Document Id: 10_30_02_1
Date Received: 2002-10-10 **Date Revised:**2002-11-27 **Date Accepted:** 2003-0109
Curriculum Topic Benchmarks: S1.4.2, S1.4.3, S2.4.6
Grade Level: High School [9-12]
Subject Keywords: volcanoes, clouds, remote sensing, satellite images, gases, aviation hazards
Rating: moderate

Volcanic Clouds and the Atmosphere

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From: The PUMAS Collection http://pumas.jpl.nasa.gov

Introduction

We frequently hear about volcanoes, eruptions, explosions, and probably think these things will never affect us, that volcanoes only exist at places far away. However, they should be a concern to everybody, since more than 50 volcanoes scattered throughout the world are active every year and their eruptions affect millions of people. Volcanic explosions produce clouds, which the atmosphere transports. This means that volcanic clouds can travel long distances and affect people that live far from their sources. Volcanoes that have been active in the last 20 years include Mount St. Helens, Washington (1980); Kilauea volcano, Hawaii (erupting since 1983); Mount Etna, Italy (2001); and Pinatubo, Philippines (1991).

Volcanic clouds contain many components, such as volcanic gases, ash, water, and aerosols. Eruptions carry large amounts of sulfur gas species, as well as other particles, and what happens to them in the atmosphere is not very well understood. In the stratosphere, sulfur dioxide gas combines with water vapor to make tiny droplets of sulfuric acid, which reflect solar radiation back to space, reducing the amount of the sun's energy that reaches the surface, and affecting global climate. Winds at the time of eruption and the volcano's latitude determine the spreading of the cloud. Examples of eruptions that have affected global climate are El Chichon in Mexico (1982; it produced global cooling ~0.3-0.5 ^oC) and Pinatubo in the Philippines (1991; global cooling ~0.6 ^oC). Such large eruptions occur about once every decade.

How do we study these phenomena?

Along with traditional monitoring techniques (using ground-based instruments and direct sampling), scientists are currently using data obtained from satellite remote sensors, which have numerous applications for volcano monitoring. Remote sensing is the detection by a satellite's sensors of electromagnetic energy that is absorbed, reflected, radiated, or scattered from the surface of a volcano or from the plume of material it produces. A variety of sensors are used to measure wavelengths of energy beyond the range of human vision, such as ultraviolet, infrared, and microwave. Examples of web sites related to remote sensing and volcanic clouds:
http://www.geo.mtu.edu/volcanoes/: Michigan Technological University's Volcanoes Page – particular links on /volcanoes/ are more relevant to this example than others (i.e. Volcanic Clouds site and Remote Sensing of Volcanoes site).
http://volcanoes.usgs.gov/About/What/Monitor/RemoteSensing/WXTRsatellites.html: Detecting eruption clouds with weather satellites and images from Mt. Spurr eruption

Activity 1: Why do we see things when using satellites?

1. Turn off the lights in the room.

2. Bang two erasers together, creating a cloud of dust.
3. Ask the students if they can see the dust (if it is dark, they will not be able to see it).
4. Shine a flashlight at the dust cloud, but not toward the students.
5. The students can see the cloud now. Why? Because some of the light is scattered off the particles and back to their eyes.
6. Leave them with a question: What takes the place of the flashlight for satellite sensors? After all, most satellites do not come equipped with searchlights that shine down on Earth.

Sunlight is scattered off of different materials, like volcanic ash, and back to the satellite. This is why satellite data images, taken at different times, can show the trajectory of volcanic clouds through the atmosphere.

Activity 2:
Look at some examples of satellite images of volcanic clouds from the Internet:

http://www.geo.mtu.edu/volcanoes/research/diss/examples/images/: Examples of AVHRR (sensor used for volcanic ash studies) images. Links for images of eruptions at Augustine volcano, Mt. Spurr, and Redoubt volcanoes (Alaska) are found on /images/Augustine, /images/spur, and /images/redoubt/, respectively.
http://www.geo.mtu.edu/volcanoes/research/diss/examples/geostationary/ruapehu.html: Ruapehu Volcano, New Zealand satellite movies

Activity 3:
How far did the cloud travel? How might an aircraft be affected?

Atmospheric scientists use computer models to forecast the position of a moving volcanic cloud for many hours into the future by using wind data at various levels.

1. Use the National Oceanic and Atmospheric Administration's (NOAA) Volcanic Ash Forecast Transport and Dispersion (VAFTAD) model to create and view the trajectory of a hypothetical volcanic cloud
2. Go to VAFTAD's web site: http://www.arl.noaa.gov/ready/vaftadmenu.html
3. Go to **Run VAFTAD** model and click on **hypothetical**
4. This page gives you a table with the names of different volcanoes and the different modes and times after eruption that you can model.
5. Choose a volcano, e.g. Augustine volcano, Alaska, with +12 & +24 hrs and look at the trajectories the clouds would follow if they erupted today.

Hazards to aviation are among the reasons that have stimulated research on the satellite detection and tracking of volcanic clouds. If an airplane flies through a volcanic cloud, its engine can suck in the ash, and under these high temperatures it will start melting and adhering to the engine. The aircraft might even ingest small rock projectiles, if close to the volcano. There have been more the 80 incidents of jet aircraft encountering volcanic clouds in the last two decades, some of which resulted in the in-flight loss of engine power. Satellite images provide critical information needed to keep commercial aircraft from entering an eruption cloud downwind from the volcano.

http://www.geo.mtu.edu/department/classes/ge404/gcmayber/: Volcanic Ash Clouds and Aircraft Safety. Links on this site lead to information about aviation safety and descriptions of historic incidents.
http://volcanoes.usgs.gov/About/What/Monitor/RemoteSensing/RemoteSensing.html: Composite satellite image showing the movement of an eruption cloud from Mt. Spurr volcano, Alaska, through time (September 16, 1992). The cloud disrupted air traffic in Canada and the US, as long as 5 days after the eruption.