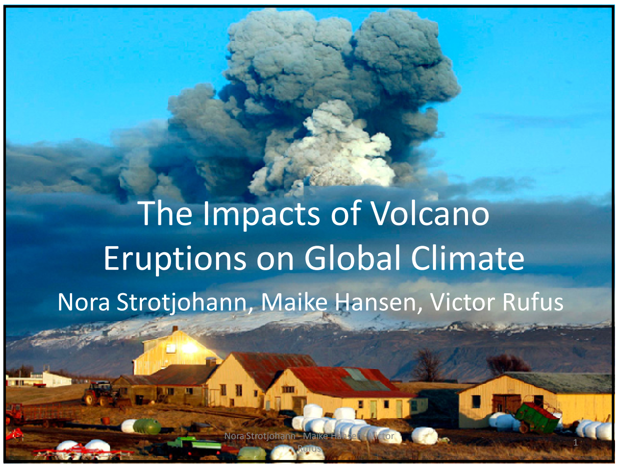

Lecture Outline

- Volcanic Eruption Emission and Ejecta
- Eruption Classifications
- Tectonic Plate Boundaries and Hotspots

- Impact on Global climate
- Effects of gas injection into atmosphere

- Supervolcanoes
- Long term global effects

Volcanic Explosive Index (VEI)

VEI = $\log_{10}$(Raised Pyroclastic Material[kg]) – 7

VEI	Description	Plume	Frequency	Examples	Occurrences in last 10,000 years*
0	effusive	< 100 m	constant	Kilauea, Piton de la Fournaise	many
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Volcanic Emissions and Ejecta

- Tephra
- Pyroclastic Flow
- Lava Flows
- Lahars
- Plume

Tephra

- Pyroclastic fragments classified by size
- **Ash** - particles smaller than 2 mm in diameter
- **Lapilli** - between 2 and 64 mm in diameter
- **Volcanic Bombs** - larger than 64 mm in diameter.

Examples of Ignimbrite Tuff

Pyroclastic Flow

- Pyroclastic Density Current (PDC)
- Superheated gaseous current
- Gravitationally driven
- Temperature < 1300K, Velocity < 700km/h
- Caused by:

i. Collapse of the eruption column or lava dome or spine
ii. Directional blast when side of volcano explodes

Lava Flows and Fountains

- Igneous rock expelled from a volcano during an eruption
- Can also be caused by increase in crustal compression stress
- Chemical composition determines viscosity and temperature
- Classified into three chemical types

i. Felsic (rich in SiO_2)
ii. Andesitic (rich in Mg and Fe)
iii. Mafic (low in SiO_2)

Mauna Ulu eruption , Kilauea Volcano, Hawaii

Lahars

- Contraction of “Belahar”, Indonesian for “Volcanic Mudflow”
- Debris flow consisting of pyroclastic material and water
- Can travel up to 100km/h and for up to 300km
- Follows the local topography for direction, mostly through river valleys
- Occur in tropical or glacial regions
- Snow and glacier melt or rainfall and typhoons contribute to the water content

Galunggung, Indonesia

Plume

- Eruption column
- Hot volcanic ash emitted by an explosive eruption
- Height < 10km, plume is washed out by rainfall
- > 10km, penetrates stratosphere with ash and volcanic gases.

Mount St. Helens, USA

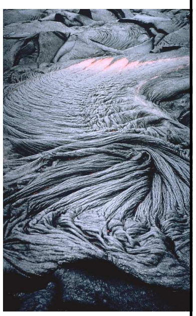
Classifications of Eruptions

	VEI
• Hawaiian	0-1
• Strombolian	1-2
• Vulcanian	2-3
• Peléan	3-4
• Plinian *	4 and above

*Includes Ultra-Plinian and Supervolcanic

Hawaiian Eruption

- VEI of 0 – 1
- Effusive eruptions of very fluid basaltic lava flows
- Plume < 1000m, comprising mostly ash
- Typical eruptions from the Hawaiian Islands Hotspot



Strombolian Eruption

- VEI of 1 – 2
- Driven by gas bubbles created by a decrease in crustal compression stress
- Gentle eruptions with Plume consisting of all types of tephra, < 3 km

Yasur Volcano, Vanuatu

Vulcanian Eruption

- VEI of 2 – 3
- More explosive than Strombolian eruption
- Tephra dispersed over wide area, ash volcanic cone and lava flows
- Plume < 10 km

Tavurvur Volcano, Near Rabaul, PNG

Peléan Eruption

- VEI 3 – 4
- Avalanches of glowing hot ash flows
- Tephra deposits less widespread than Vulcanian and Plinian eruptions
- Plume < 20 km

Mayon Volcano, Phillipines

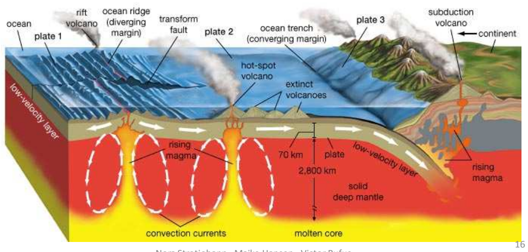
Plinian Eruption

- VEI 4 and above
- Cataclysmic explosions
- Plumes up to 45km in height and can penetrate the stratosphere
- Large amount of tephra ejected
- Felsic lava flow

Redoubt Volcano, Kenai Peninsula, Alaska, USA

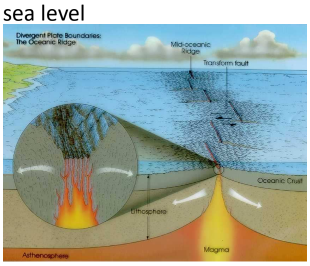
Where volcanoes systems occur?

- Divergent Plate Boundaries
- Convergent Plate Boundaries
- Hotspots



Divergent Plate Boundaries

- Volcanoes occurs predominantly within oceanic regions
- Iceland, best example of diverging oceanic plates breaching sea level

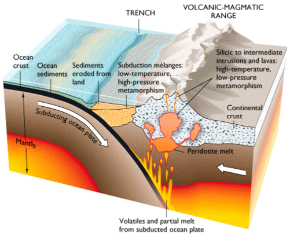


Divergent Plate Boundaries

- Eyjafjallajökull, Iceland

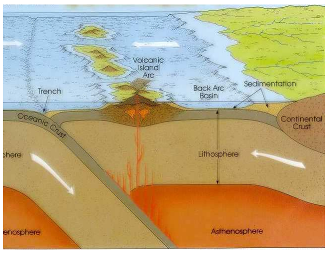
Convergent Plate Boundaries

- Oceanic – Continental Subduction Zone
- Resulting in mountain ranges and volcanoes on continental plates



Convergent Plate Boundaries

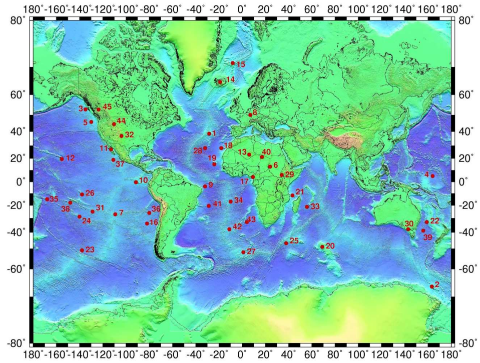
- Oceanic – Oceanic Subduction Zone
- Creates Volcanic Arcs



Convergent Plate Boundaries

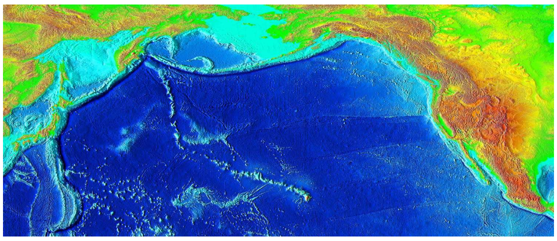
- **Mt Vesuvius** (erupted 79 AD), VEI=4 Apennines Subduction System
- **Pinatubo** (1991) VEI=6, formed by the Phillipine Mobile Belt sliding over the Eurasian Plate along the Manila Trench to the west
- **Lake Toba** (74 000 BP) VEI=8, part of the Sunda Arc, a result of the northeasterly movement of the Indo-Australian Plate which is sliding under the eastward-moving Eurasian Plate
- **Mount Tambora** (1815) VEI=7, on the island of Sumbawa, Indonesia, is flanked both to the north and south by oceanic crust. This raised Mount Tambora as high as 4,300 m (14,100 ft), formerly one of the tallest peaks in Indonesian archipelago.

Hotspots



Hotspots

- Yellowstone (640 000 BP) VEI=8
- Hawaiian Hotspot



Impact on Global Climate

Volcanic Explosion Index

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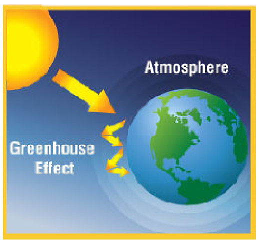
Emitted gases

- Only injection in stratosphere (8 – 18km height) has to be considered, otherwise washed out by rain
- Mainly H_2O and CO_2 (greenhouse gases)
- Sulfur → most important impact
- Chlorine and others in small amounts

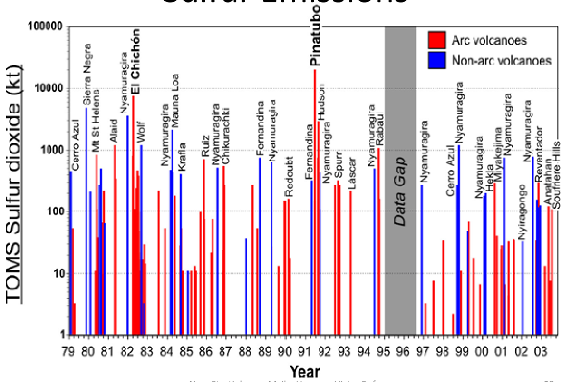
The Greenhouse Effect



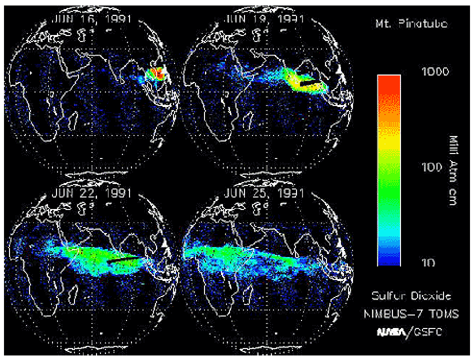
- Mainly water vapor, CO_2, methane, N_2O
- Emissions by volcanoes normally > 1% compared to human-made CO_2
- Cooling due to aerosols (sulfur) dominates

Sulfur Emissions

Sulfur Emissions



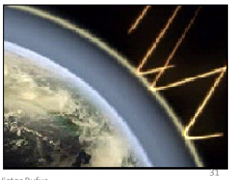
Pinatubo Aerosol Cloud



Sulfur Acid Aerosols

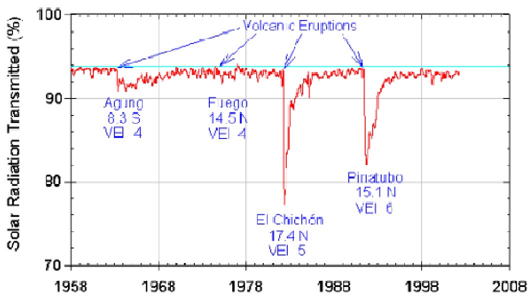
Aerosol = liquid/solid particle that floats in gas

- sulfur + water → sulfur acid (70:30)
- Icy or liquid spheres with d~500 nm
- solar radiation is absorbed, scattered or reflected → increased albedo
- Slowly settle down during the next 1-3 years

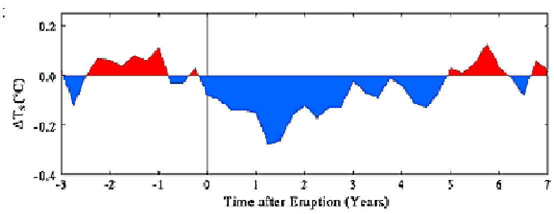


Cooling Effect

Mauna Loa Observatory Atmospheric Transmission

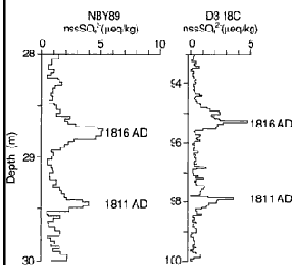


Cooling Effect



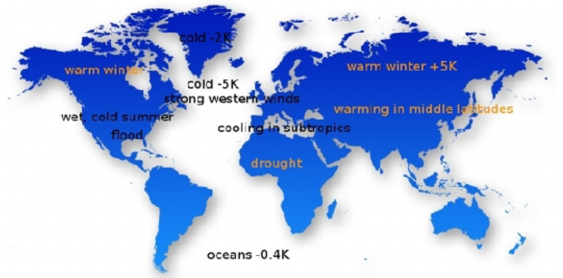
Composite global surface temperature change near the time of the five volcanos producing the greatest optical depths since 1880: Krakatau (1883), Santa Maria (1902), Agung (1963), El Chichon (1982) and Pinatubo (1991).

Sulfur deposition in Iceshields



- Cores from Antarctic and Greenland
- 1815 Eruption of the Tambora (Indonesia)
- 1809 “Unknown Eruption”

Weather anomalies after Pinatubo eruption

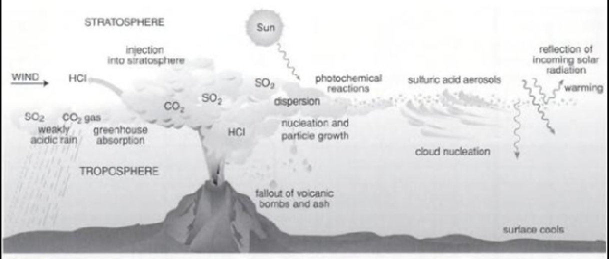


- Global cooling of 0.2K
- → Global and local weather patterns influenced

Effect on Ozone Layer

- Ozone layer is in stratosphere (shields earth from UV radiation)
- Natural balance disturbed by human-made chlorofluorocarbons (CFC)
- Volcanic aerosols increase impact of CFCs
- Pinatubo: ozone depletion by 50% over Antarctica
- Recovers within some years

Effects on the Atmosphere



Super-Volcanoes

Super-Volcanoes

- Volcanoes that erupt more than 1 000 km³ of tephra (pumice and ash) in a single event
- Eruptions 100 times stronger than normal eruptions
- VEI > 7

Volcanic Explosion Index

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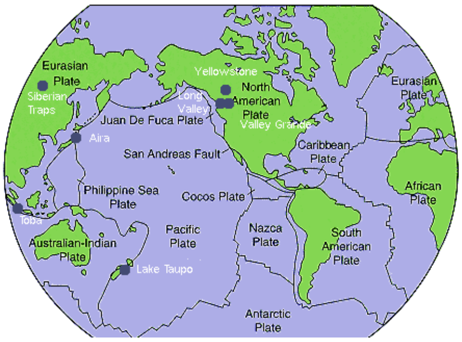
Super-Volcanoes



Consequences of a Super-eruption

- Volcanic ash covers a large part of a continent
- **Climatic changes**: Aerosols and fallout in atmosphere for up to six years → atmosphere reflects solar radiation back and absorbs heat

  → cooling of 3-5K for Toba-like eruption

  → **Volcanic winter**

Volcanic winter

Puyehue volcano erupts in Chile , June 2011, http://www.boston.com/bigpicture/2011/07/ash_covered_landscape.html

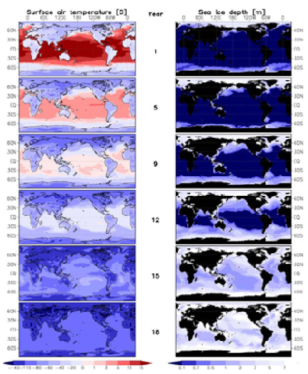
Volcanic winter

- 1815 Mount Tambora in Indonesia (VEI=7)

→ frost and snow in summer in New England

- Super volcano eruption could reduce radiation of the sun by 25%

Snowball experiment - 0% radiation



Without radiation
→ sea freezes totally within 15 years

http://www.mpimet.mpg.de/en/science/internal-projects/super-volcano/presentations.html

Consequences of a Super-eruption

- Climate system is complex → not sure whether observations from smaller eruptions can be extrapolated
- Maybe also other effects become important e.g. CO_2 and Methane concentration in the atmosphere, air pollution and ozone depletion
- Can produce huge hurricanes

History

- Last super-eruption 640 000 BP
- Long thought to be extinct
- 1973 north of lake had risen 0.76m since 1923
- 1985 swarm of tiny earthquakes → volcano alive
- In the 1950s 3 ash layers found → sign of huge pyroclastic flows

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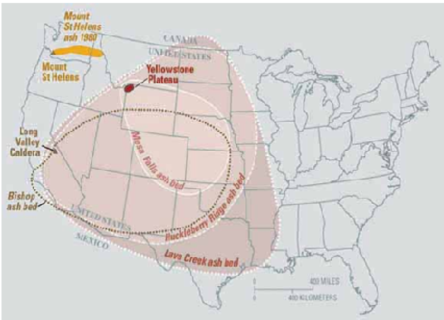
Ashlayers



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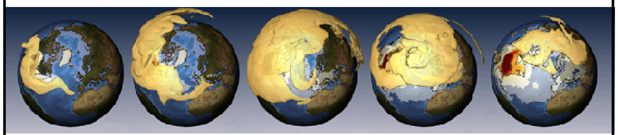
Future of Yellowstone



Simulation for a Yellowstone eruption

- Yellowstone eruption very unlikely but possible
- Ash would spread around the word
- Global cooling effect as seen for Pinatubo would be much larger→ new ice age?

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Lake Toba (Sumatra, Indonesia)

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Lake Toba: Toba catastrophe

- Erupted 74 000 BP
- 300x stronger than Tambora eruption in 1815
- 6 - 10 years volcanic winter
- Genetic bottleneck theory :

human population reduced to 10 000 or 1 000 pairs

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Conclusion and Findings

- Volcanic Eruption Emission and Ejecta
- Eruption Classifications
- Tectonic Plate Boundaries and Hotspots

- Impact on Global climate of Plinian eruptions of VEI>5
- Global cooling (eg. Pinatubo of 0.2K for approx. 3 yr)
- Complexity of climate systems, limited predictability

- VEI >7 Supervolcanoes
- Significant related climate changes
- Expected global cooling (3-5K for approx. >4 yr)

"The bright sun was extinguish'd and the stars
Did wander darkling in the eternal space,
Rayless, and pathless, and the icy earth
Swung blind and blackening in the moonless air;
Morn came and went - and came, and brought no day..."

A section from "Darkness" by Lord Byron, written in June 1816 on the shores of Lake Geneva in the midst of the "Year without Summer", 14 months after the great eruption of the Tambora volcano in Indonesia.