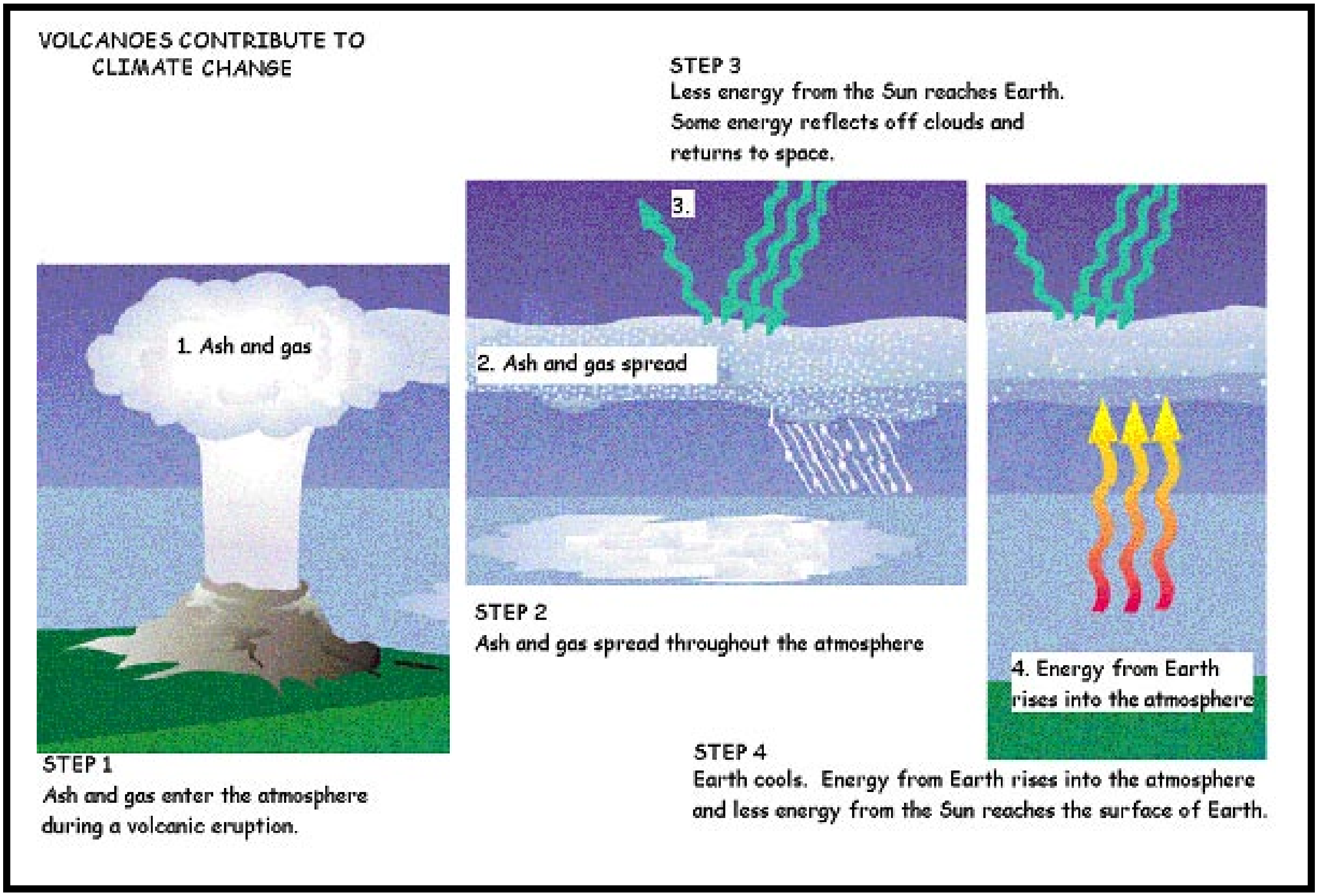


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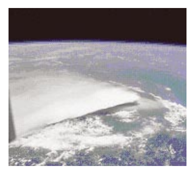
Image of the atmosphere in pristine condition taken by NASA astronauts.
Source: http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=STS41D&roll=32&frame=14

Mt. St. Helen's, WA, photographed from the International Space Station following the 1980 eruption.
Source: http://eol.jsc.nasa.gov/debrief/Iss005/topFiles/ISS005-E-18511.htm

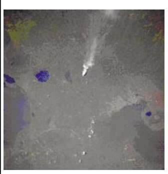
Image of the atmosphere following a volcanic eruption and the formation of an aerosol layer as photographed by NASA astronauts.
Source: http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=STS41D&roll=32&frame=14

The eruption of Mt. Etna, Sicily, as photographed from the International Space Station.
Source: http://eol.jsc.nasa.gov/debrief/Iss005/topFiles/ISS005-E-19024.htm

Photograph of a pristine atmosphere.
Source: http://eol.jsc.nasa.gov/debrief/Sts109/topFiles/STS109-345-32.htm

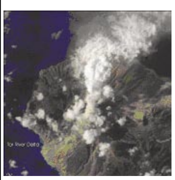


The Rabaul eruption plume, New Britain Island September 1994 photographed from the space shuttle.
Source: http://eol.jsc.nasa.gov/sseop/EFS/photoinfo.pl?PHOTO=STS064-40-10



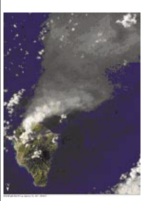
A plume of volcanic ash from the volcano, Masaya, in Nicaragua, swept by the wind.
Source: http://eol.jsc.nasa.gov/sseop/EFS/photoinfo.pl?PHOTO=STS51A-32-64

Dormant volcano Augustine in Alaska.
Source: http://vulcan.wr.usgs.gov/Volcanoes/Ecuador/images.html



Ash and steam, Soufriere Hills Volcano, Montserrat photographed from the International Space Station.
Source: http://eol.jsc.nasa.gov/debrief/Iss004/topFiles/ISS004-E-8972.htm

Dormant volcano Cotopaxi located in Ecuador with a global positioning system in the foreground.
Source: http://vulcan.wr.usgs.gov/Volcanoes/Ecuador/images.html



Ash and steam, Soufriere Hills Volcano, Montserrat as photographed from the International Space Station.
Source: http://eol.jsc.nasa.gov/debrief/Iss004/topFiles/ISS004-E-8973.htm

Geologists monitoring gas emissions on Mt. St. Helen's, Washington
Source: http://vulcan.wr.usgs.gov/Photo/Monitoring/Emissions/images.html

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Name ______________________

Date __________ Class __________

Changes in the Landscape, Changes in the Atmosphere

Draw a view of the landscape near the volcano at different times after an eruption.

Before the eruption	During the eruption	Three weeks after the eruption	One year after the eruption

Draw a view of the Earth's atmosphere, as seen from space, before, during, and after the volcanic eruption. The Earth and volcano are not to scale




Before the eruption	During the eruption	Three weeks after the eruption	One year after the eruption