Volcanology: multidisciplinary science for a versatile campus

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Volcanology at Michigan Tech (1970 – present)

Bill Rose
Volcanology, remote sensing

Gregg Bluth
Ash/gas interaction

John Gierke
Palaeomag.

Jimmy Diehl

Matt Watson
Remote sensing

Jeremy Shannon

Greg Waite
Seismology

Chad Deering
Petrology

Shiliang Wu
Atmos. chemistry

Thomas Oommen
Slope stability

Alex Kostinski & Raymond Shaw
Cloud physics
Volcanism and Keweenaw copper

Greenstone lava flow
~1 Billion years old

Native copper
J. Jaszczak

Chalcocite ($\text{Cu}_2\text{S}$)
Wikipedia

Where did the sulfur go?
Satellites detect smelter SO$_2$ emissions in Peru

- Peruvian smelters were among the world’s largest industrial sources of SO$_2$ in 2005-2010
- Signature of ‘Anthropocene’

[Image of map showing smelters and SO$_2$ emissions]

Average OMI SO$_2$ vertical column Sep 2004 - June 2005

[Carn et al., GRL 2007]
Consequences of natural hazards

Adapted from Plag et al. (2015)

- Greenstone flow
- Global climate change (gas emissions)
- Anthropogenic climate change
- Volcanoes
- St Helens, Vesuvius
- Mass extinction
- Global catastrophe
- Floods and droughts
- Tsunamis
- Earthquakes
- Large igneous provinces

log(damage, fatalities) vs. Probability of occurrence (percent/year)
Volcanoes: Earth’s recyclers

Adapted from: Hoshyaripour, EOS, (2017)

Aviation impacts

Radiative effects

SO$_2$ → H$_2$SO$_4$ gas → aerosol

Ozone depletion

H$_2$O
CO$_2$
SO$_2$
Ash

Transport

Physiochemical processing

Semi-direct and indirect effect

Ash surface releases nutrients (e.g., Fe, Si) and toxic elements (e.g., F) upon deposition.

Biosphere

Magma

Lithosphere

Hydrosphere

Subduction

Ash surface is generated through syn-eruptive processes.

Ash surface provides catalysts (e.g., transition metals) for chemical reactions.

Deposition

Ash surface is altered through post-eruptive processes in the eruption plume/cloud.
The view from space

Sarychev Peak (Kurile Is, Russia)

June 12, 2009

International Space Station (NASA)

Satellites detect volcanic heat, gas & ash emissions, and ground deformation.
Aura (2004-)

OMI - SO₂, NO₂, BrO
TES - SO₂
MLS - strat. SO₂, HCl

CloudSat (2006-)

CPR (radar) – precipitation, hydrometeors

Aqua (2002-)

MODIS - SO₂, ash, sulfate
AIRS - UTLS SO₂, ash

Volcanic CO₂?

The A-Train

CALIPSO (2006-)

CALIOP (LiDAR) - cloud altitude, aerosol phase
Some misconceptions about volcanic activity

- Every explosive volcanic eruption leads to cooling of climate
  - Not enough SO$_2$, most of the time
  - But volcanic cooling can be significant
- Volcanic emissions of SO$_2$ (a greenhouse gas) are causing climate change
  - Issues: lifetime of SO$_2$, magnitude of emissions
- Volcanic emissions of CO$_2$ are causing global warming
  - Issues: what is the magnitude of volcanic CO$_2$ emissions relative to anthropogenic emissions?
- Solutions
  - Education, publications, public outreach (e.g. Smithsonian Institution; http://volcano.si.edu/E3/)
  - Social media (Twitter etc.)
Volcanic SO$_2$ emissions (since 1978) – all eruptions

Carn et al., JVGR [2016]

~700 eruptions; 100 Tg total SO$_2$

SO$_2$ Emissions by Volcanic Eruptions

Contact: S.A. Carn, Michigan Tech (scarn@mtu.edu)
Volcanic SO$_2$ emissions (since 1978) – tropics

~577 eruptions; 78 Tg total SO$_2$

SO$_2$ Emissions by Volcanic Eruptions

Contact: S.A. Carn, Michigan Tech (scarn@mtu.edu)
Volcanic \( \text{SO}_2 \) emissions (since 1978) – stratosphere

~33 eruptions; 37 Tg total \( \text{SO}_2 \)

SO\(_2\) Emissions by Volcanic Eruptions

Contact: S.A. Carn, Michigan Tech (scarn@mtu.edu)
1816 – the ‘Year Without a Summer’

‘The snow was 18 inches deep in Cabot, Vt., on June 8. On June 11, a temperature of 30.5 degrees was recorded in Williamstown, Mass. Frozen birds dropped dead in the streets of Montreal. Lambs died from exposure in Vermont.’

http://www.newenglandhistoricalsociety.com/1816-year-without-summer/

- Tambora (1815): ~60 Tg SO$_2$
- Pinatubo (1991): ~17 Tg SO$_2$

[Bluth et al., 1992; Guo et al., 2004; Self et al., 2004]
Stunning footage shows a giant Russian volcano violently erupting for the first time in 250 YEARS

- The 7,103ft tall (2.2km high) Kambalny volcano is in the Kamchatka peninsula in the far east of Russia
- The colossal volcano recently became active and spewed out a 60-mile long ash plume visible from space
- Snow-topped volcano last erupted and poured out lava during the reign of Catherine the Great in the 1700s

But Nasa scientists warned that the volcano may have spewed out large amounts of sulphur dioxide (SO2), which is harmful to human lungs.

'The higher SO2 amounts downwind could be due to multiple factors, including variable emissions at the volcano (such as an initial burst), increasing altitude of the plume downwind or decreasing ash content downwind,' Simon Carn, an atmospheric scientist at Michigan Technological University, told the Earth Observatory.
Flavors of volcanic emissions

‘Eruptive’

Mt St Helens, WA (USGS)
(Sporadic)

‘Passive’

Turrialba, Costa Rica
(Continuous)
Global volcanic SO$_2$ emissions inventories

A time-averaged inventory of subaerial volcanic sulfur emissions

R.J. Andres and A.D. Kasgnoc
Institute of Northern Engineering, University of Alaska Fairbanks

[Andres & Kasgnoc, JGR, 1998]

• Climate impact of tropospheric volcanic emissions (sulfate aerosol)
• Estimation of global fluxes of other volcanic gases (e.g., CO$_2$)
• Identifying field sites for volcanic gas studies
Volcanic SO₂ emissions in Central America
Mike Huckabee claimed that a single volcanic eruption “will contribute more than 100 years of human activity” toward global warming. Humans actually pump over 100 times as much CO$_2$ into the atmosphere every year than all the world’s volcanoes combined.

http://www.factcheck.org/2015/07/huckabee-hot-air-on-volcanoes/

Fioletov et al. (2016); Carn et al. (2017)
Satellites provide consistent, long-term records

- Analysis of earthquake-triggered volcanic activity
- Only possible with global, long-term satellite data

Avouris et al. (2017)
Deep Space Climate Observatory (DSCOVR)

Earth Polychromatic Imaging Camera (EPIC)

http://epic.gsfc.nasa.gov

NASA Climate missions under threat

Feb 26, 2017

L₁ Earth-Sun Lagrange Point

OCO-3 (CO₂ mission) also targeted
‘Republican governor Bobby Jindal questioned why "something called 'volcano monitoring' " was included in the nearly $800 billion economic stimulus bill Obama signed earlier this month.’ (Feb 2009)
Submarine volcanoes: a new frontier

Bogoslof volcano (Aleutian Is, Alaska)

Images courtesy of Alaska Volcano Observatory (AVO) https://avo.alaska.edu/

- Hazardous but difficult to observe
- Submarine ROV/AUV to map subsurface topography?
‘Open-vent’ volcanoes

- Santiaguito (Guatemala): unique, aerial view of hot, exploding lava dome
- ‘Laboratory’ volcano for studying volcanic processes.

Semeru, Java (GVP)
Karymsky, Russia
Sakura-jima, Japan
Remote sensing of volcanic gas emissions

Active volcanic vents are ‘extreme’ environments analogous to some other planets – can we design new sensors and materials for such extremes?

MIDAC FTIR
Stirling-cooled MCT detector
~2-15 µm, 0.5 cm⁻¹
The challenge of data visualization

• Telling stories with data (e.g., NASA Earth Observatory)
• Computing, cognitive and learning sciences

Hazards and impacts of volcanic ash

Aviation impacts

Aviation Hazards of Volcanic Ash

- Mineral grains
- Lithics
- Volcanic glass

Grain size affects how quickly ash particles fall out of the atmosphere.

As the ash disperses, aggregation causes particles to fall out of the atmosphere more quickly.

Sharp-edged, abrasive particles can damage windshields, lowering visibility, and erode compressor blades and other metallic surfaces.

Glass can melt in the jet combustion chamber and resolidify on turbine blades, lowering engine performance.

The composition of the glass affects its melting temperature and viscosity.

Compressor erosion leads to loss of efficiency and surge margin.

Molten ash sticks to turbine surfaces, reducing surge margin.

USGS/AVO

Size, shape, composition, atmospheric processing

K. Cantner (AGI)

Volcanic ash samples

Health

Aggregation

Van Eaton et al. (2012)
• Volcanic emissions are important, and their atmospheric impact is increasing.

• Long-term satellite monitoring of volcanic activity is crucial, but some current & future NASA assets and funding are under threat.

• The multidisciplinary nature of volcano science offers several new avenues for exploration.

https://www.nap.edu/