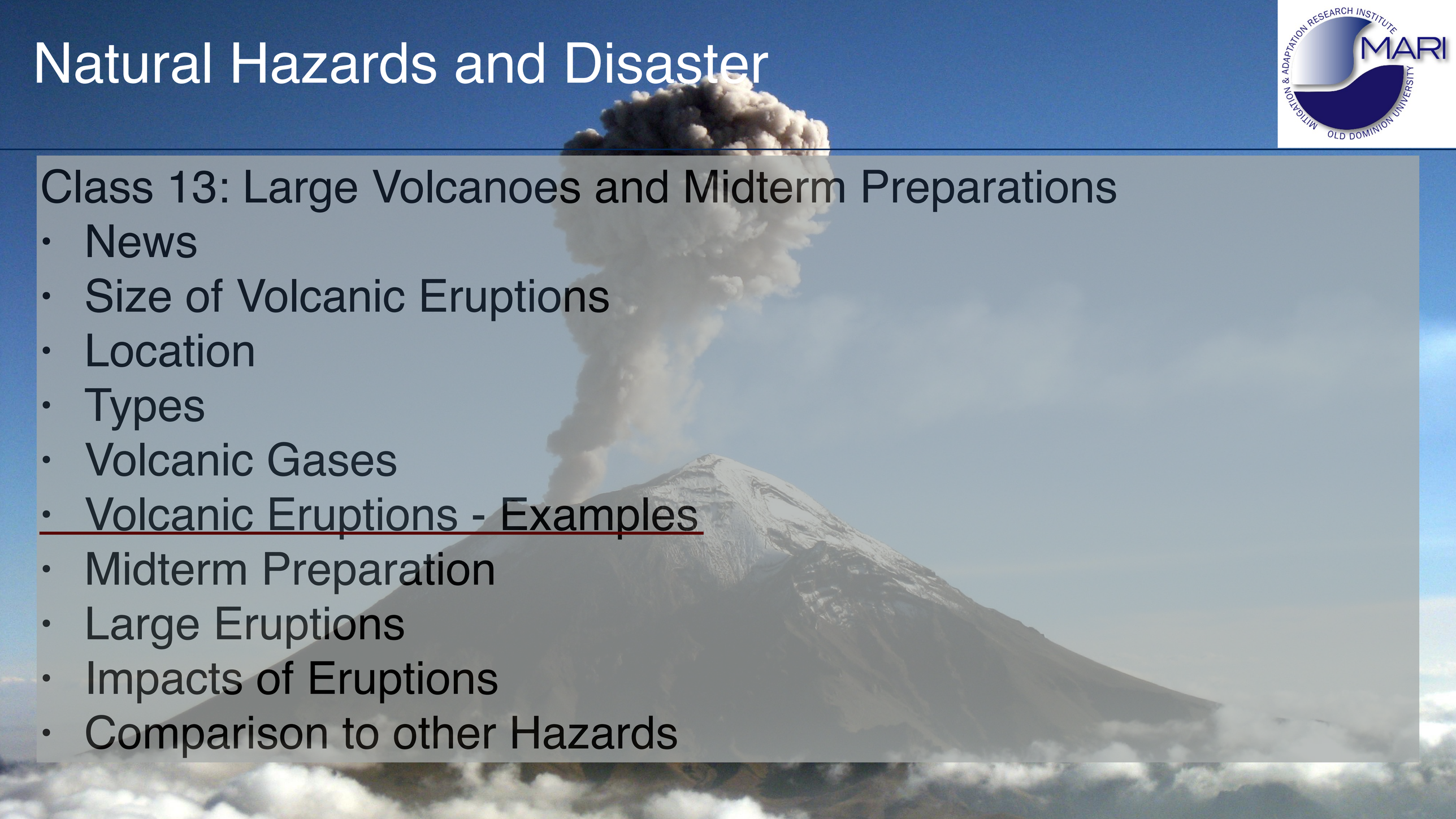
Natural Hazards and Disaster



Class 13: Large Volcanoes and Midterm Preparations

- News
- Size of Volcanic Eruptions
- Location
- Types
- Volcanic Gases
- Volcanic Eruptions - Examples
- Midterm Preparation
- Large Eruptions
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Midterm Preparation

Three specific examples:

- Extraterrestrial: Carrington Event in 1859
- Earthquake: April and May 2015, Nepal
- Volcanic Eruption: 2010 Iceland

Questions will relate to:

- the hazard: general description of the type, the specific event;
- the disaster: extent of damage and lives lost;
- cascading impacts;
- the specific reasons for the extent of the disaster;
- particulars of the risk management cycle, in particular: risk assessment prior to the event, early warning; impact mitigation, and recovery;
- potential impacts of similar events in the future.

Carrington Event 1859

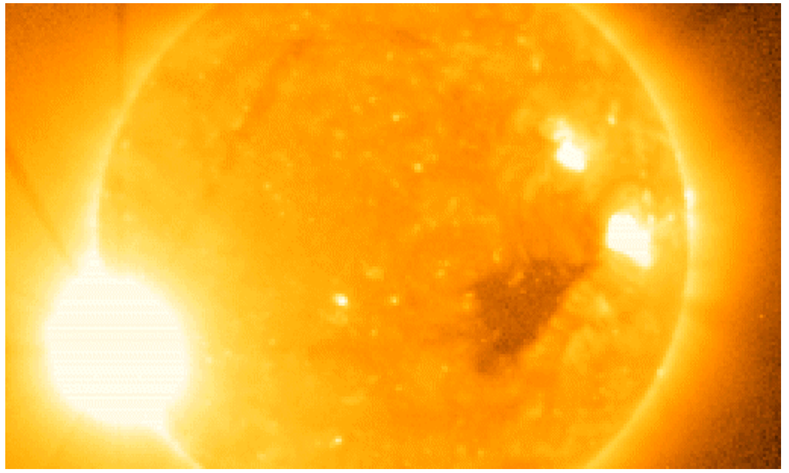
The Carrington Superstorm

Records of major solar flares and their associated coronal mass ejections first began in 1859. Solar flares are classified today according to their strength in watts per square meter reaching Earth, using a lettered scale in which each level is 10 times greater than the next lower rating. For example, an M0 flare is ten times greater than a C9, and an M3 is ten times greater than an M2. The strongest, most damaging flares are given X values, with no upper limit. On September 1, 1859, an intense white-light solar flare was observed by British astronomer Richard Carrington. This was the first recorded observation of a solar flare, which lasted for about 5 minutes and is now classified as an X15 Super Geomagnetic Storm. When the intense burst of energy reached Earth it caused aurora-induced electrical currents in telegraph wires that were sufficient to give electric shocks to telegraph operators. In the hours before dawn next morning, bright auroras were visible as far south as Cuba.

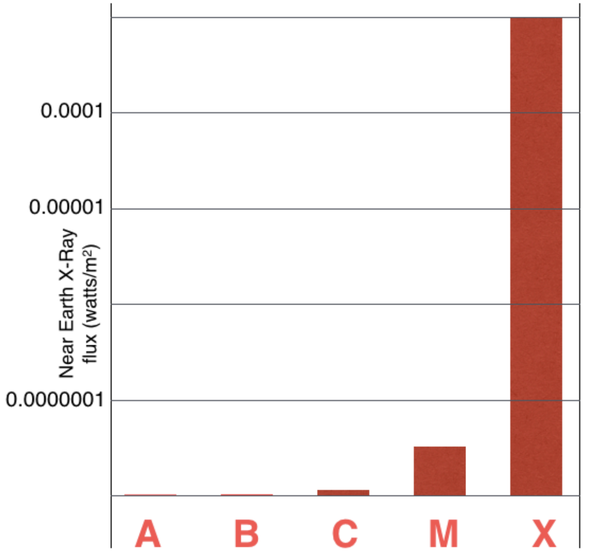
A large solar flare on August 4, 1972, disrupted telephone communication across the state of Illinois and caused AT&T to redesign its power system for transatlantic cable.

On April 2, 2001, an X20 flare became one of the largest so far on record; it generated a 2,000 km/s CME blast that, fortunately, was not directed toward Earth.

The July 23, 2012 solar flare of a similar strength as the Carrington Event nearly hit Earth.



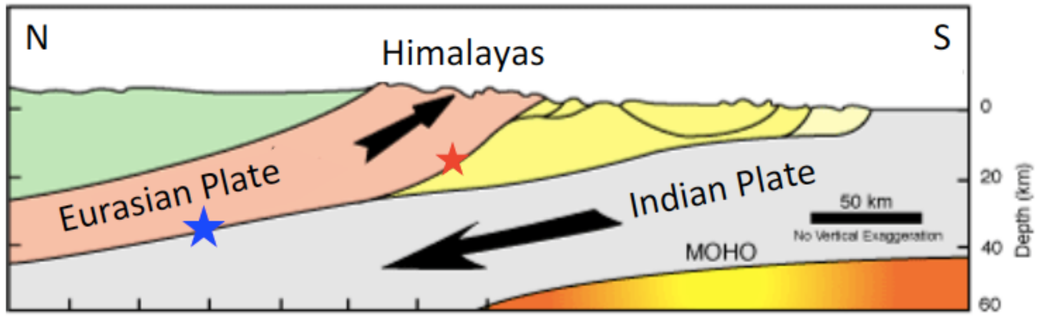
NOAA's GOES-13 satellite recorded this Xray image of a solar flare on December 5, 2006. The flare was not as intense as the Carrington flare, but it still damaged the satellite's imaging instruments.



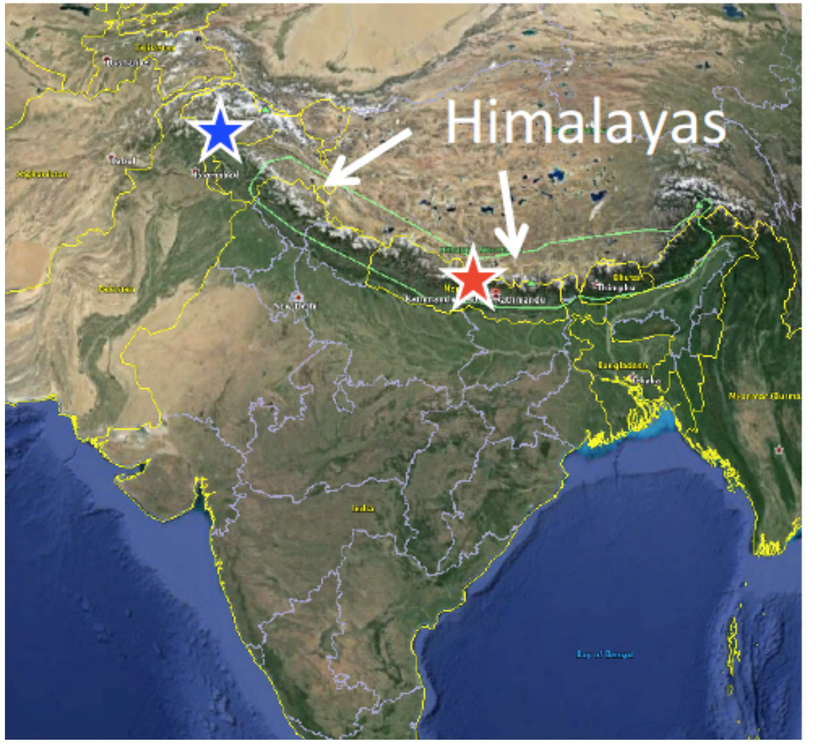
NASA's letter-scale rating of solar flare strength. The logarithmic scale goes from 1 to 9 within each letter, and extends beyond 20 for X-level flares.

April and May 2015 Earthquakes in Nepal

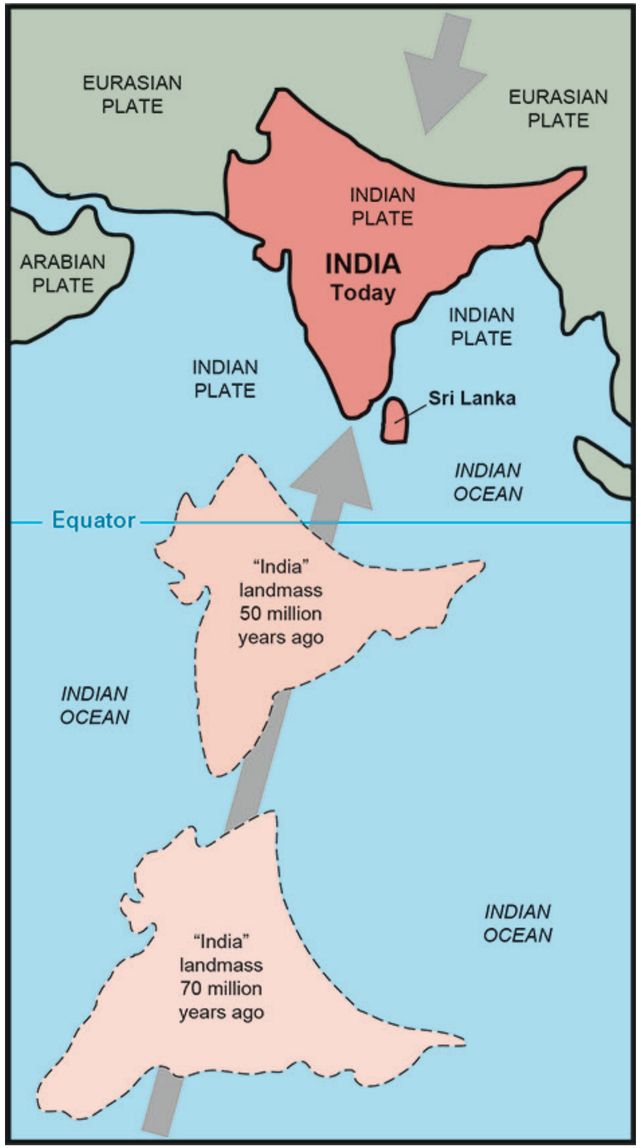
Oct. 8, 2005, Azad Kashmir, Mw=7.6, I=VIII, Depth 26 km
Death 86,000 to 87,000, Damage $5.2 billion



North-South profile of the present Indian-Eurasian plate boundary, with approximate focal depths of the 2005 Kashmir (blue star) and 2015 Nepal (red star) earthquakes.



The Indian Plate's northward migration culminated in continent-continent collision at between 50 and 40 million years ago, causing the uplift of the Himalayas. Epicenters marked by stars on Google Earth image for the 2005 Kashmir (blue) and 2015 Nepal (red) earthquakes.



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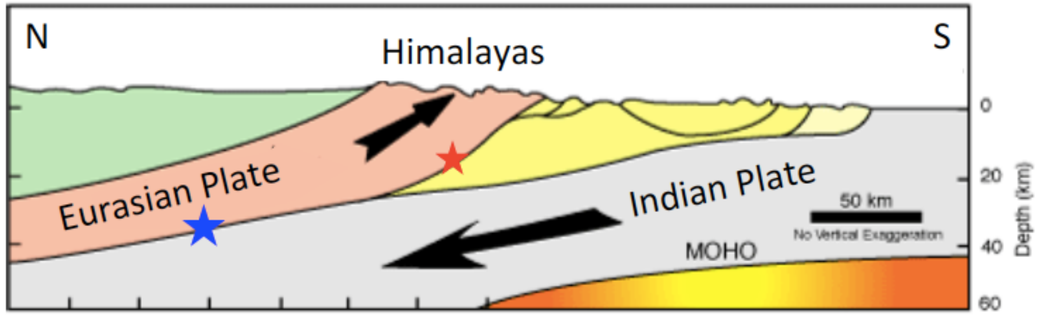
Deaths: 9,000, Damage: $10 billion

May 12, 2015, Nepal, Mw=7.3, Depth 15 km
Deaths: 218



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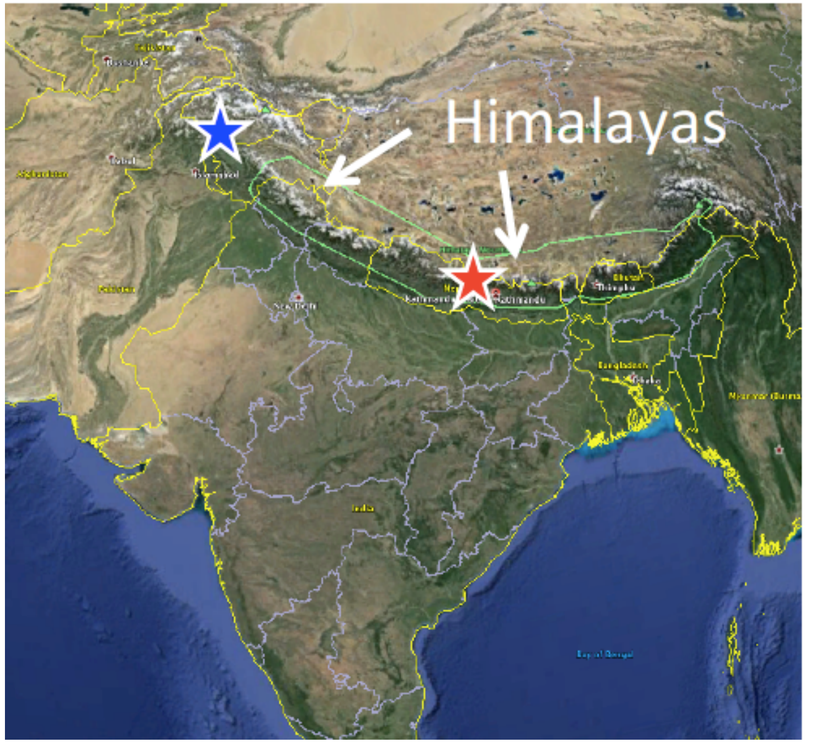

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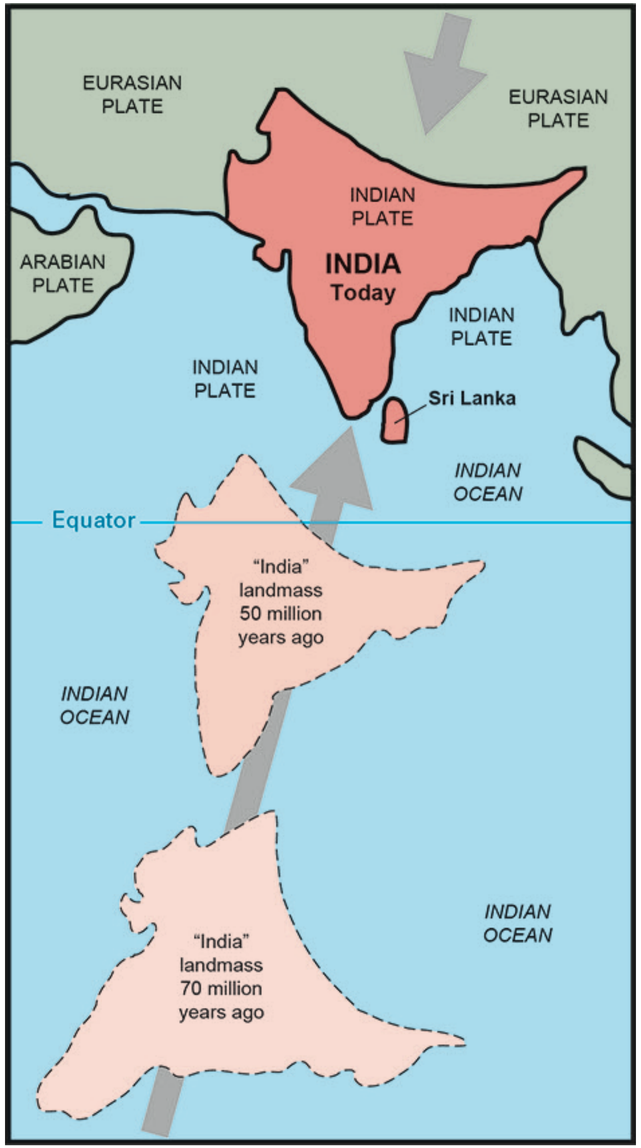

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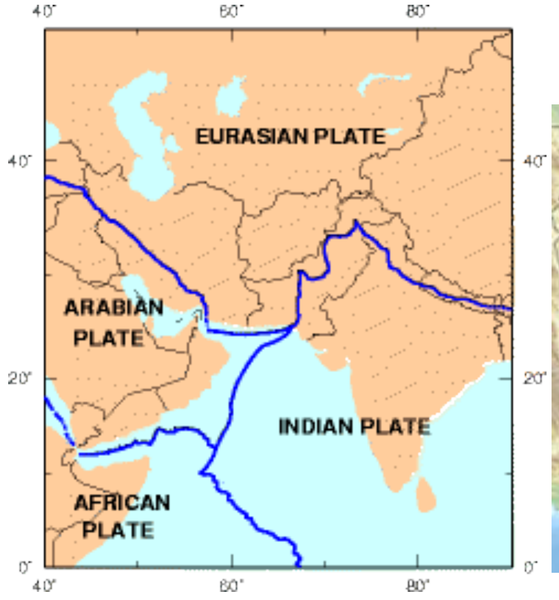

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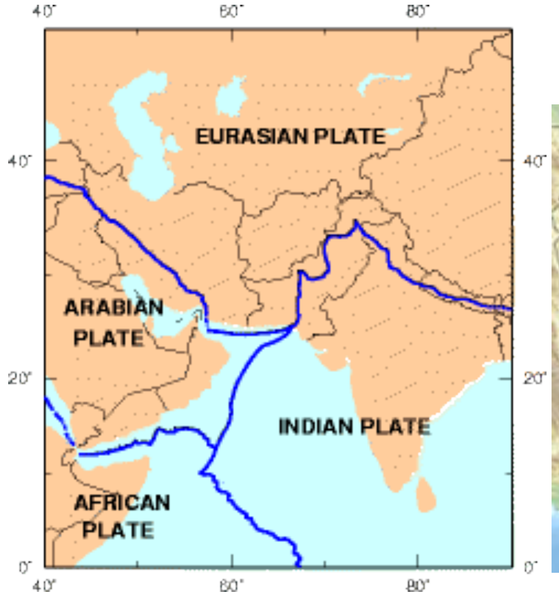

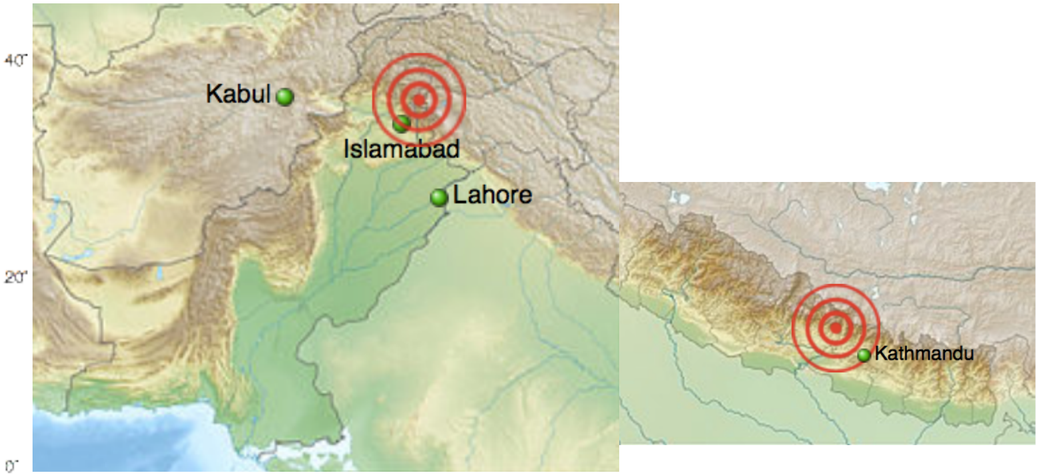

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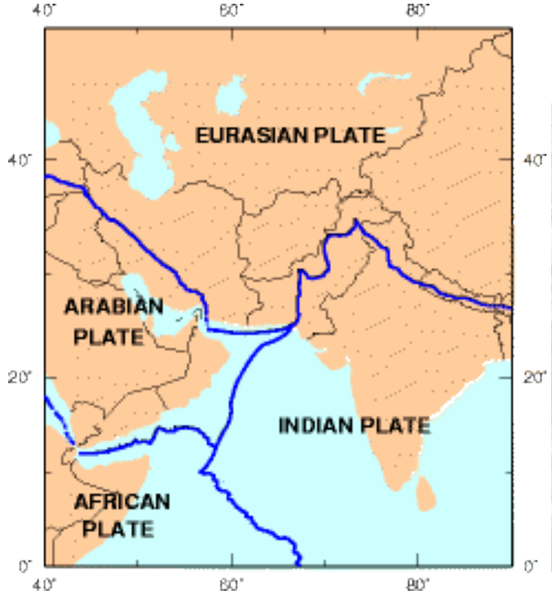

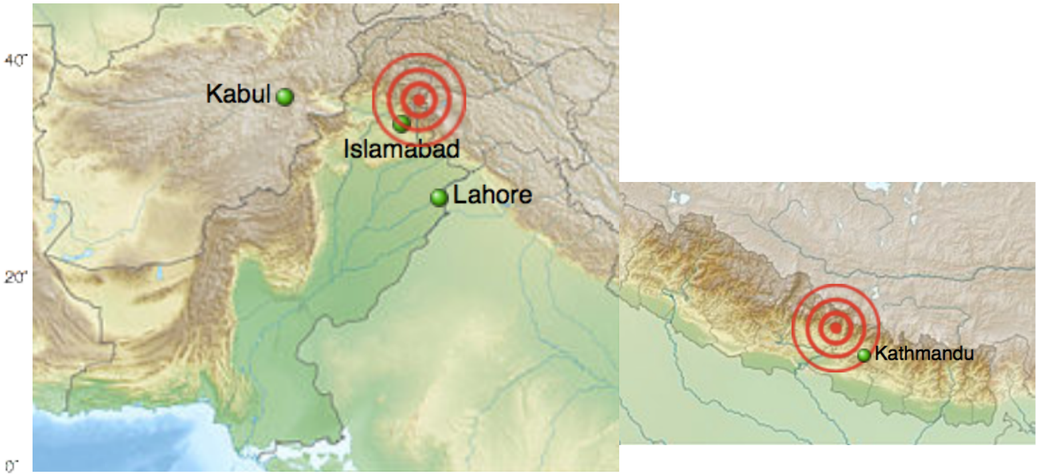

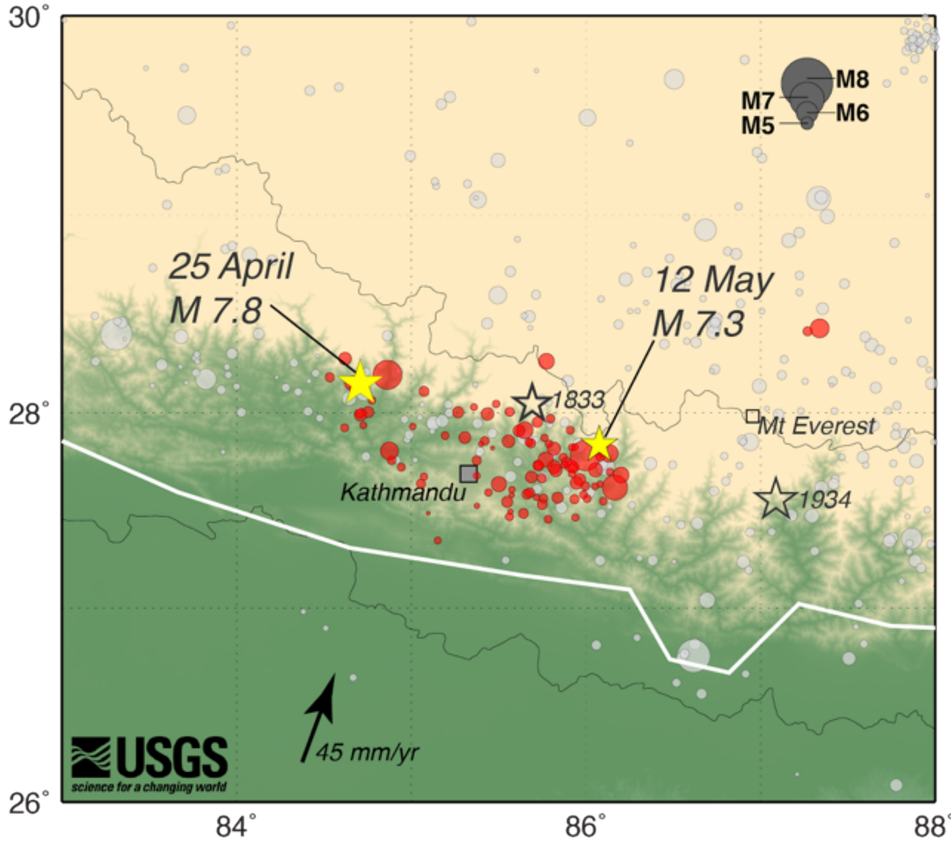

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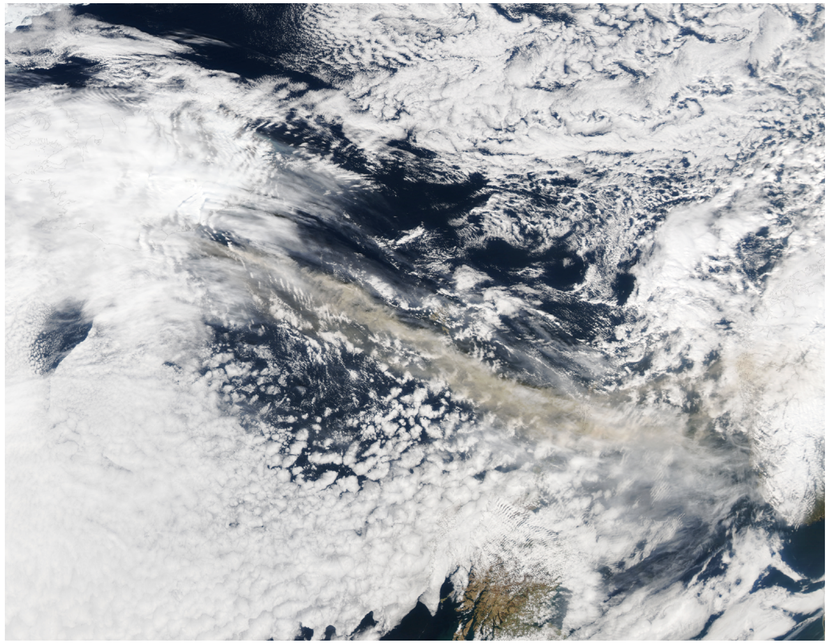
Nepalese village near Gorkha destroyed by a landslide that occurred during the April 2015, M_W 7.8 earthquake.

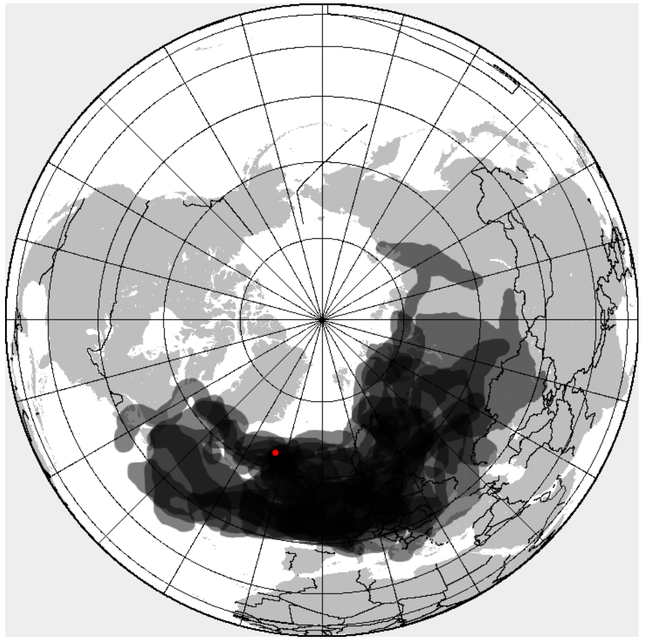
Destruction in Punjab, Pakistan Kashmir, caused by 23 seconds of ground shaking during the October 2005, M_W7.6 earthquake.

2010 Eyjafjallajökull Eruptions

Eyjafjallajökull, 2010: VEI 4, 0.25 km^3



Main eruption: April 14-20, 2010



Composite map of the volcanic ash cloud spanning 14–25 April 2010, based on data by the London Volcanic Ash Advisory Centre's website

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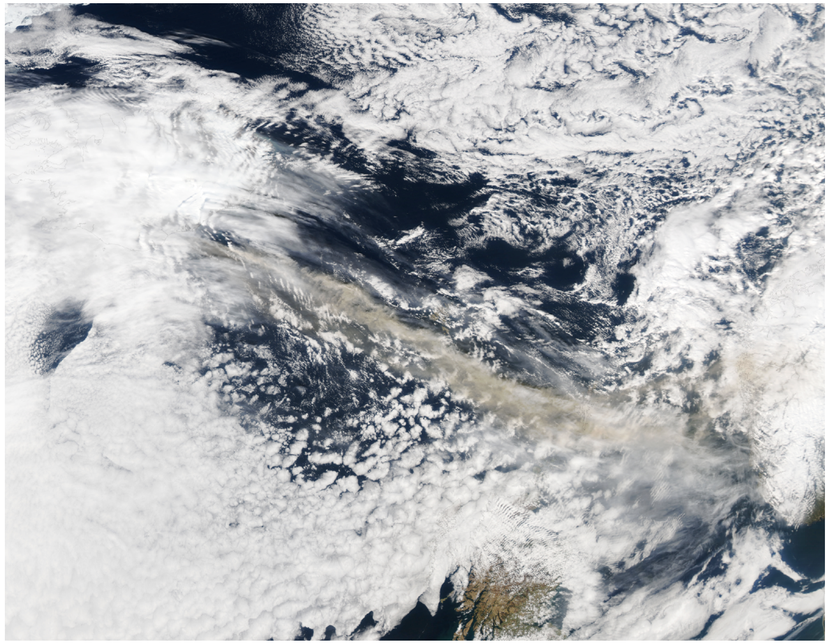
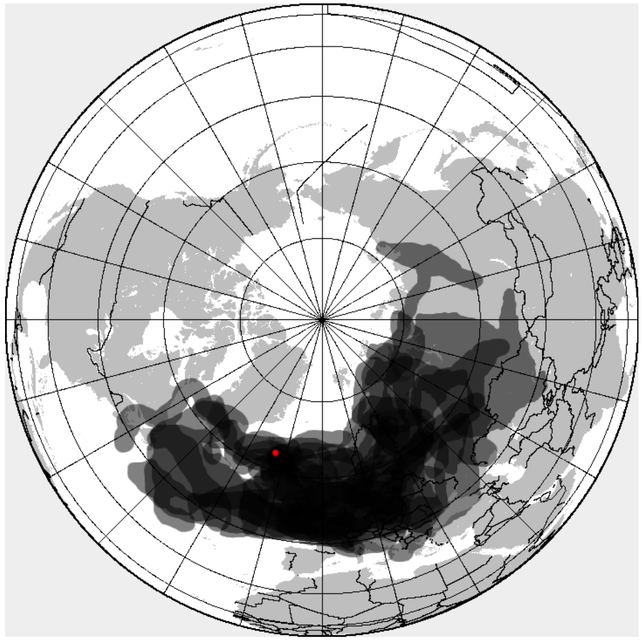


Main eruption: April 14-20, 2010

Laki 1783-85: VEI 6, 14 km^3



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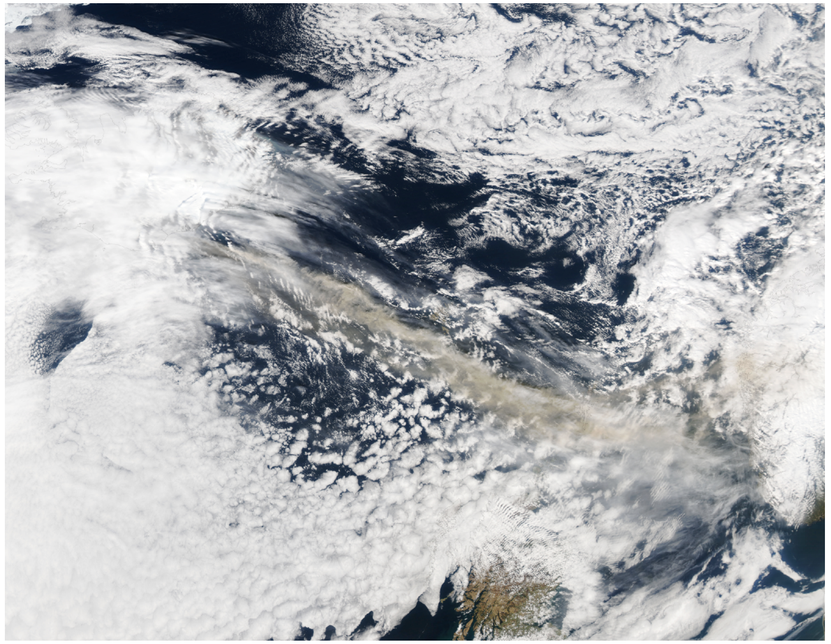
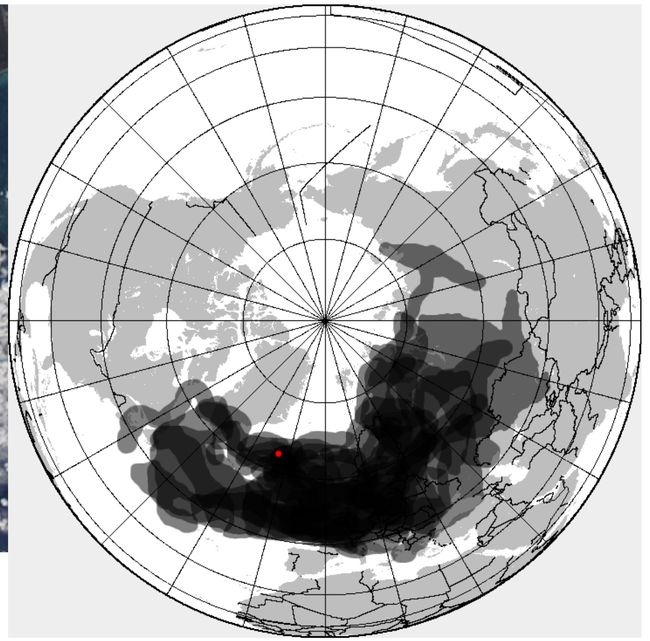


Saturday 17 April — Thick ash poured from Iceland's Eyjafjallajökull volcano when the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite acquired this image on April 17, 2010. The ash in this image is at two different altitudes. A concentrated plume rises over a more diffuse cloud of ash, casting a dark shadow on the ash below. The volcano had been emitting ash in puffs that reached between 16 000 (4.9 km) and 24 000 feet (7.3 km), according to the Icelandic Met Office. The higher plume seen here is likely from a more explosive event. NASA image Monday 19 April.



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https://www.bgs.ac.uk/research/volcanoes/icelandic_ash.html

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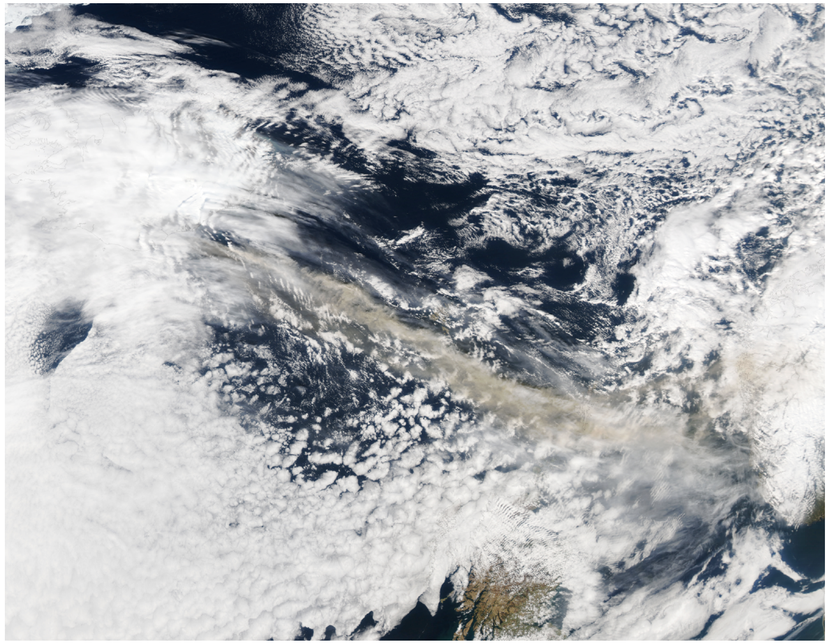
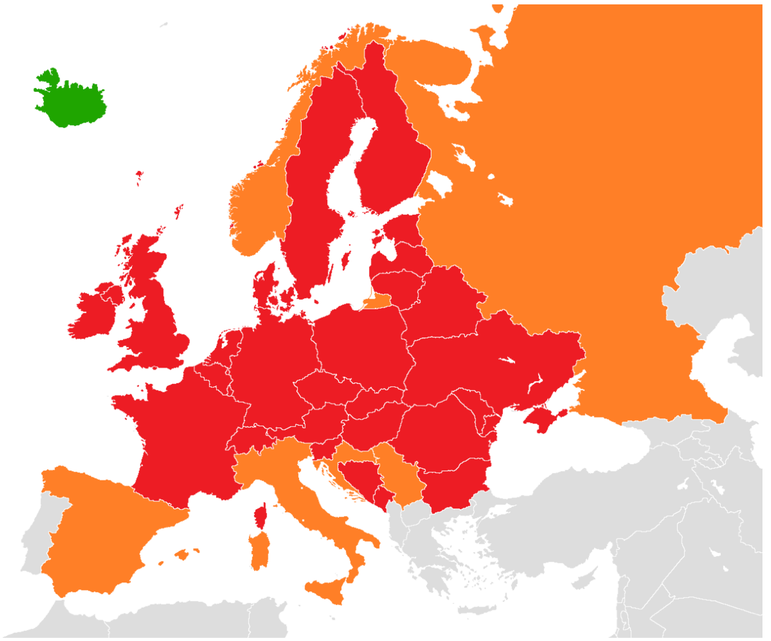
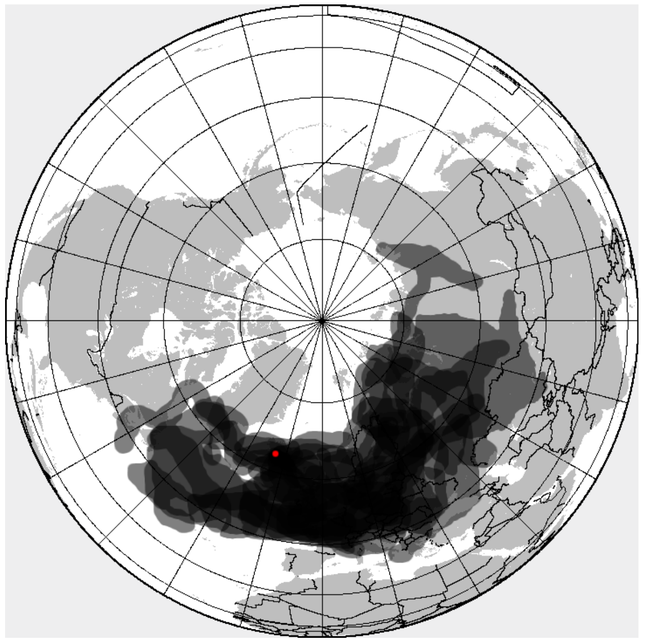


Major airspace restrictions between April 14 - 23, 2010



Airspace completely (red) or partially (orange) closed to IFR traffic on 18 April 2010



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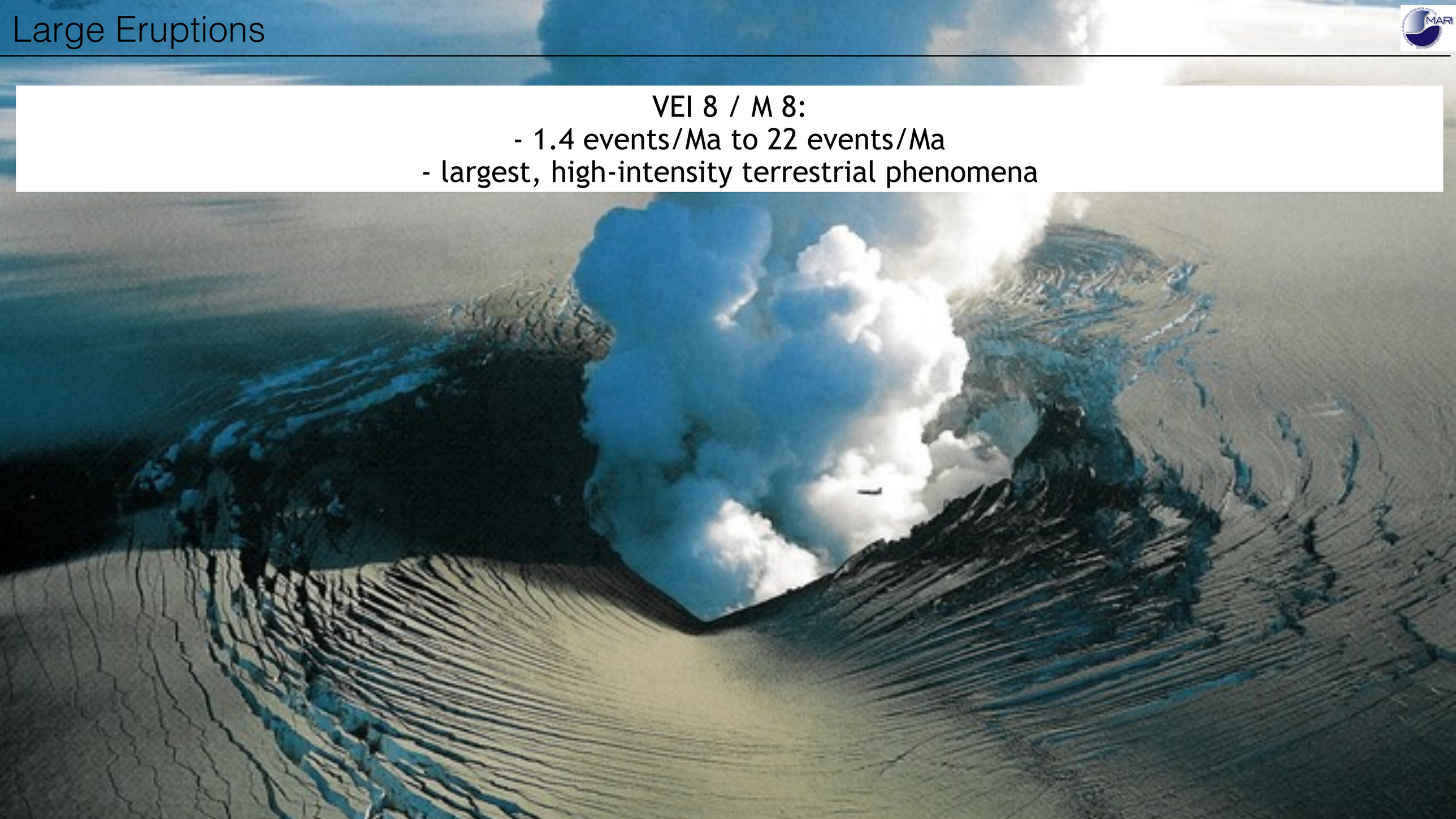
Large Eruptions

VEI 8 / M 8:
- 1.4 events/Ma to 22 events/Ma
- largest, high-intensity terrestrial phenomena



Large Eruptions

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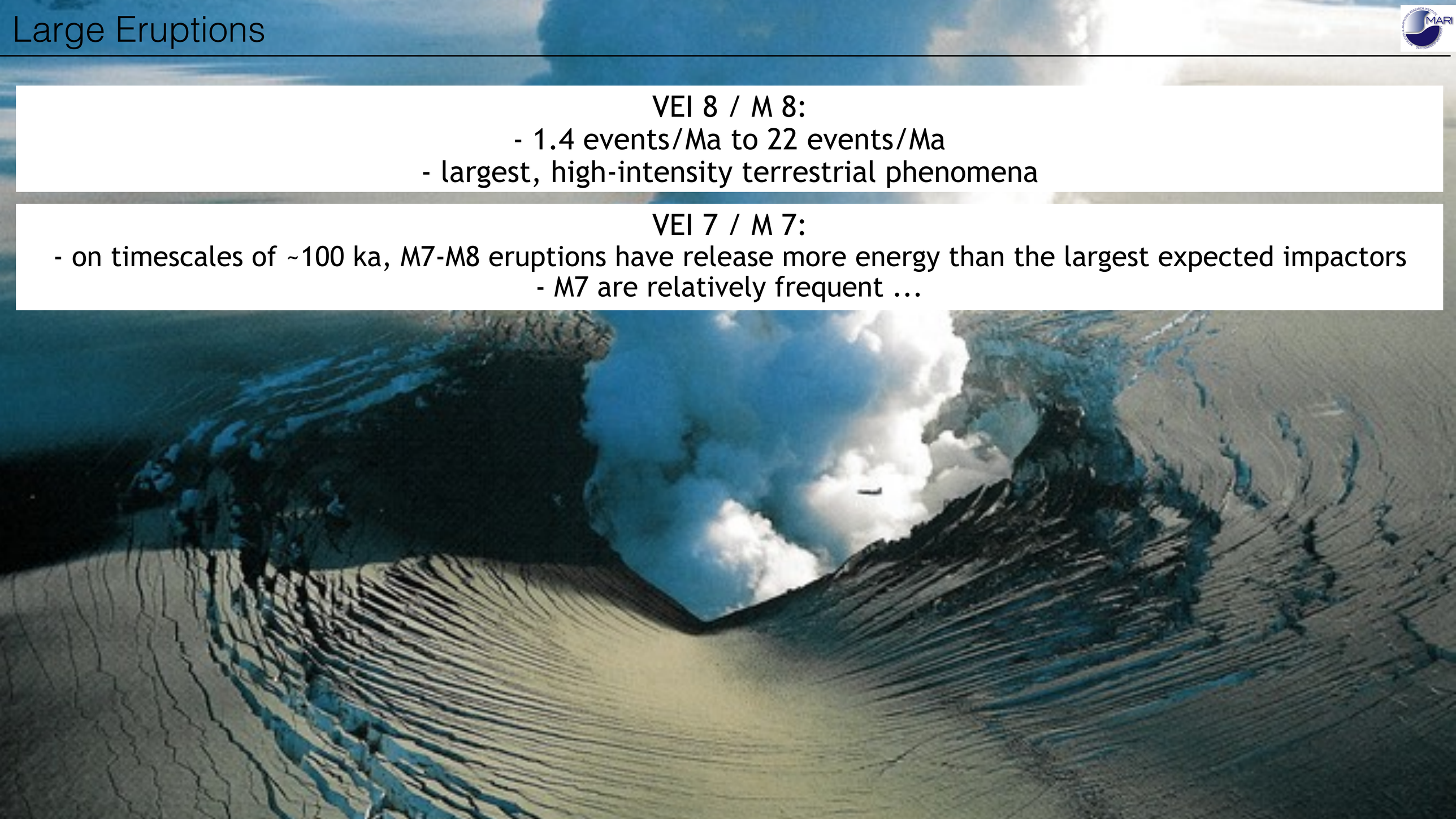
VEI 7 / M 7:
- on timescales of ~100 ka, M7-M8 eruptions have release more energy than the largest expected impactors
- M7 are relatively frequent ...



Large Eruptions

Year	Location	VEI	km^3	Deaths	Comment
2011	Puyehue-Cordon Caulle, Chile	4	30		
2010	Merapi, Indonesia	4		353	MCD: pyroclastic flows
2010	Eyjafjallajökull, Iceland	4	0.25	0	Caused severe traffic distortions
1991	Pinatubo	6	6-16	847	MCD: failing roofs
1985	Nevado de la Ruiz, Colombia	3	0.03	25,000	MCD: Lahar
1980	St Helens	5	1	57	
1919	Kelut, Indonesia			5,100	MCD: mudflows
1912	Novarupta, Alaska	6	15-30	unknown	
1902	Mount Pelee, Martinique	4	>0.1	29,000	MCD: pyroclastic flow
1902	Santa Maria, Guatemala	6	20	>5,000	
1883	Krakatau, Indonesia	6	21	36,000	MCD: tsunami
1882	Galunggung, Indonesia	5		4,000	MCD: mudflows
1815	Tambora, Indonesia	7	150	92,000	MCD: starvation
1783-85	Laki and Grimsvoth, Iceland	6	14	9,400	MCD: famine and fluorine poisoning; deaths are for Iceland only
1660	Long Island	6	30		
1650	Kolombo	6	60		
1631	Vesuvius, Italy			3,500	MCD: mud and lava flows
1600	Huaynaputina	6	30		
1580	Billy Mitchell	6	14		
1477	Baroarbunga, Iceland	6	10		
1280	Quilotoa	6	21		
969 ± 20	Changbai, China	7	76-116		
230	Taupo	7	120		
79	Vesuvius, Italy	5	2.8-3.8	3,400	MCD: Ash flows
1610 ± 14 BC	Santorini	7	99		
4350 BP	Kikai	7	80-220		
5550 ± 100 BC	Kurile	7	140-150		
5677 ± 50 BC	Crater Lake	7	150		
26500 BC	Oruanui, New Zealand	8			
73000 ± 4000 BP	Toba, Indonesia	8	2500-3000		Killed up to 60% of the global population; MCD: starvation
640000 BP	Yellowstone	8	1000		

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an the largest expected impactors

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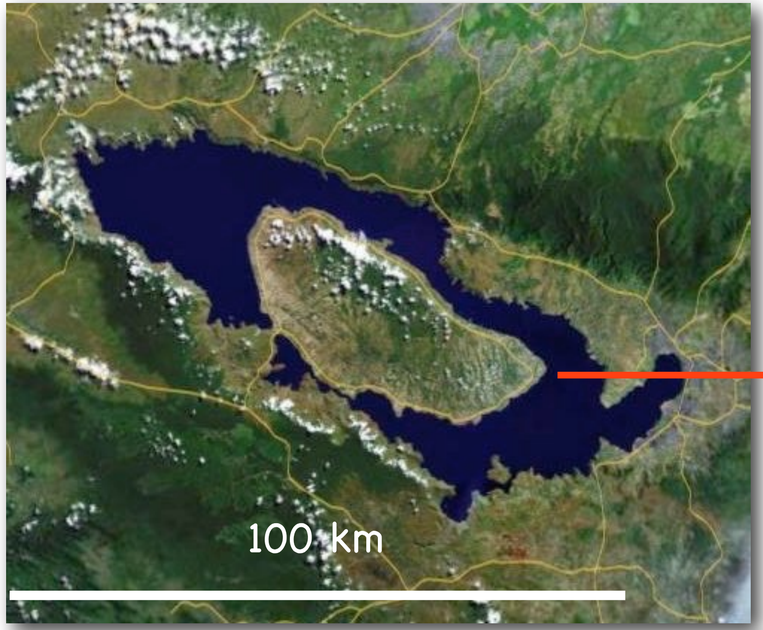
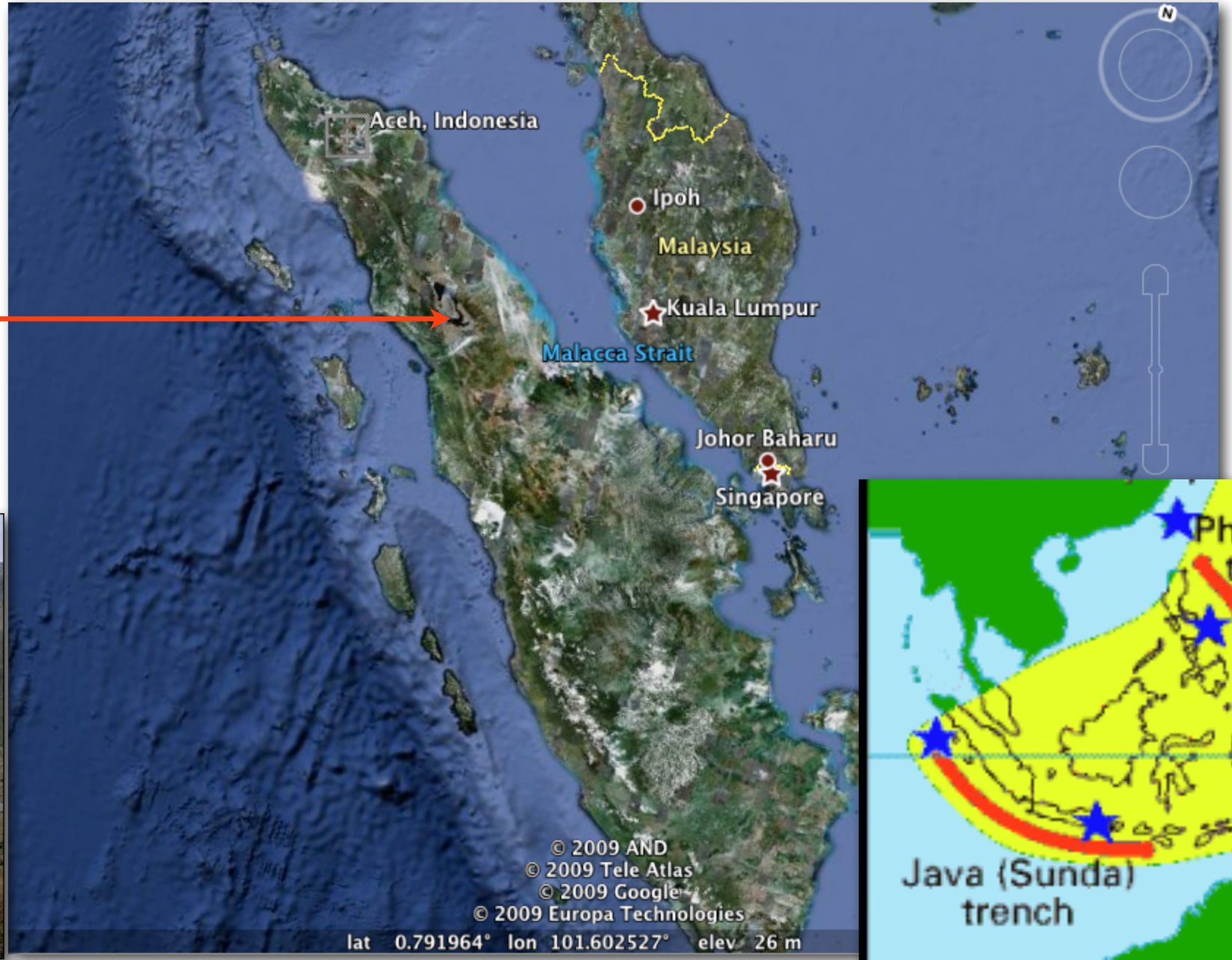
an the largest expected impactors

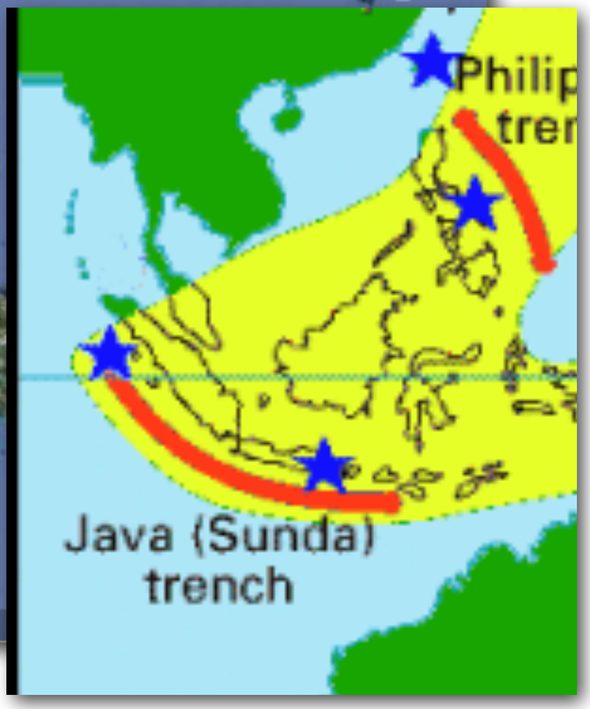
VEI 7 / M 7:

- at least seven events in the Holocene
- ~5% - 10% chance that this will happen in the 21st century
- Will have very different impact than previously

Large Eruptions





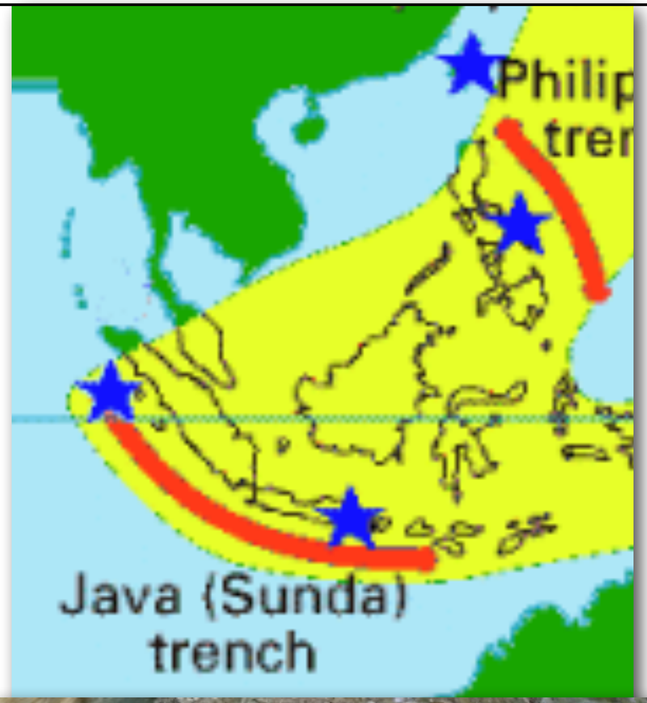


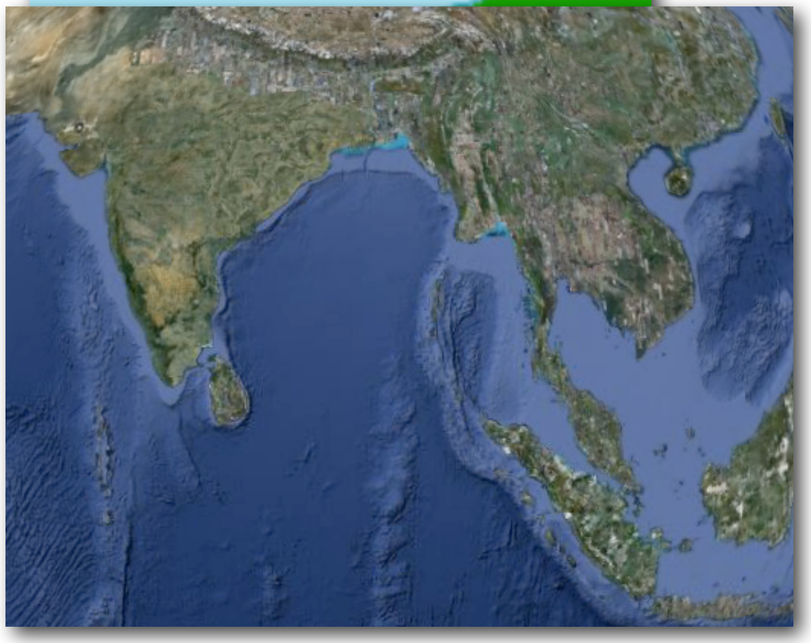
Large Eruptions

Lake Toba

Lake Toba

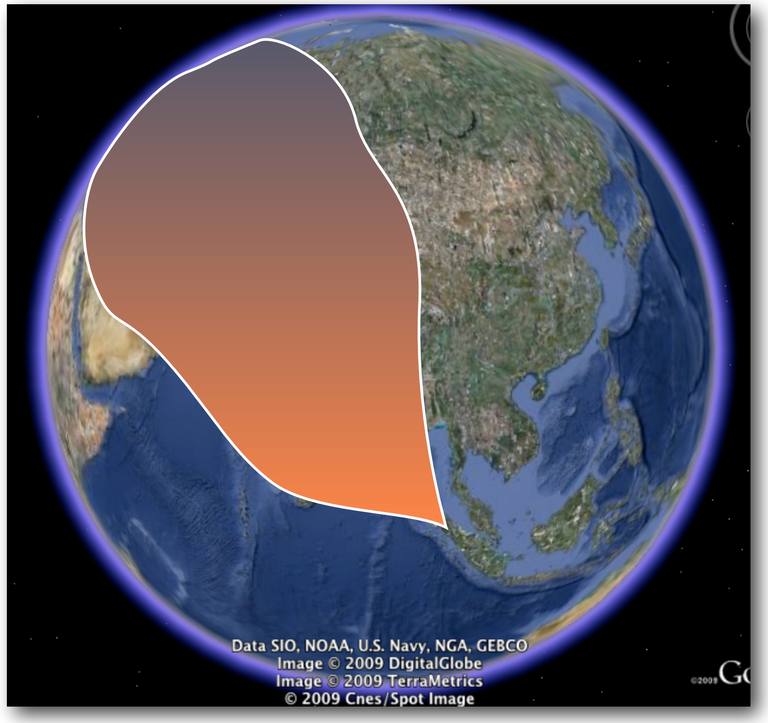
- 4 overlapping volcanoes on 400,000 year cycle- last cataclysmic eruption ca.74,000 years ago
- Over 700 million tons of ash & pyroclastic deposts (contrast with Mt St. Helens!)
- Ash layer 15 cm (6 inches) thick over all of India
- Ash also present in Greenland Ice Cores





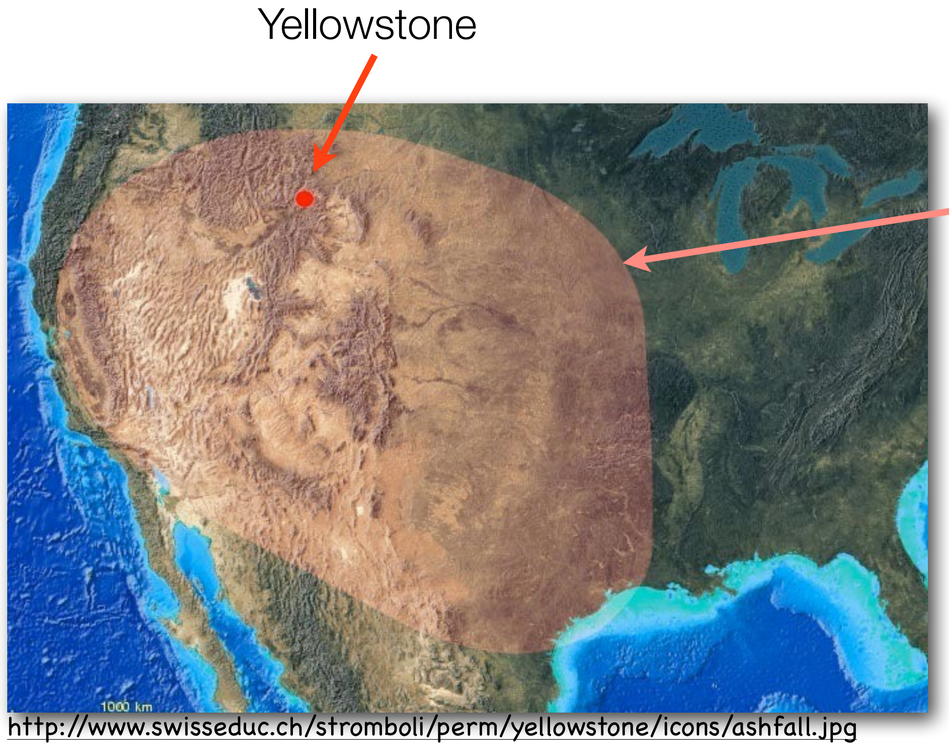
Large Eruptions

- At least 3°C (with extreme estimates of -15°C) drop in global average temperature - snow for most of year in temperate climates
- Evidence from mitochondrial DNA suggests catastrophic number of humans killed, thus reducing genetic diversity, but this is controversial...
- ...evidence from artifacts below and above ash layer suggests at least some humans survived in the region



Ash plume spread to NW

Large Eruptions



http://www.swisseduc.ch/stromboli/perm/yellowstone/icons/ashfall.jpg

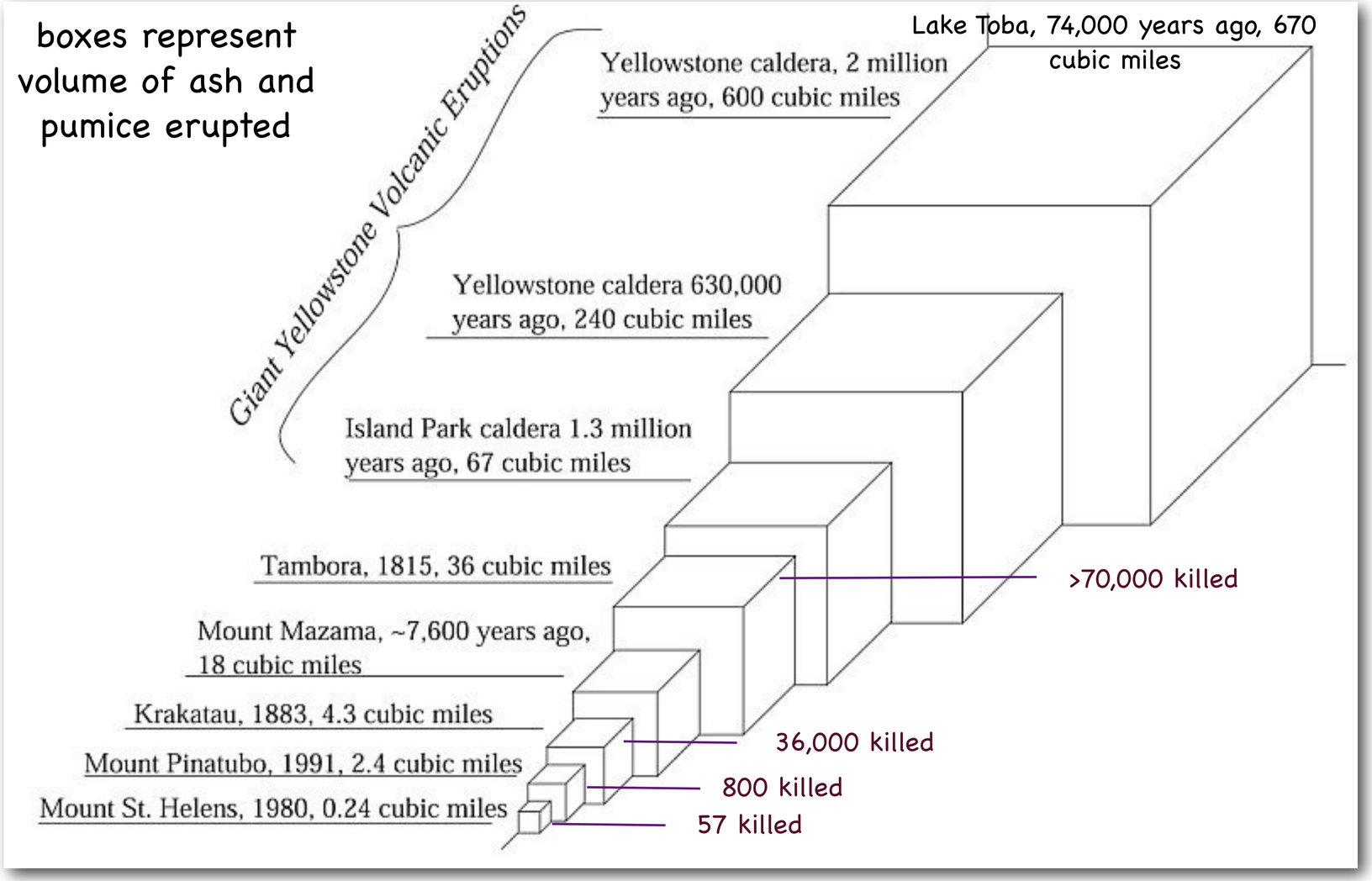
Yellowstone, MT

Limit of Yellowstone caldera ash deposits

http://www.tulane.edu/~sanelson/images/yellowstoneash.gif

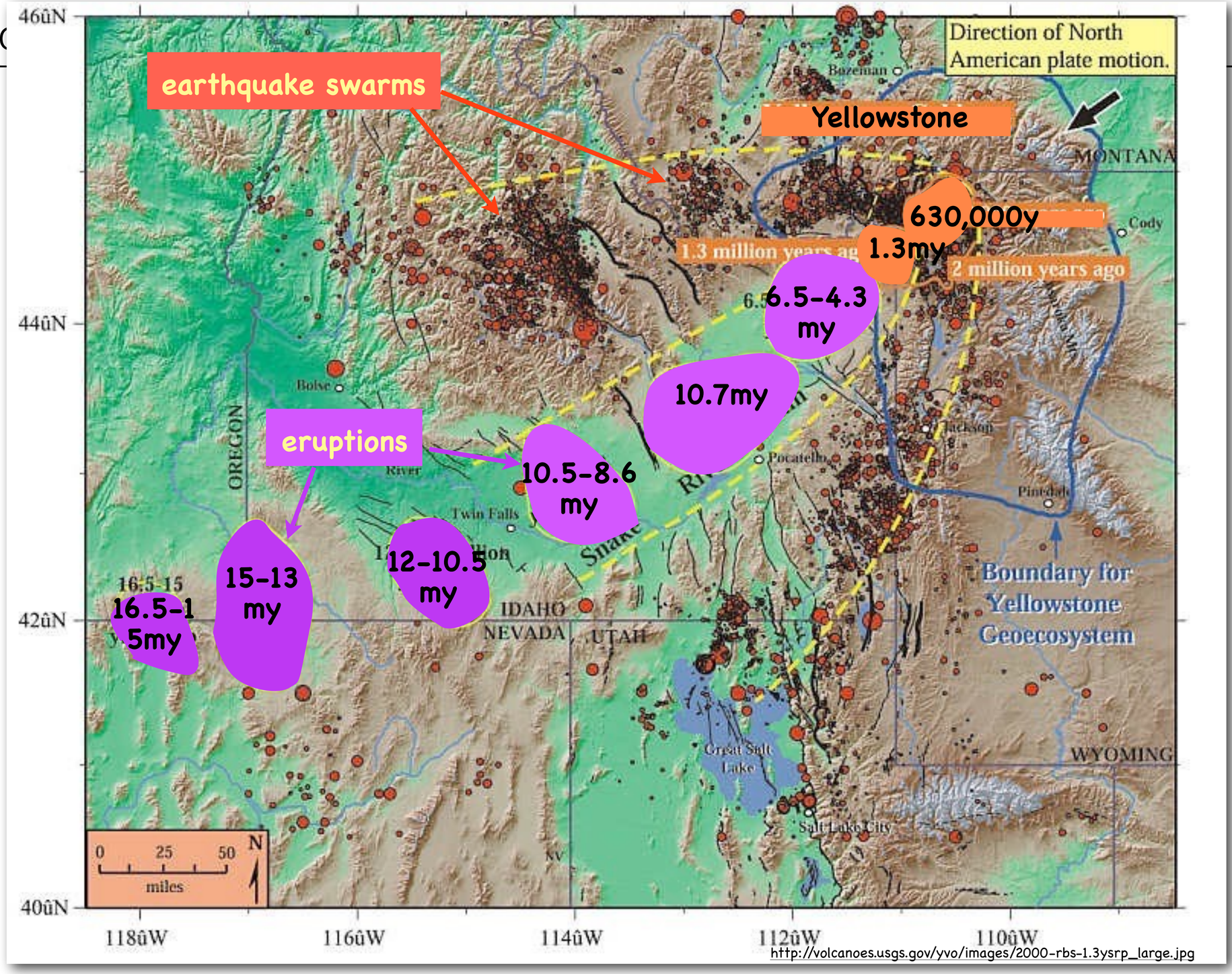
Supervolcano - an eruption that ejects >1000 km^3 (>240 $miles^3$) of ash and pumice in a single event

Eruption size vs. casualties



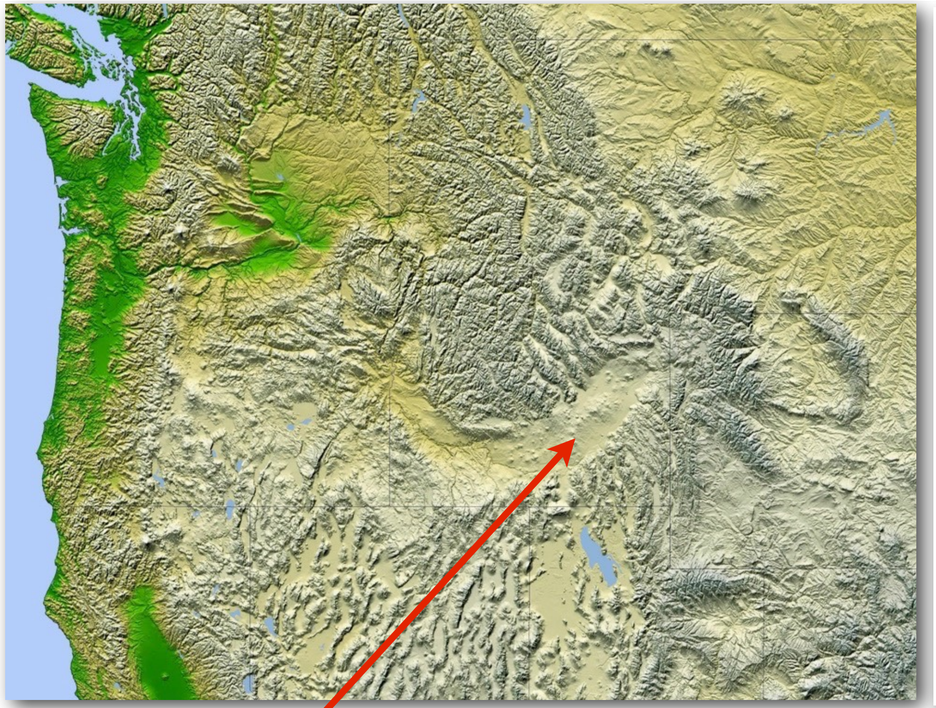
http://tetonwyo.org/em/docs/images/

Large Eruptic

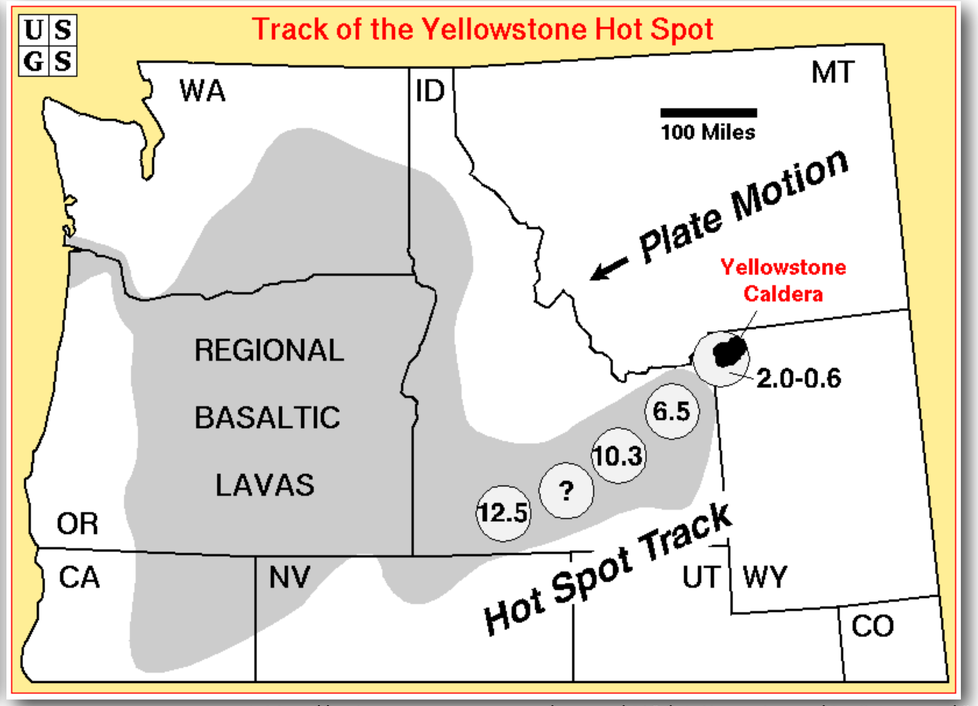


http://volcanoes.usgs.gov/yvo/images/2000-rbs-1.3ysrp_large.jpg

Large Eruptions

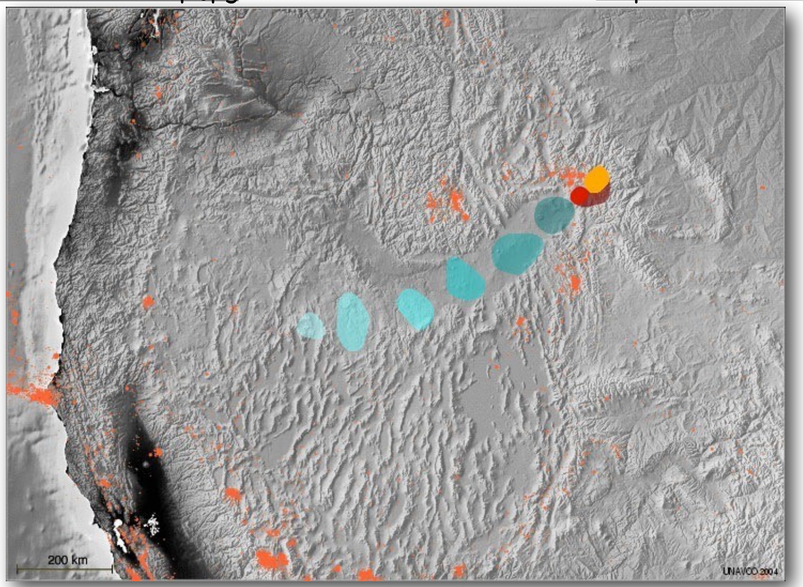


http://geology.com/shaded-relief/northwest-shaded-relief-map.jpg



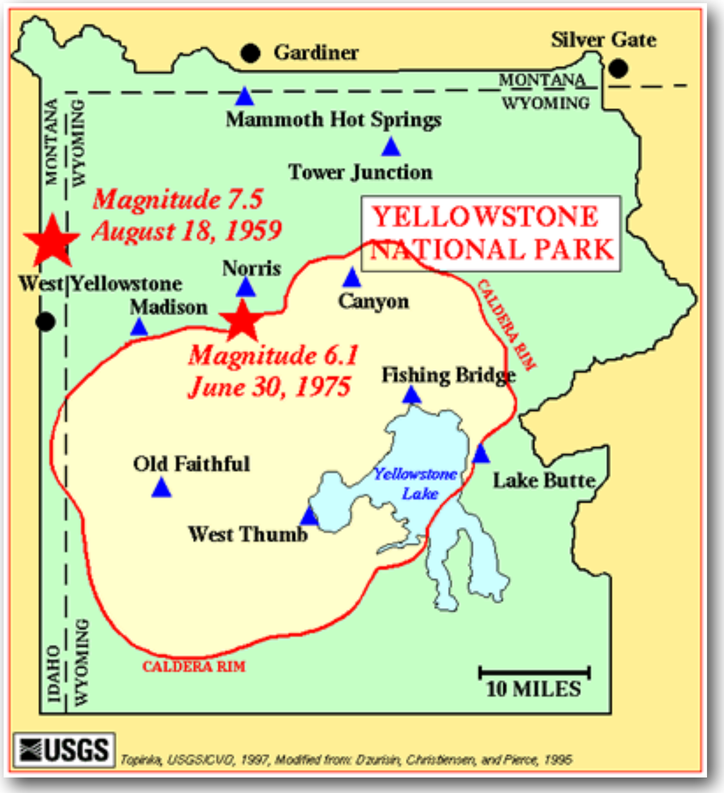
http://vulcan.wr.usgs.gov/Imgs/Gif/Yellowstone/OFR95-59/figure1.gif

hot spot track is evident in topography

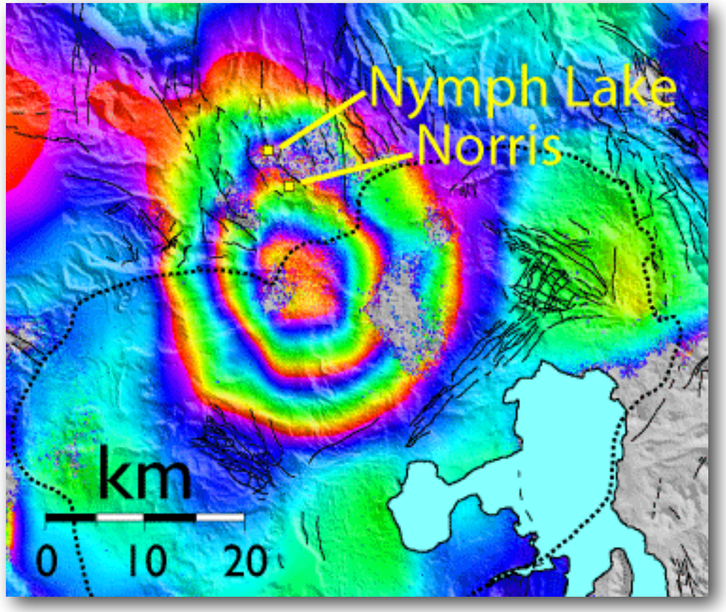


http://www.swisseduc.ch/stromboli/perm/yellowstone/icons/migration.jpg

Large Eruptions



2004-2006 interferogram
(ground deformation pattern)



http://volcanoes.usgs.gov/yvo/images/96_00norris.gif

shows relative changes in
ground surface uplift

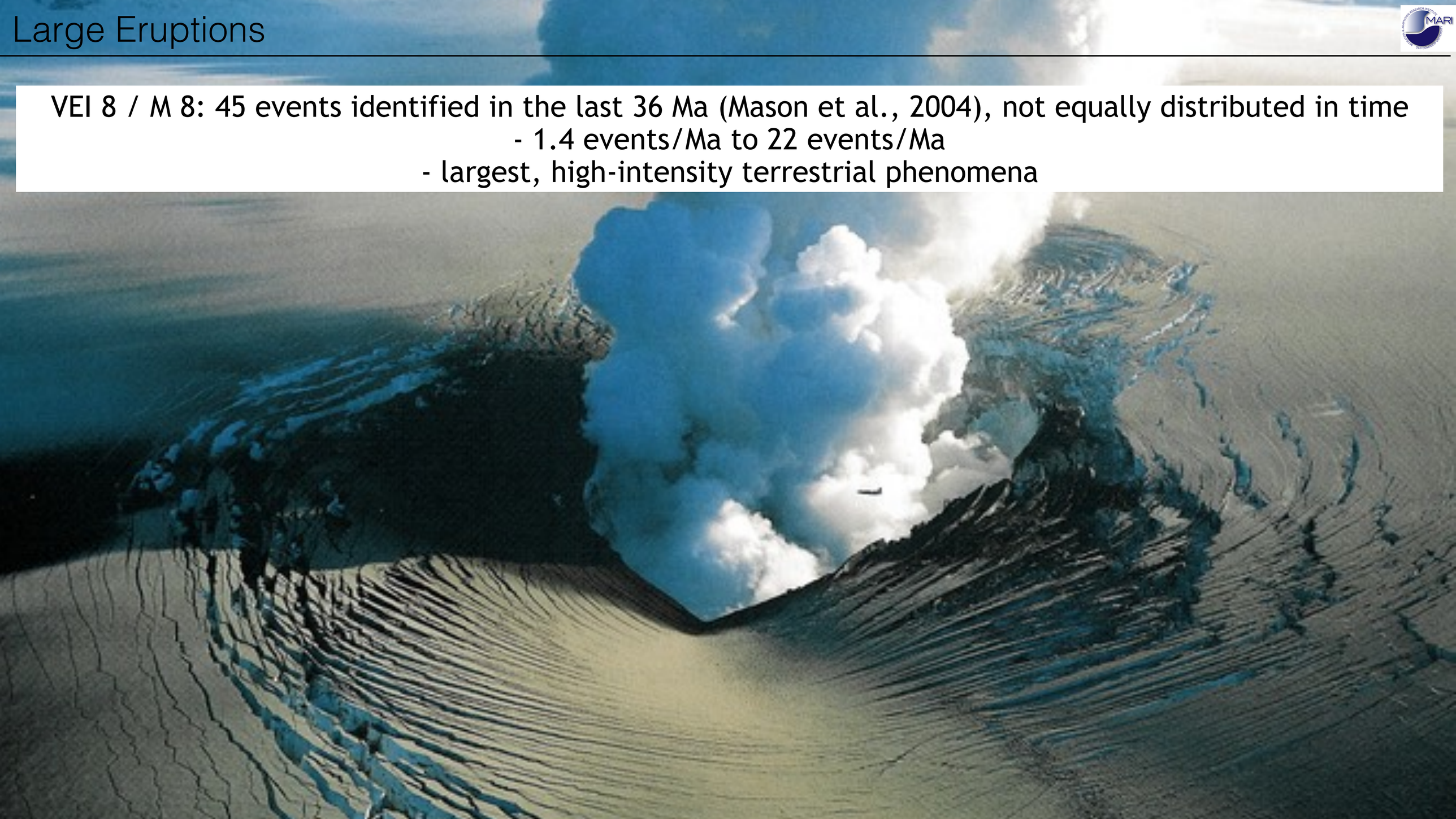
a sleeping giant, or going out
with a fizz....?

Large Eruptions

Large Eruptions

VEI 8 / M 8: 45 events identified in the last 36 Ma (Mason et al., 2004), not equally distributed in time

- 1.4 events/Ma to 22 events/Ma
- largest, high-intensity terrestrial phenomena



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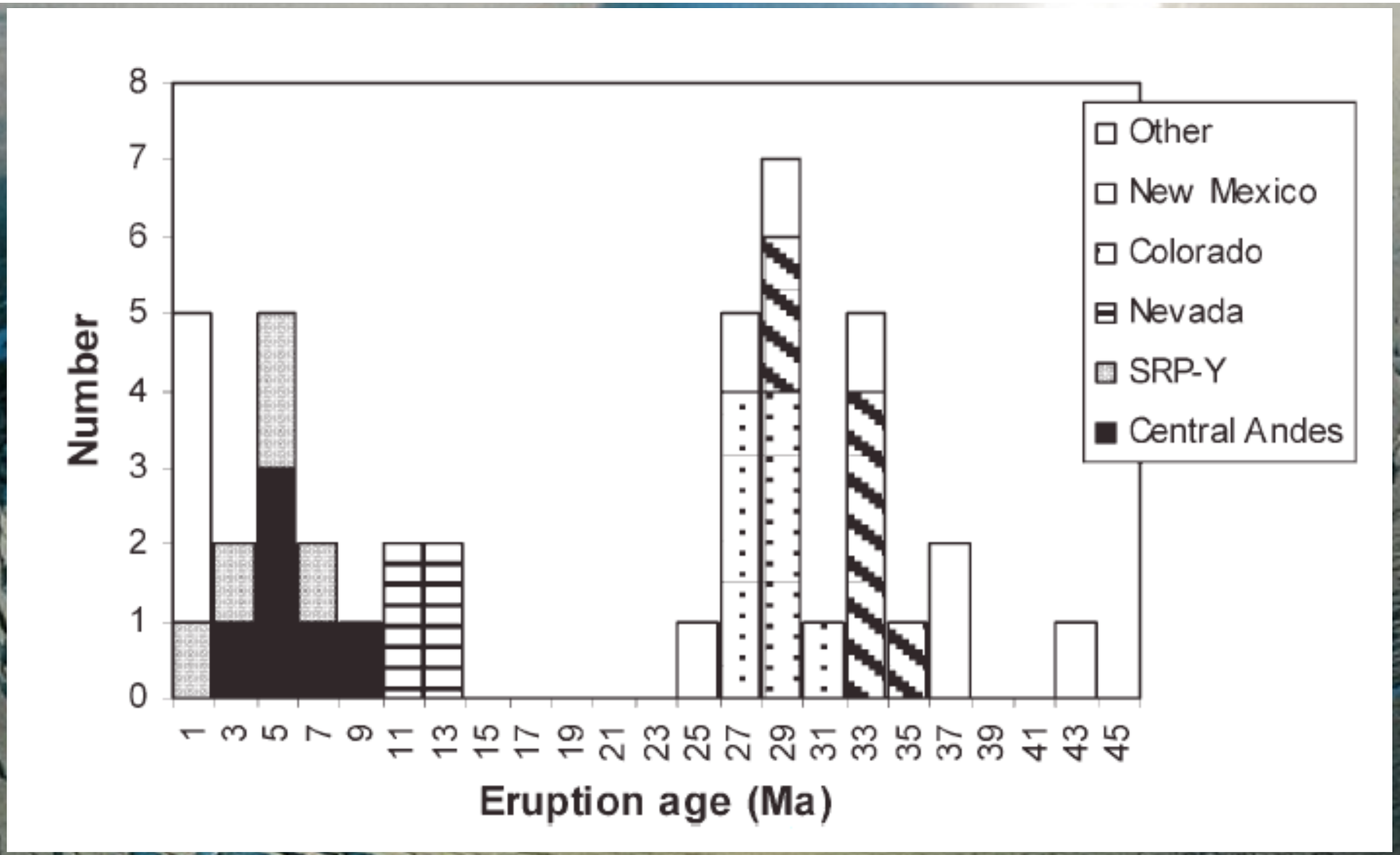


Large Eruptions

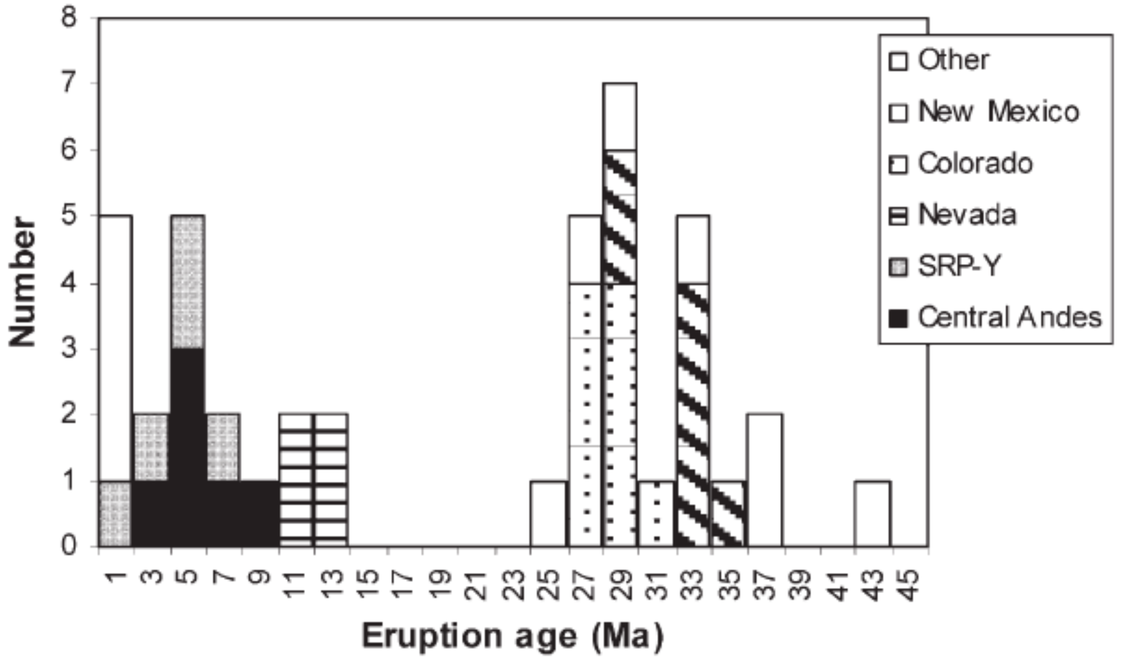
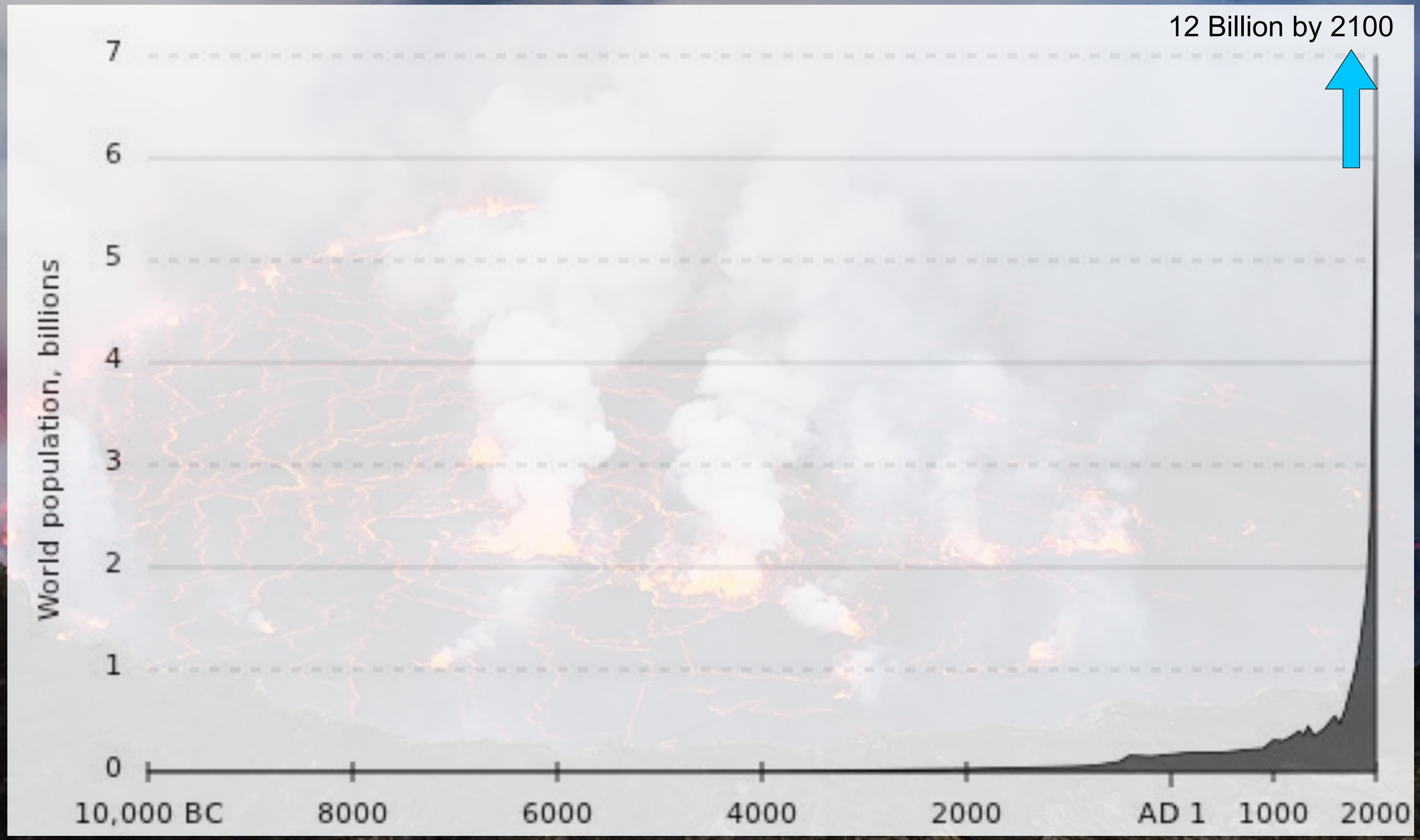


Fig. 5 Histogram (at 2 Ma intervals, with age of the midpoint given on the x axis) showing the time distribution of the 42 known eruptions of M8 and larger over the past 46 Ma. Key geographical areas are highlighted (New Mexico, Colorado, Nevada are in the south-western USA; SRP is the Snake River Plain-Yellowstone province of western USA). Although the record is incomplete, the bimodal pattern of known eruptions may be real, and probably reflects the control of global tectonics on rates of occurrence of large eruptions. Known events from the past 13.5 Ma are dominated by eruptions in the Central Andes and the Snake River Plain-Yellowstone province, while events between 25 and 38 Ma are dominated by eruptions in Colorado and New Mexico, south-western USA. No large silicic provinces are known from the period 17–25 Ma

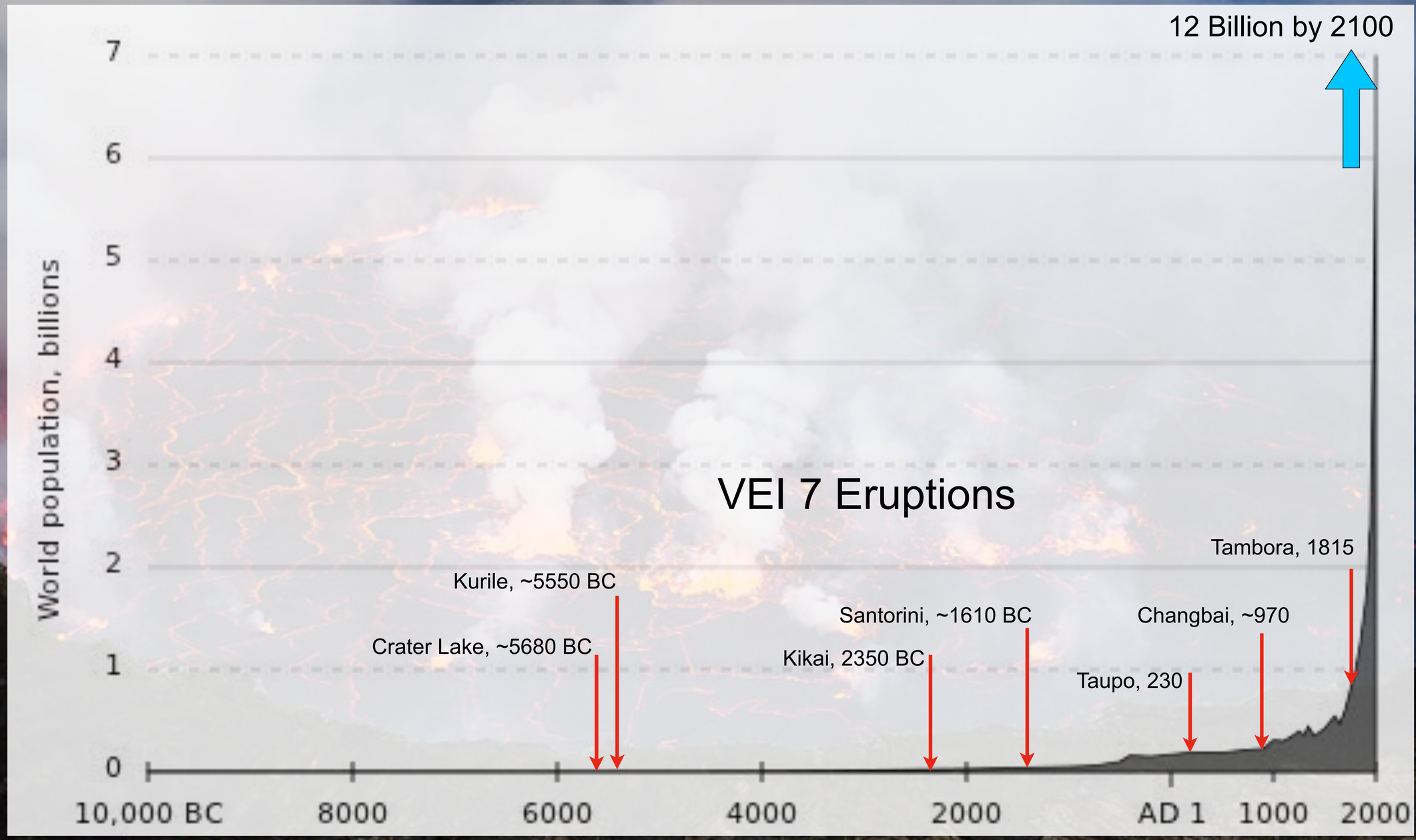
Mason et al., 2004

Large Eruptions

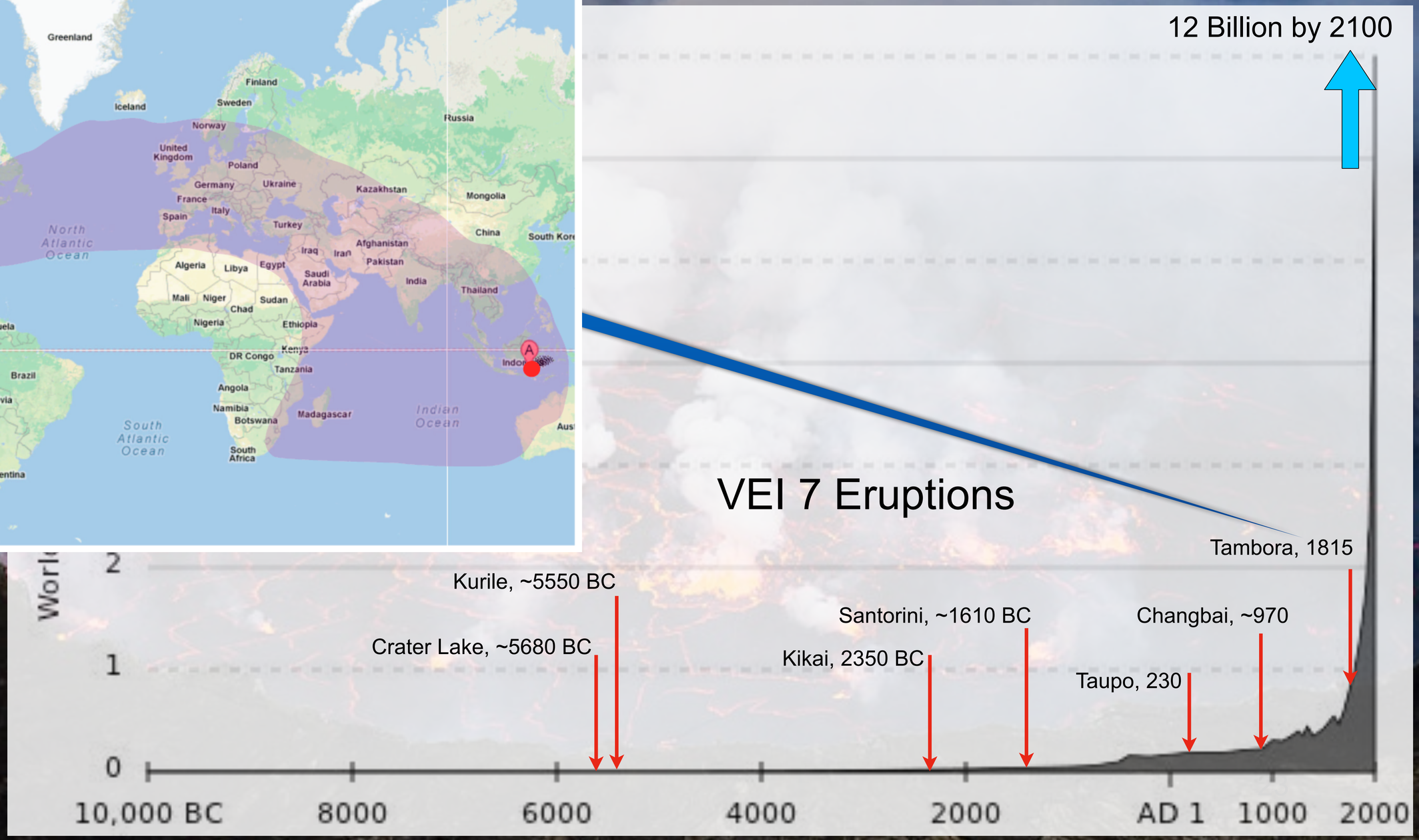
Large Eruptions



Large Eruptions



Large Eruptions



Natural Hazards and Disaster

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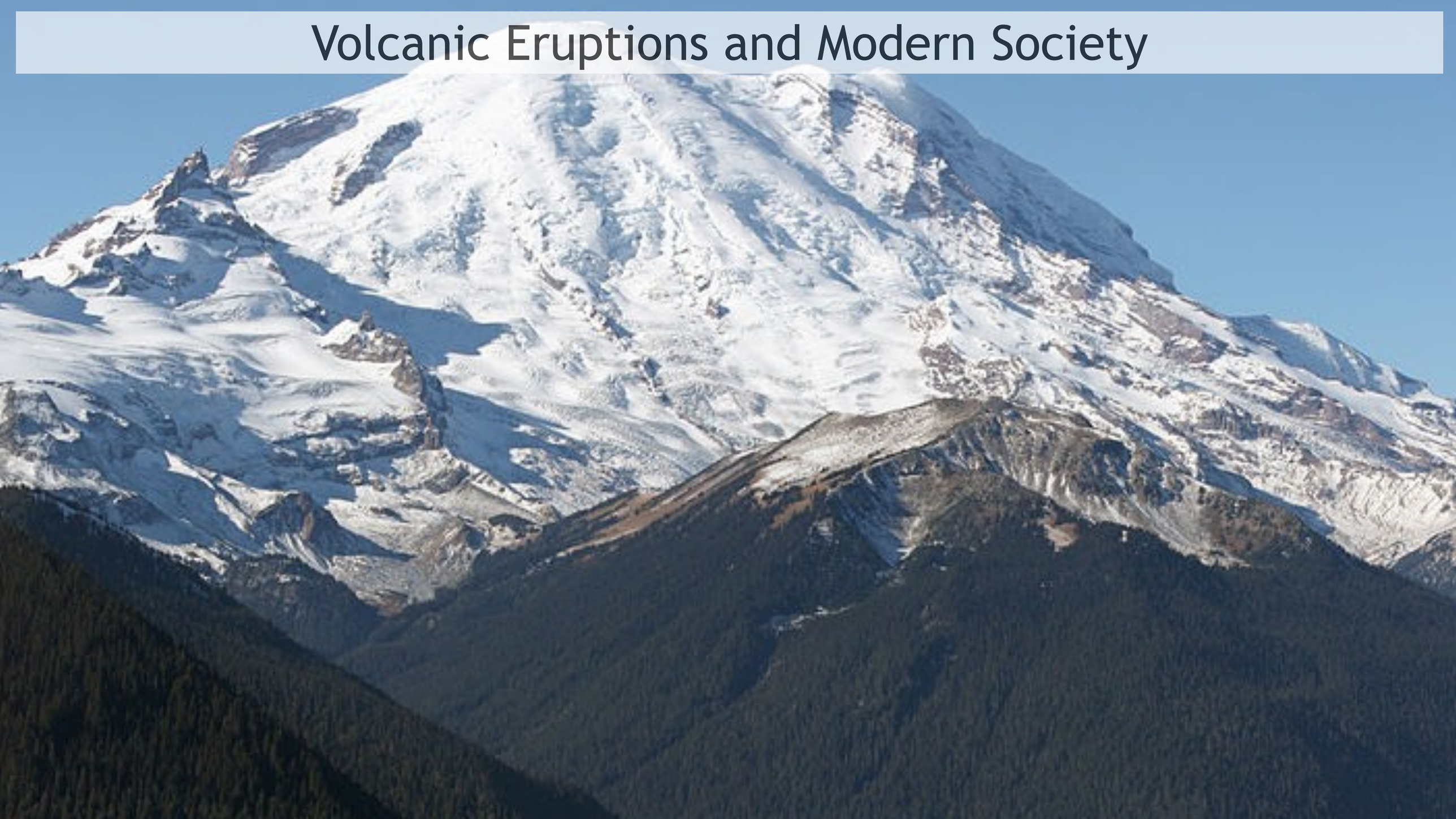
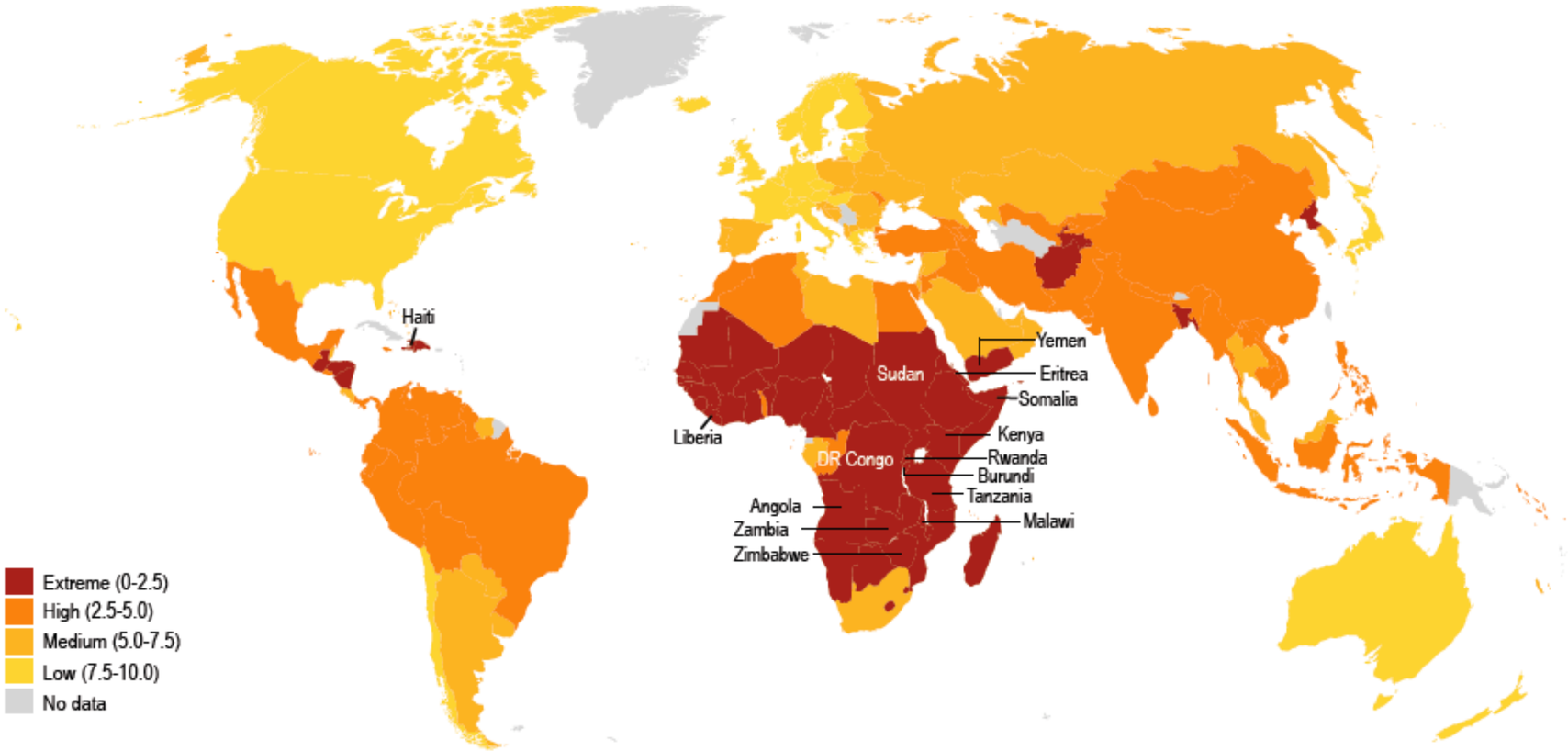
Volcanic Eruptions and Modern Society



Volcanic Eruptions and Modern Society

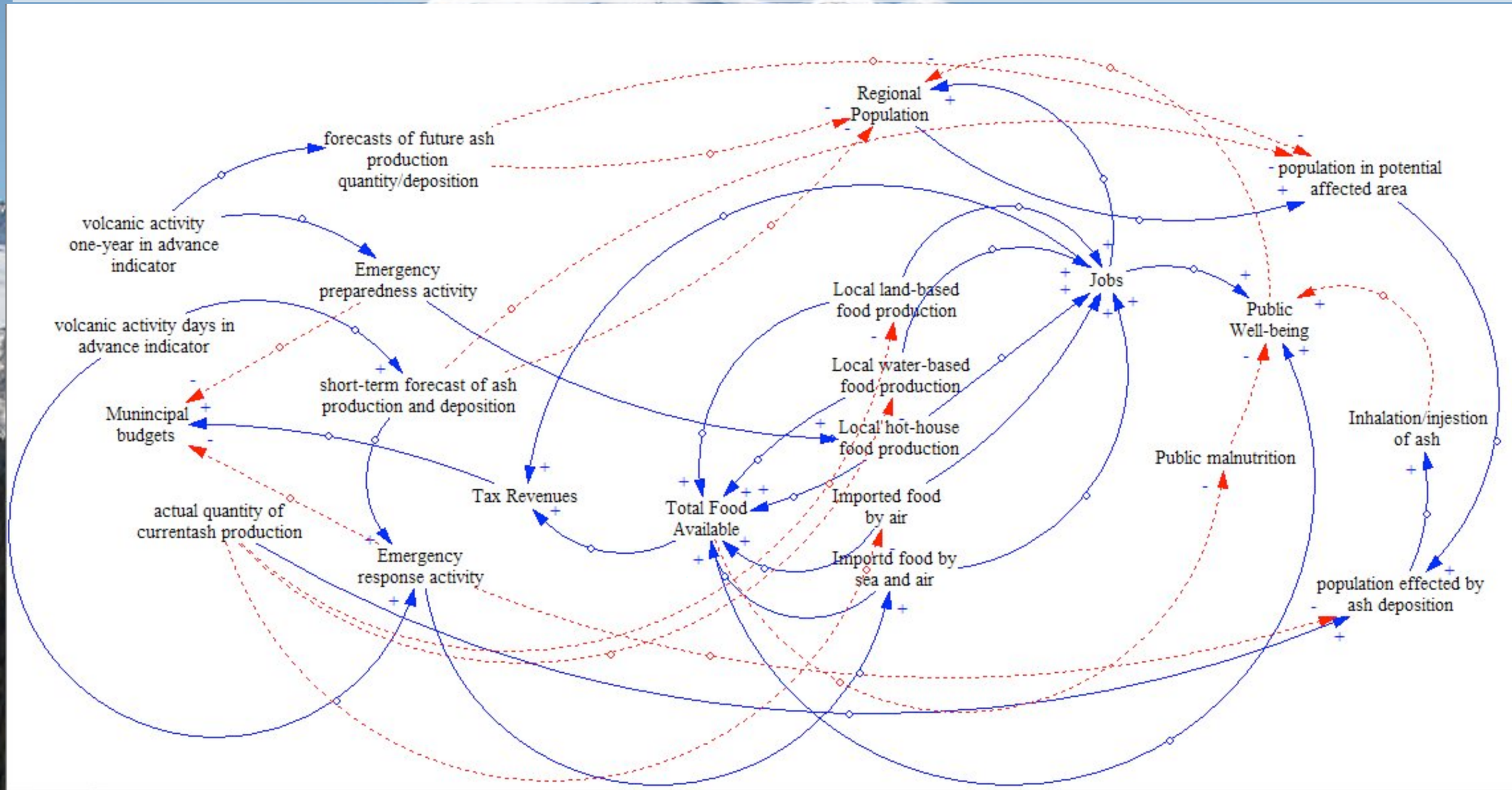
Volcanic Eruptions and Modern Society

Maplecroft's global map of food security

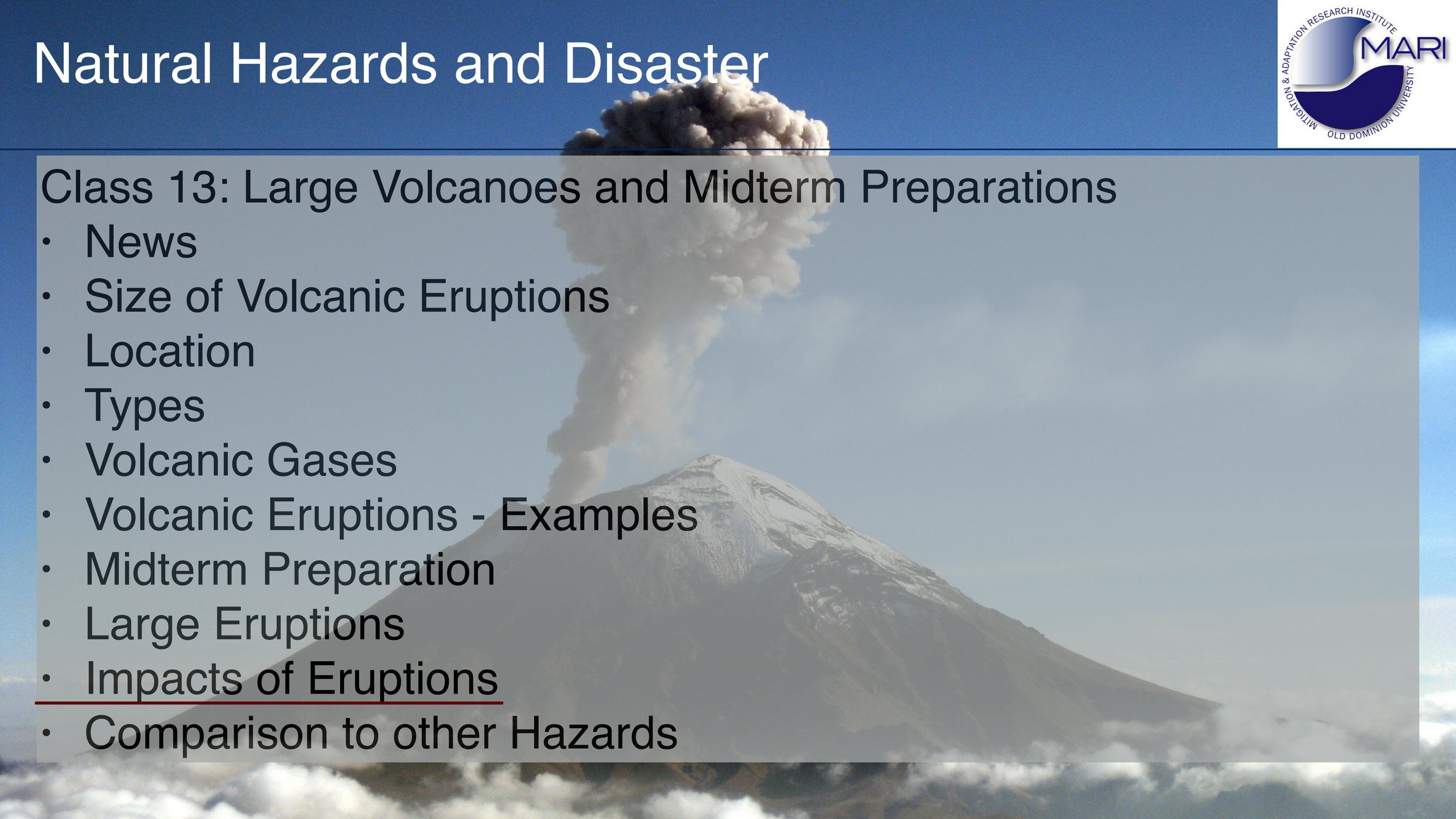


Food Security Index: This map is the visual representation of the Maplecroft Food Security Index (FSI). The FSI evaluates the risk of food insecurity in 162 countries across the globe. It provides a quantitative assessment of the availability, stability and access to food supplies, as well as the nutritional outcomes that result from food insecurity. Each country is assigned an index score based on its performance across 18 key indicators, classified into four sub-indices. Four categories of risk have been identified based on the FSI value for each country – extreme risk (0.0-2.5), high risk (2.5-5.0), medium risk (5.0-7.5) and low risk (7.5-10.0).

Volcanic Eruptions and Modern Society



Natural Hazards and Disaster



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Comparison

Hazard	Events	Fatalities	Per year	Affected	Per year	Damage	Per year	*R*
Drought	410	558,565	19,261	1,551,455,122	53,498,452	76,949	2,653	0.036
Cyclone	1,211	402,911	13,893	496,560,639	17,122,781	533,371	18,392	0.081
Earthquake	706	385,630	13,298	136,333,515	4,701,156	351,079	12,106	0.283
Tsunami	18	229,551	7,916	2,481,879	85,582	10,046	0.346	9.249
Flood	2,887	195,843	6,753	2,809,481,489	96,878,672	397,334	13,701	0.007
Heatwave	126	89,889	3,100	4,614,411	159,118	21,990	758	1.948
Volcano	140	25,197	869	4,080,791	140,717	2,871	99	0.617
Landslide	366	20,008	690	7,031,523	242,466	6,060	209	0.285
Cold wave	156	11,595	400	6,875,103	237,073	5,902	204	0.169
Tornado	182	4,780	165	12,710,204	438,283	31,511	1,087	0.038
Avalanche	73	3,532	122	69,637	2,401	807	28	5.072
Wild fire	294	1,666	57	5,766,092	198,831	42,807	1,476	0.029

Plag et al., 2015

Table 4. Detailed disaster statistics for the period 1980 to 2008. Data from http://www.preventionweb.net/english/professional/statistics/. The database is the OFDA/CRED International Disaster Database, maintained by University Catholique de Louvain, Brussels, Belgium. Data version: v11.08. Damage is in million US $. Hazards are ordered according to fatalities. *R* is the ratio of fatalities to the affected population in percent. See Table 3 for a caveat on the accuracy of the numbers.

Comparison

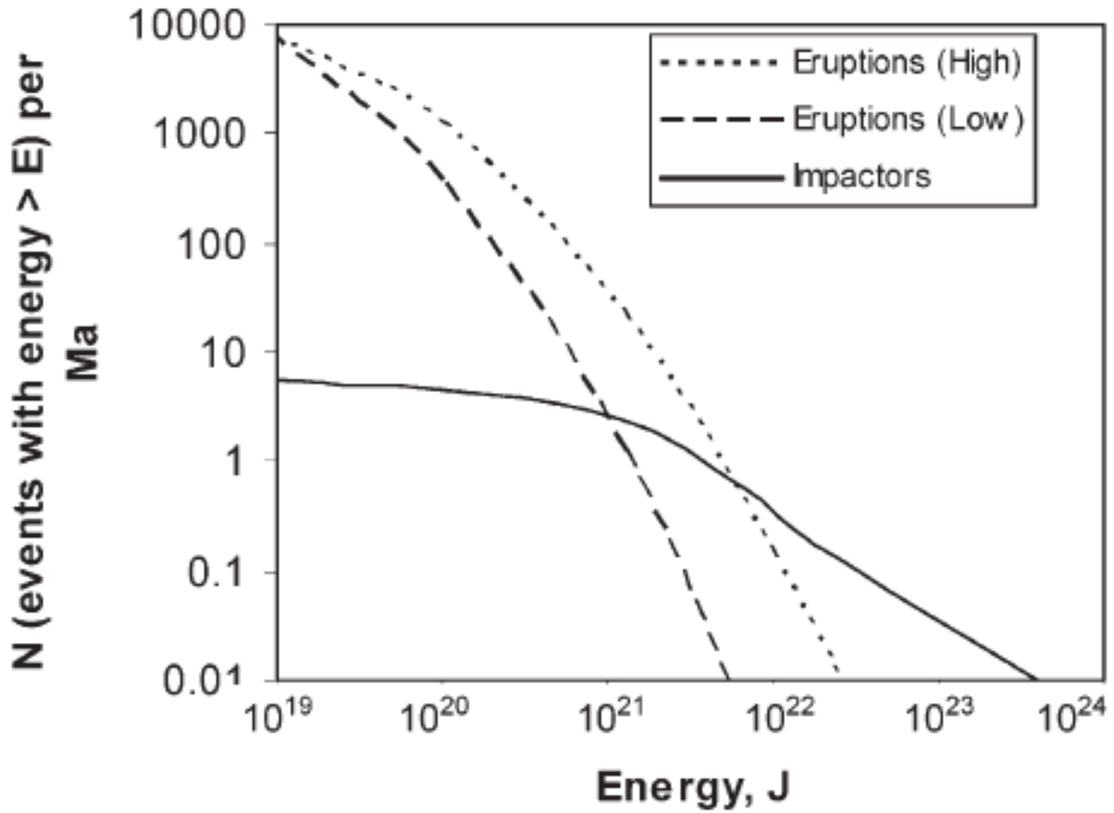
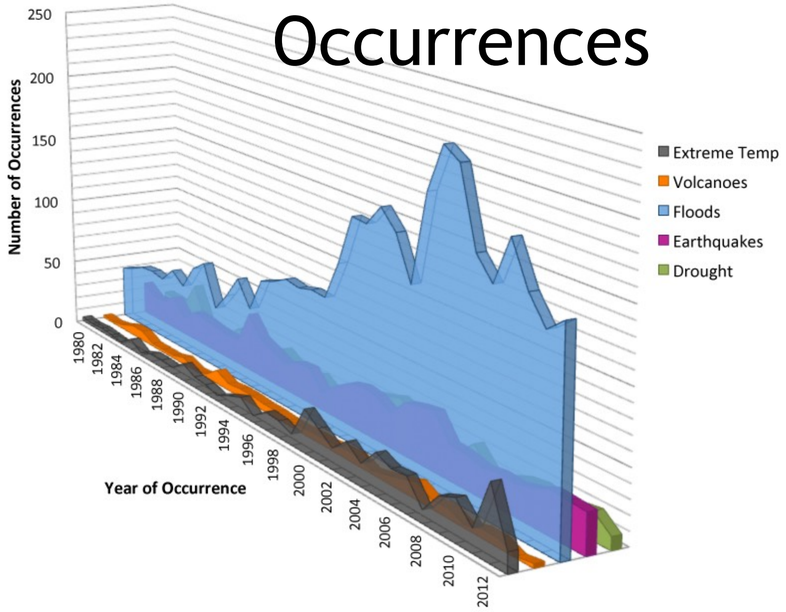


Fig. 9 Comparison of the energy and frequency of large volcanic eruptions and impacting asteroids. The impactor curve is based on estimates of the rate of cratering of Earth's surface over the recent past (Hughes 2000). The volcanic eruption curves are based on the upper and lower estimates of eruption frequencies of 22 events/Ma (high) and 1.4 events/Ma (low). For event energies of up to about 10^{21}–10^{22} J (a frequency of ~10 events/Ma) volcanic eruptions are more frequent than asteroid collisions of equivalent energy

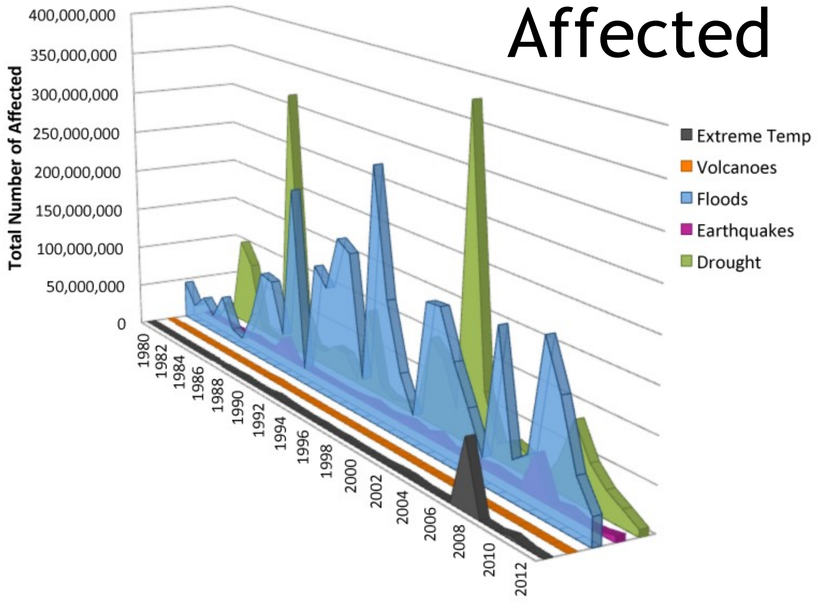
Mason et al., 2004

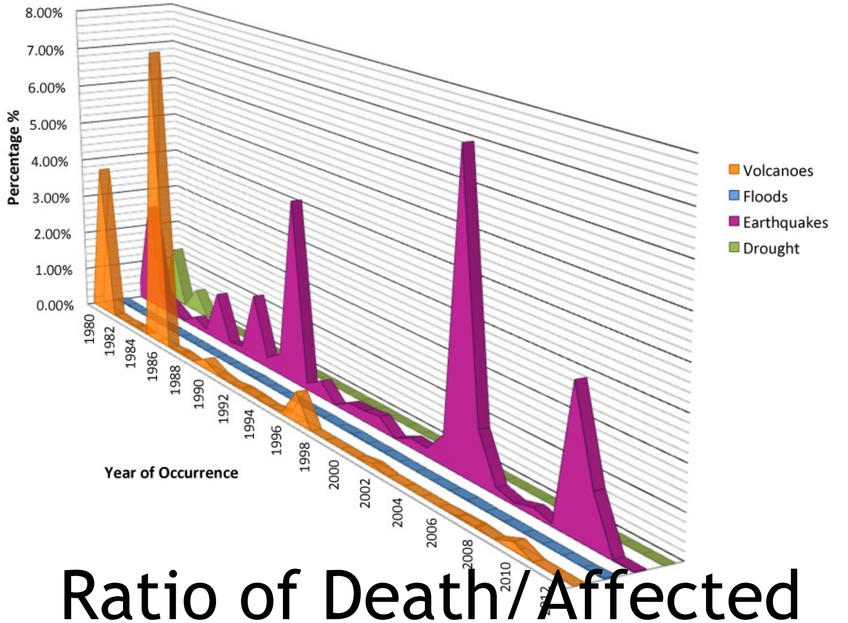
Comparison

Occurrences



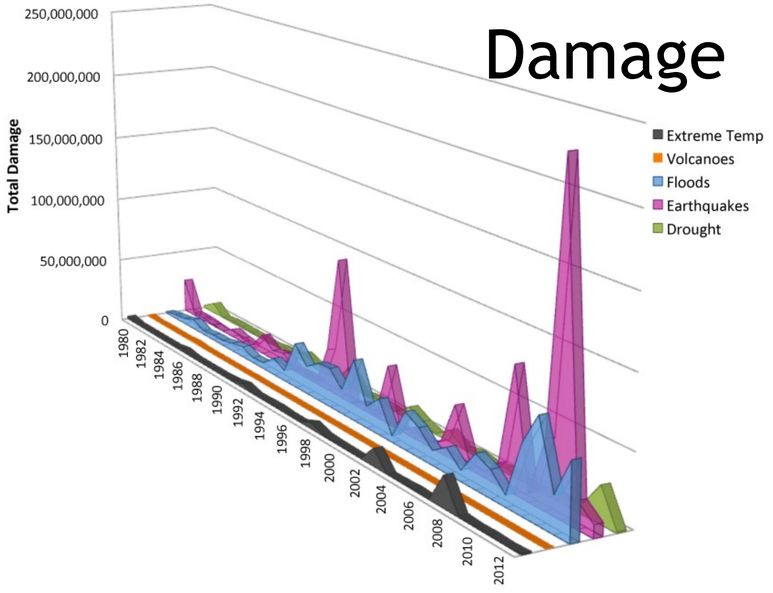
Affected



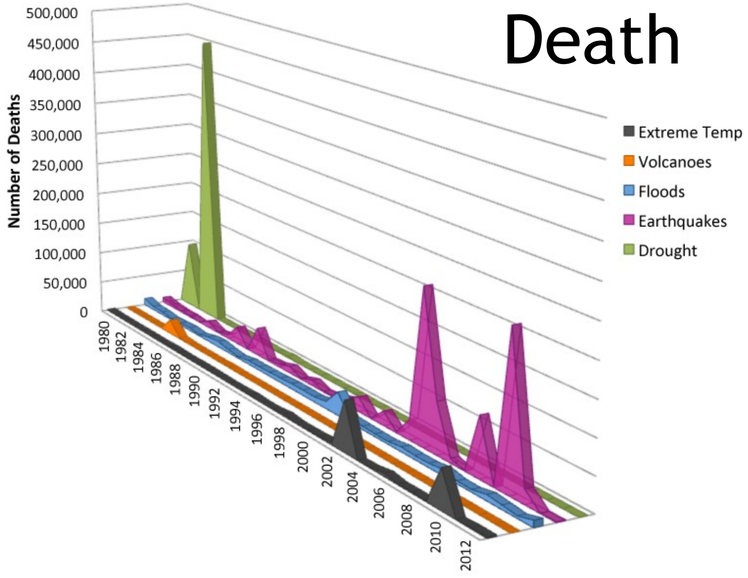


Ratio of Death/Affected

Damage



Death

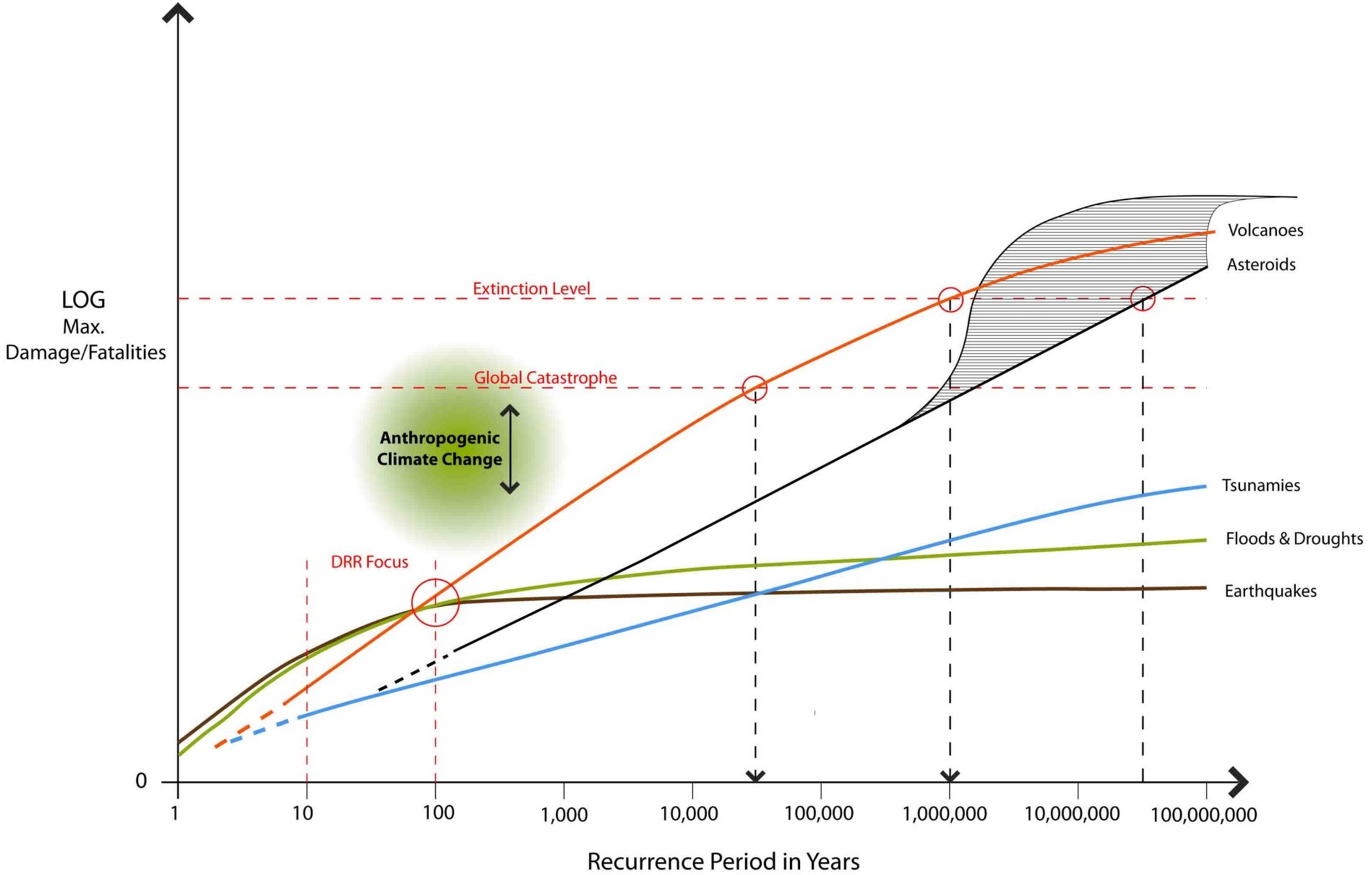


International Disaster Database

http://www.emdat.be/advanced search/.

Comparison

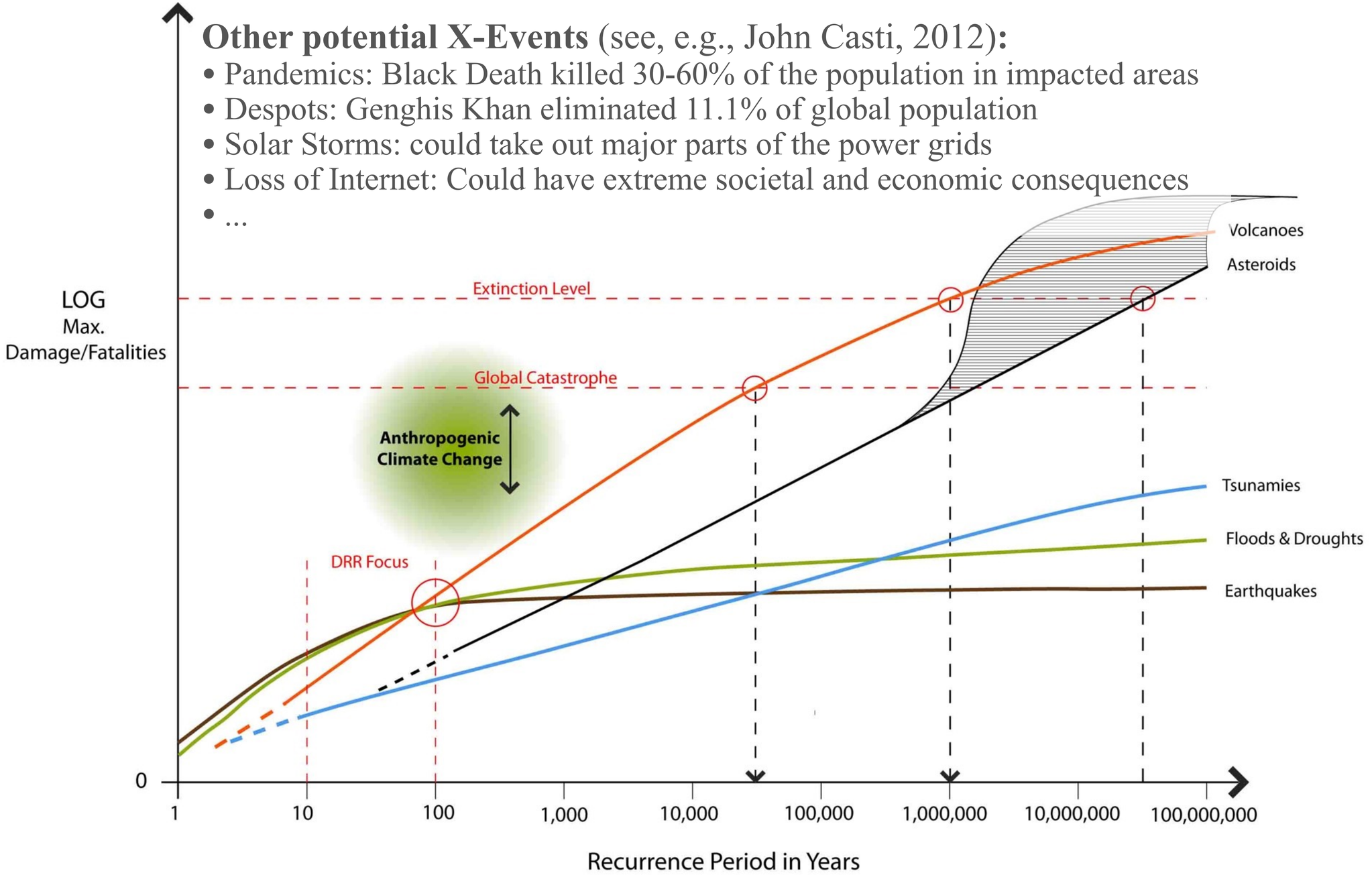
Comparison


LOG
Max.
Damage/Fatalities
Extinction Level
Global Catastrophe
Anthropogenic
Climate Change
DRR Focus
Volcanoes
Asteroids
Tsunamies
Floods & Droughts
Earthquakes
0
1
10
100
1,000
10,000
100,000
1,000,000
10,000,000
100,000,000
Recurrence Period in Years

Comparison

Other potential X-Events (see, e.g., John Casti, 2012)**:**

- Pandemics: Black Death killed 30-60% of the population in impacted areas
- Despots: Genghis Khan eliminated 11.1% of global population
- Solar Storms: could take out major parts of the power grids
- Loss of Internet: Could have extreme societal and economic consequences
- ...



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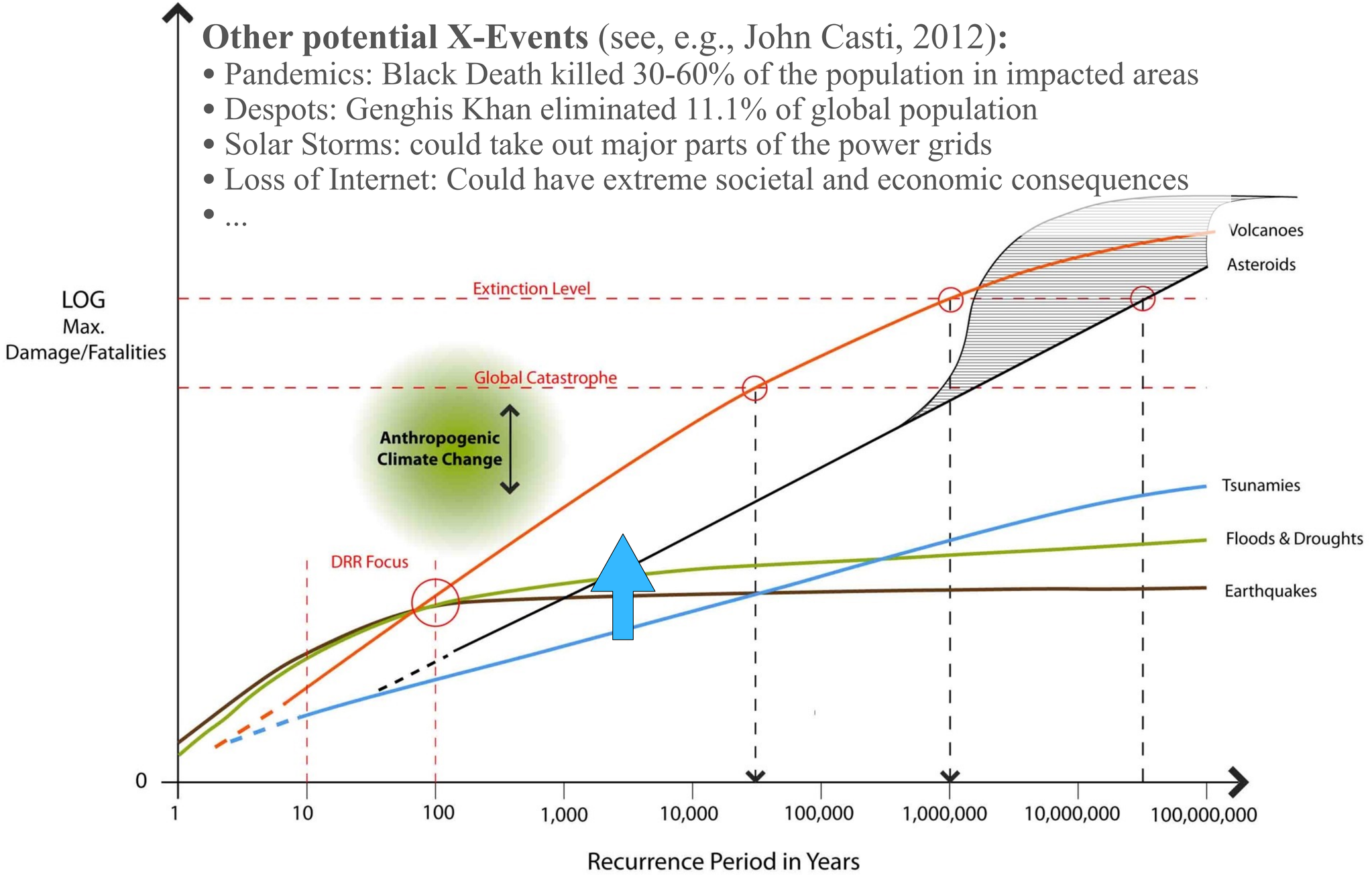

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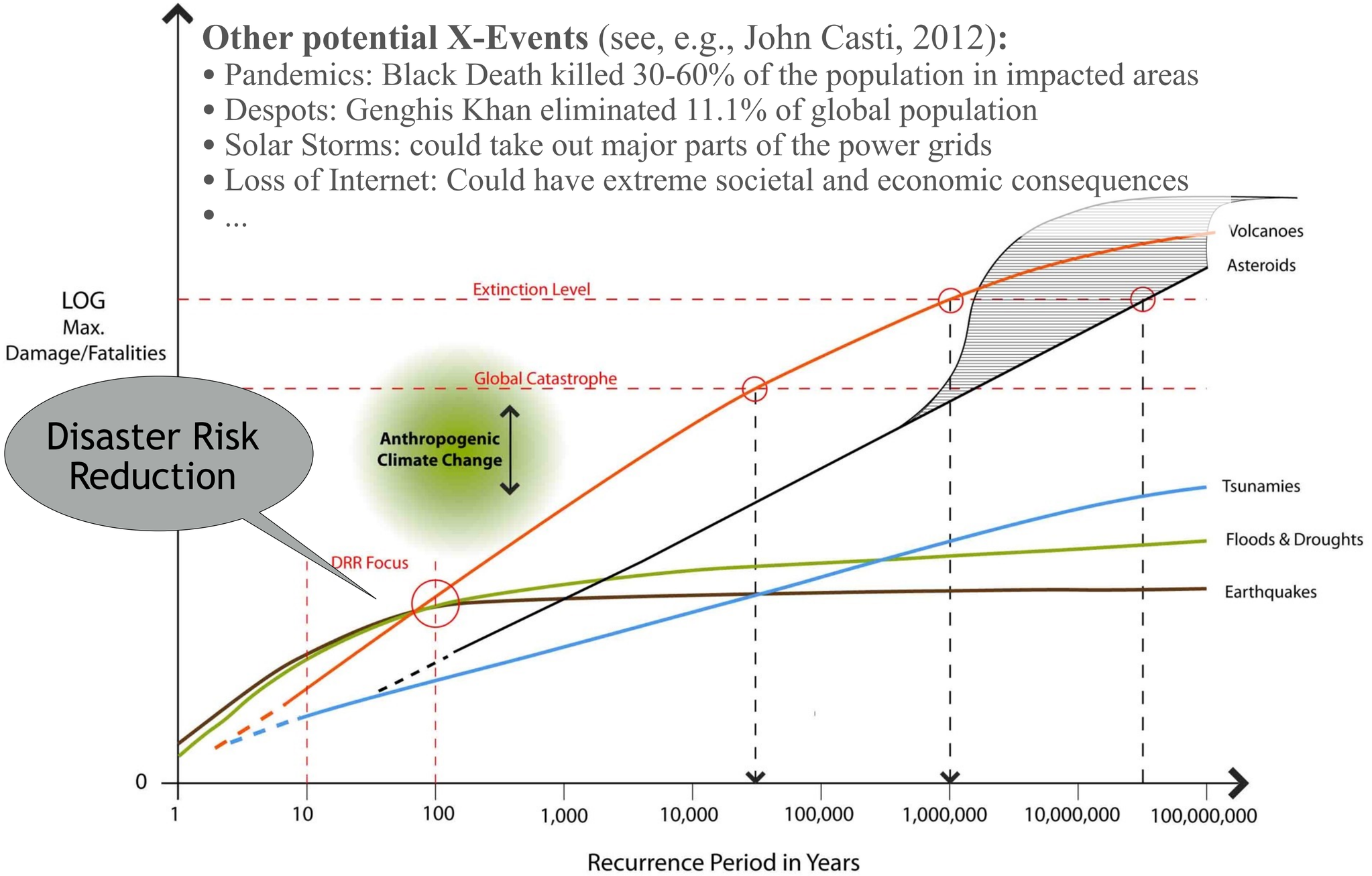

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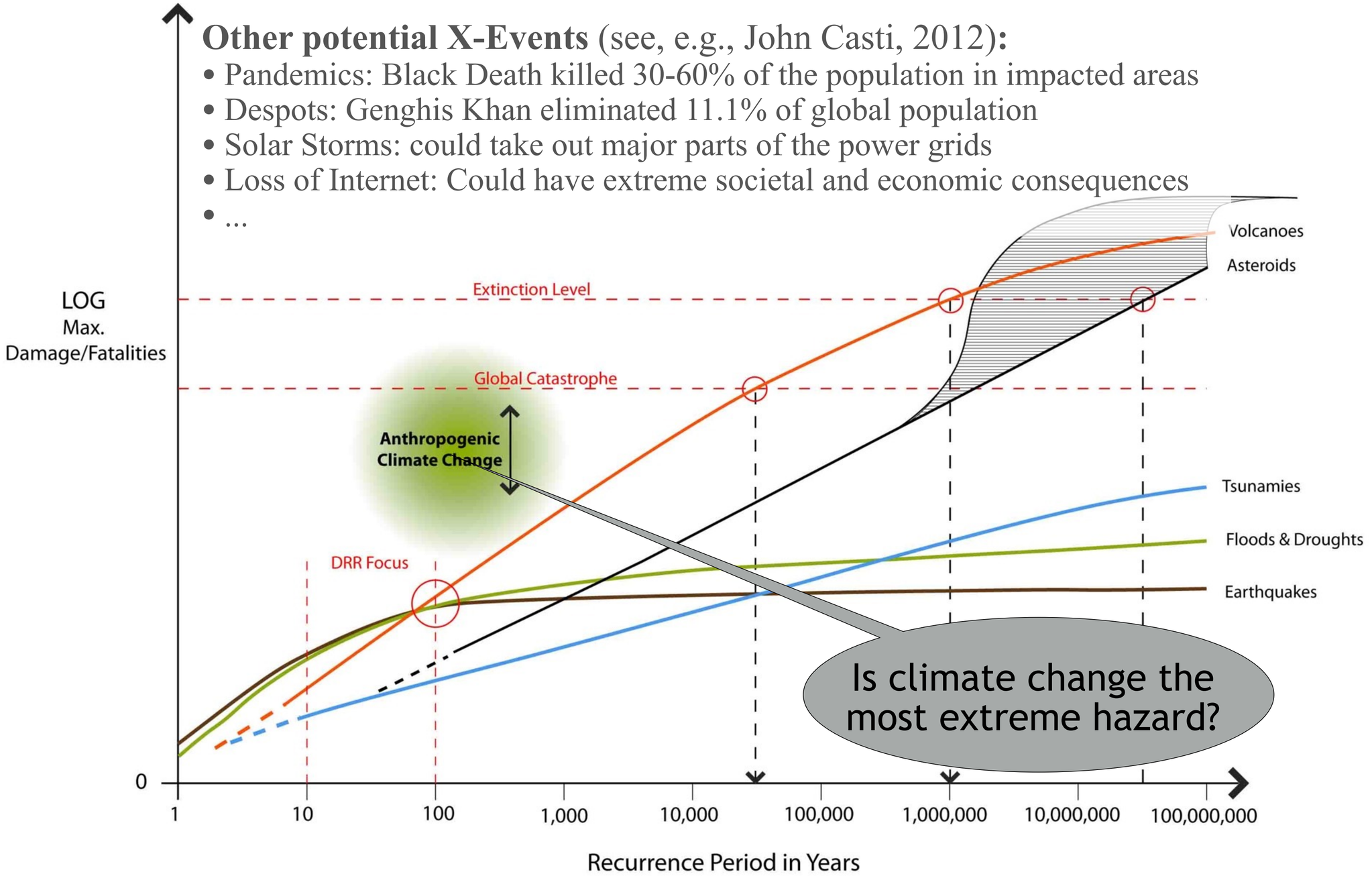
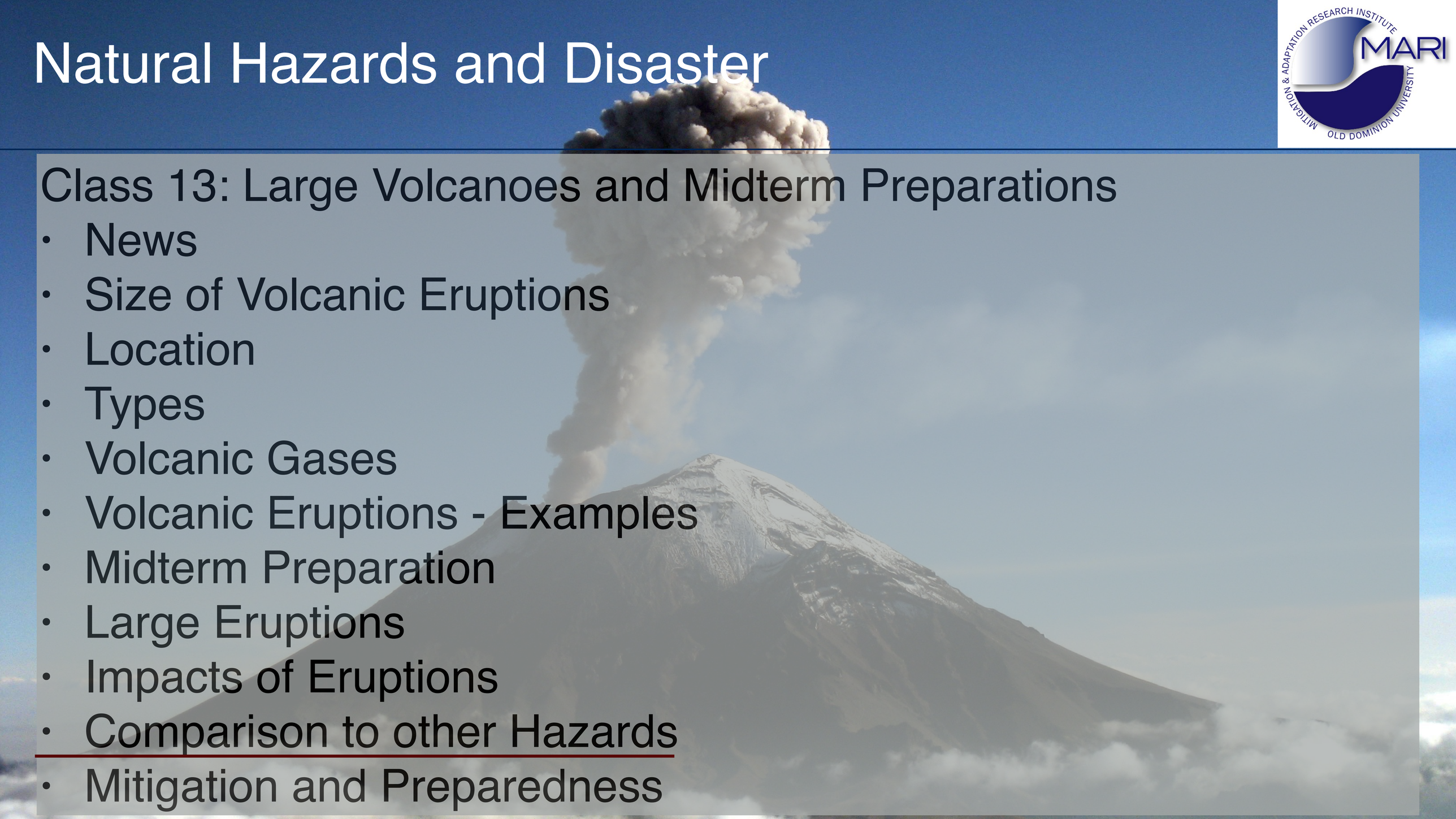


Natural Hazards and Disaster



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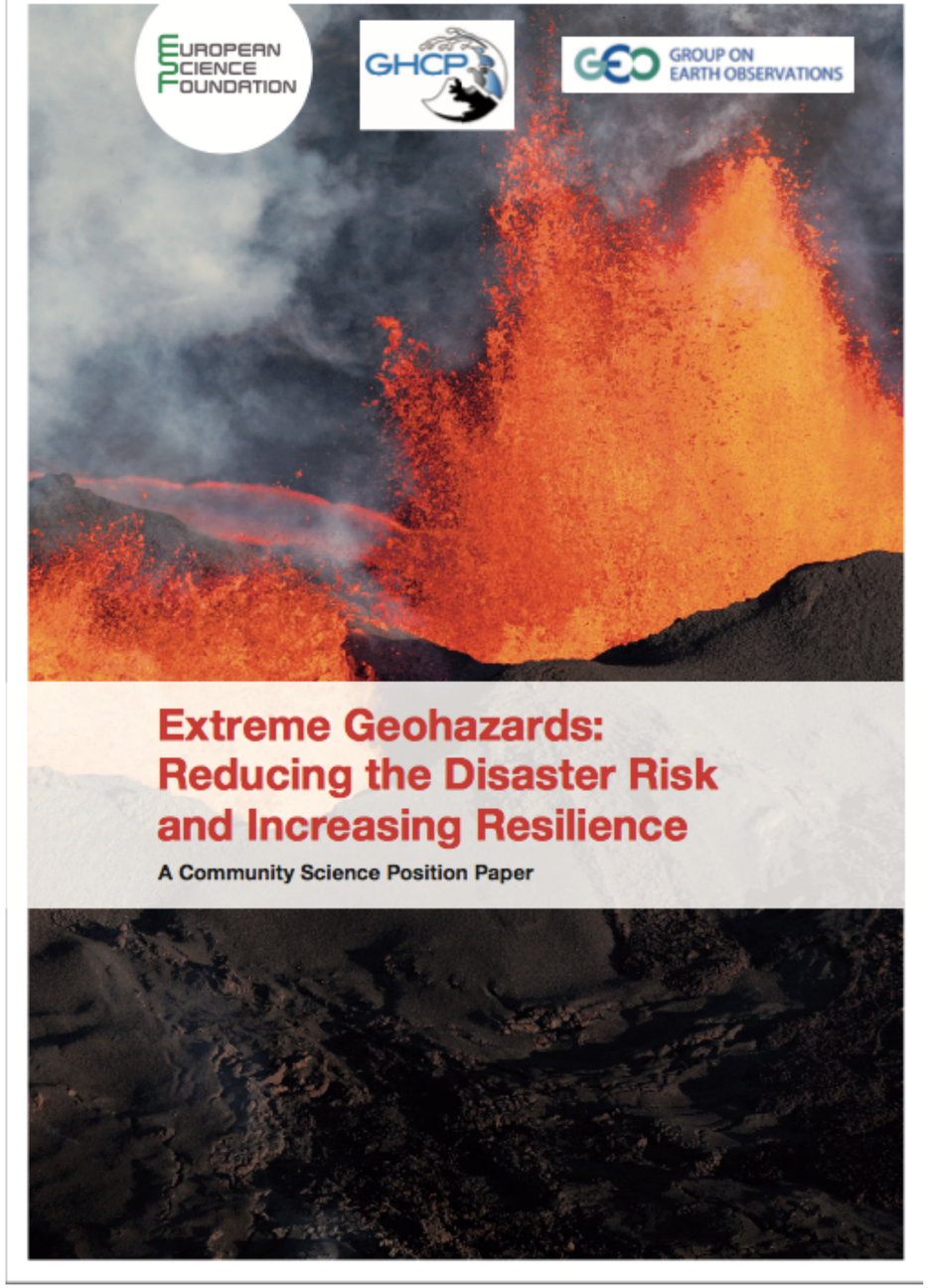
Mitigation and Preparedness

Mitigation - the effort to reduce the consequences of disasters

- Structural (e.g. levees to hold back lahars)
- Management (e.g. evacuation)
- Reducing vulnerabilities and increasing preparedness

What information do we need for risk management?



Mitigation and Preparedness

Recurrence interval, T_R- avg. time between eruptions

- can be on geological time frame
- or on human time frame

$$T_R = N/n$$

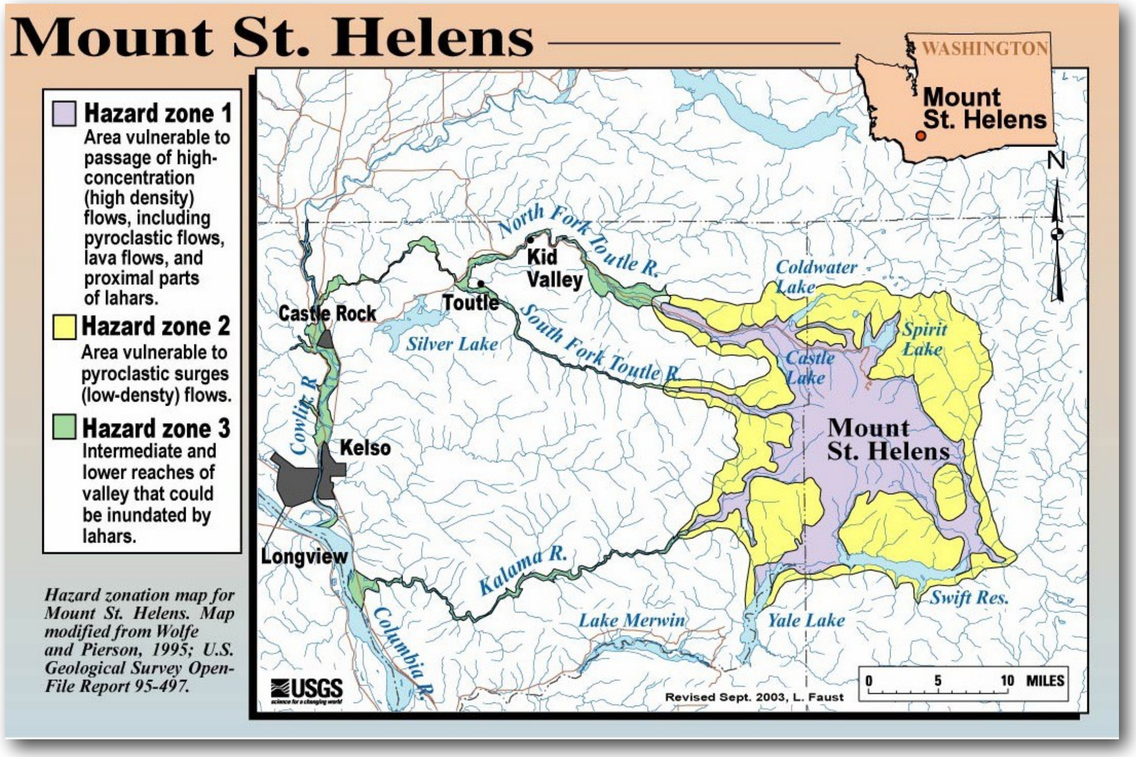
units of T_R can be in years, thousands of years, millions of years

N is number of years (or thousands, or millions of years) in the record

n is number of events

Mitigation and Preparedness

Hazard map - past distribution of ash, lava, pumice, lahars, etc.



- important to study prevailing winds (for ash flows) and topography (for lahars)

Population density in region of hazard

Mitigation and Preparedness

Cost

preparedness:

- risk assessment
- construction of barriers (local)
- food security (regional and global)
- relocation (local to regional)

before and during eruption:

- early warning
- evacuation
- rescue
- damage assessments

After eruption:

- clean-up
- restoring
- relocation
- risk assessment

Risk assessment

What information do we need?

1. Probability, P, of recurrence $P = 1/T_R$

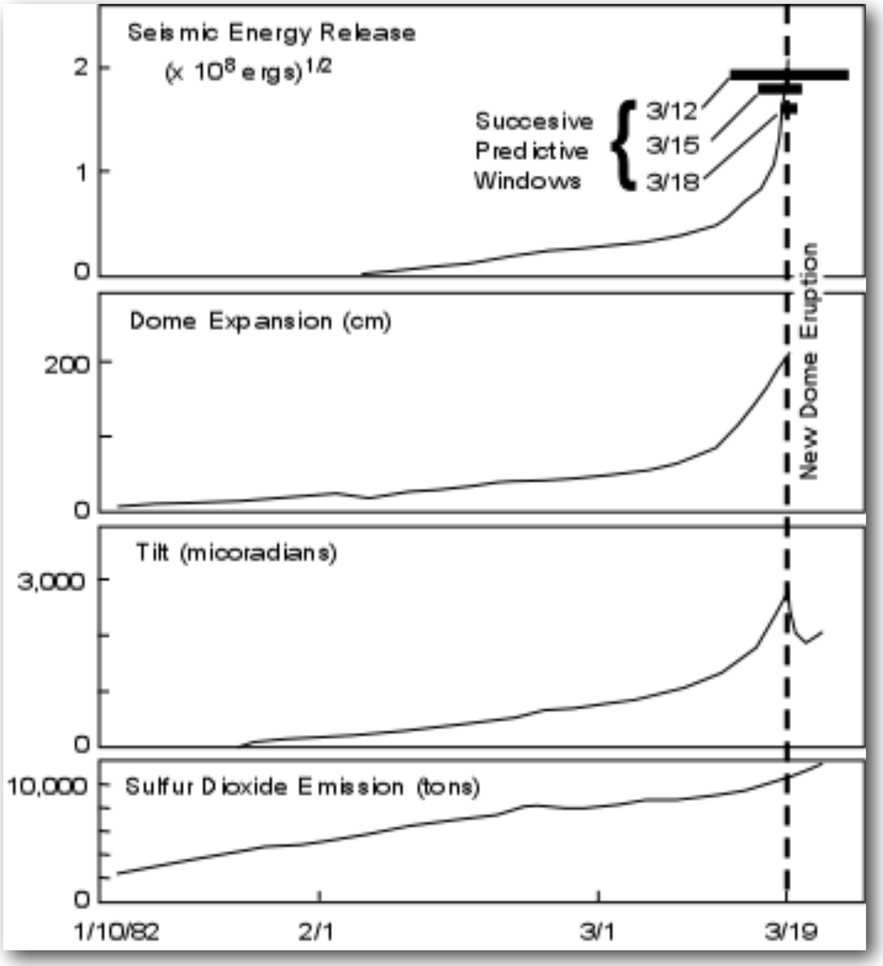
units of P, like T_R, can be in years, thousands of years, millions of years

T_R = Recurrence interval (volcanic eruption frequency)

2. Hazard Map

3. Predictors - Early warning signals

Early warning signals include:



http://www.tulane.edu/~sanelson/images/rruptprecurs.gif

data from 1982 Mt St Helens eruption

Increase in local earthquake activity

Change of shape of volcano

Increase in gas emission and/or change in composition of gases