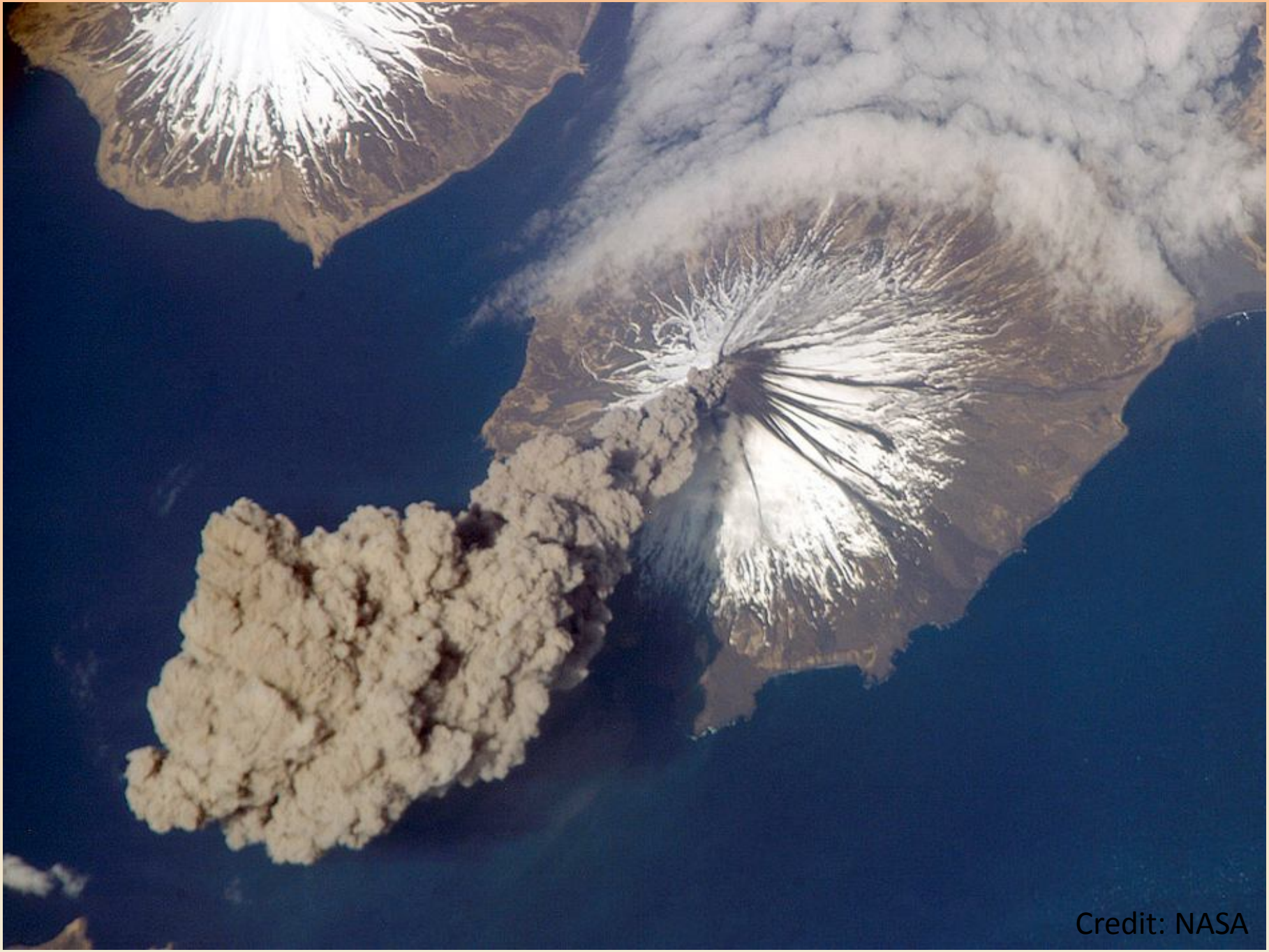
Importance of volcanic activity in climate change models

Petra Belobrk, Zita Brigljević, Gordana Medunić

University of Zagreb, Faculty of Science, Department of Geology
Horvatovac 95, 10 000 Zagreb


Credit: NASA

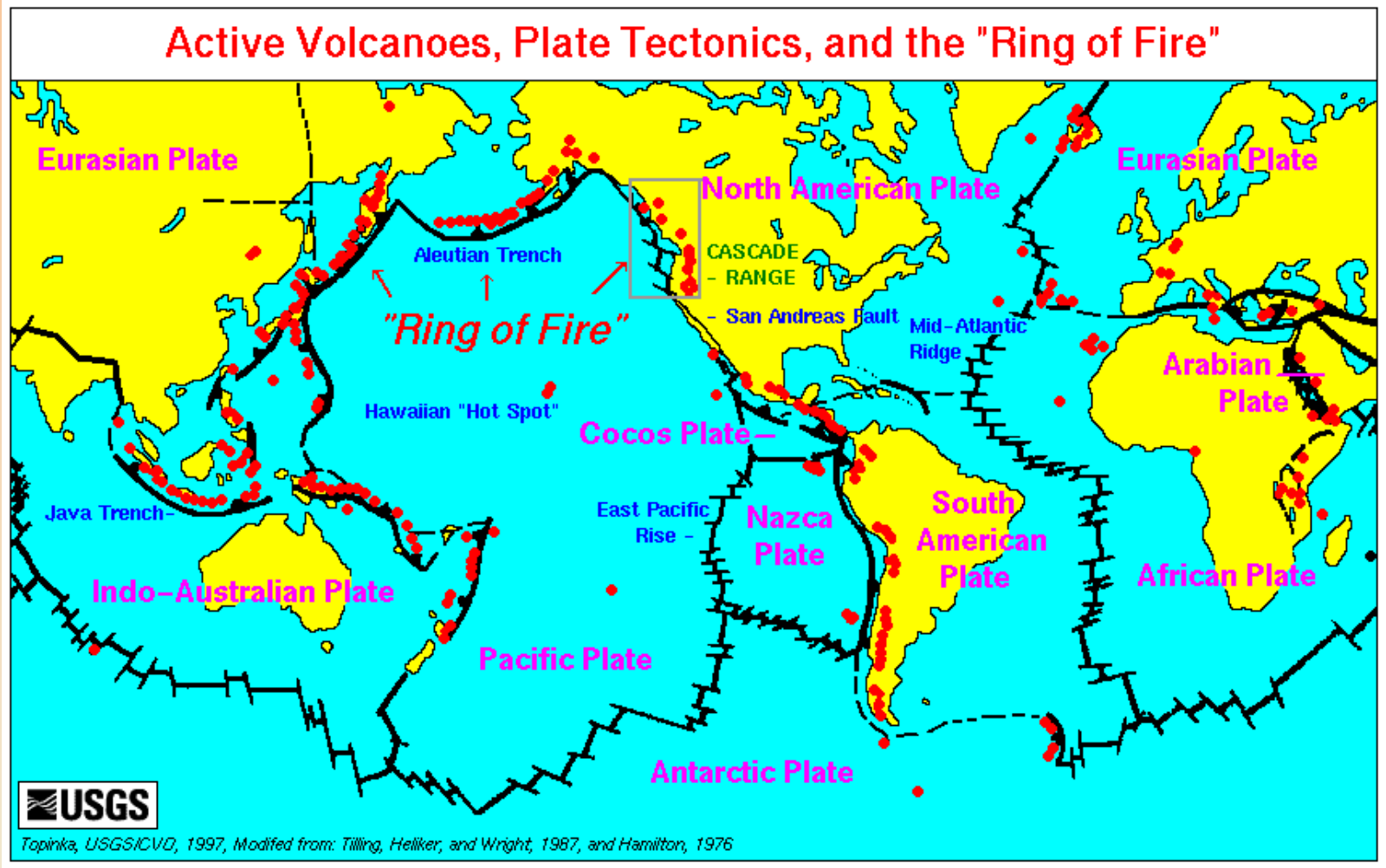
- Advancement in science and engineering → application in Earth Sciences
- Climate change models → understanding the past and foreseeing the future
- Oreskes et al. (1994): how can mathematics calculate something as non – linear as climate?

What kind of eruption can affect climate?

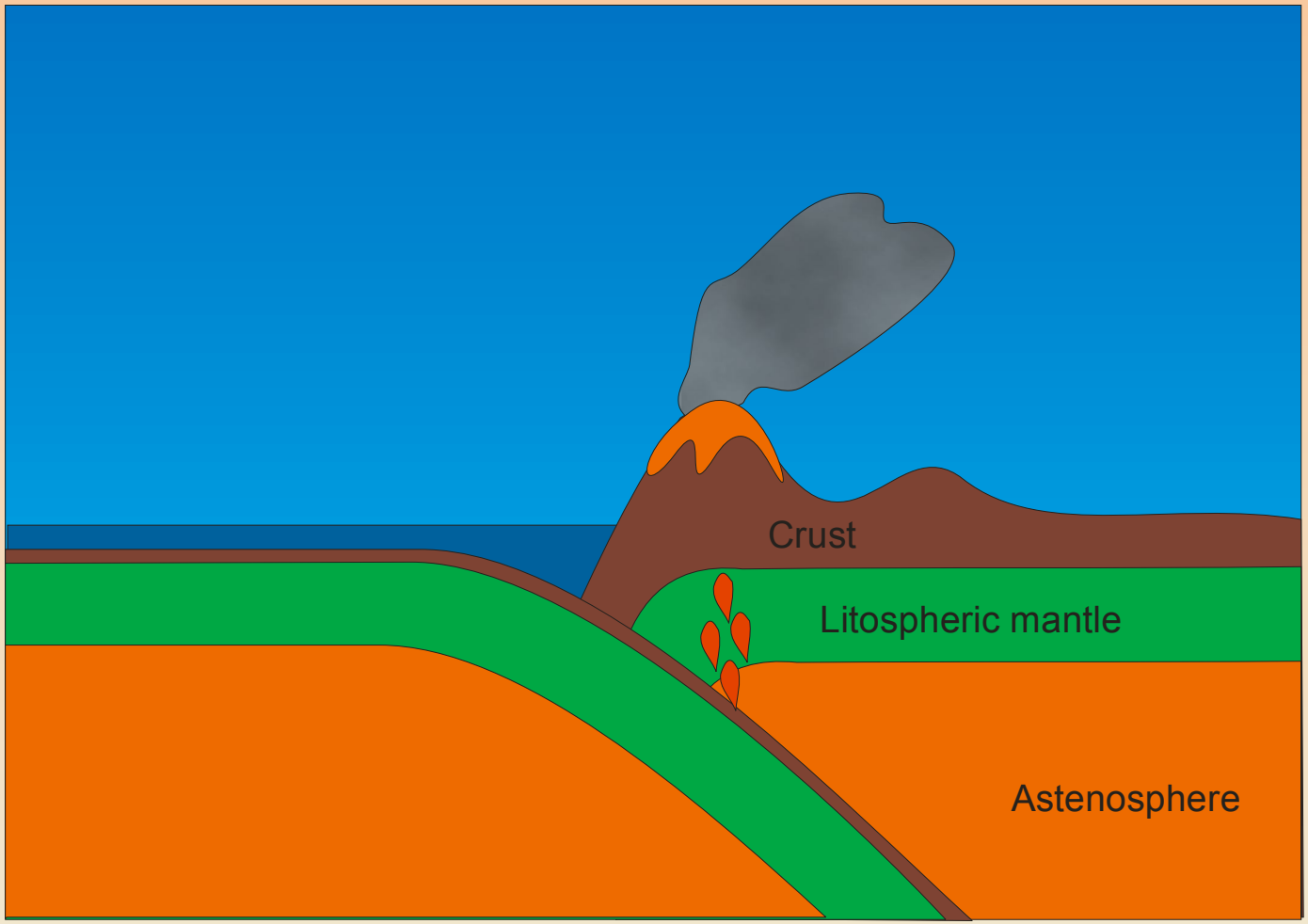
- Highly explosive volcanoes (VEI scale)
  → high eruption column
  → great amounts of ejecta

- High concentrations of sulphur within the volcano

″The Ring of Fire″



Convergent plate boundary



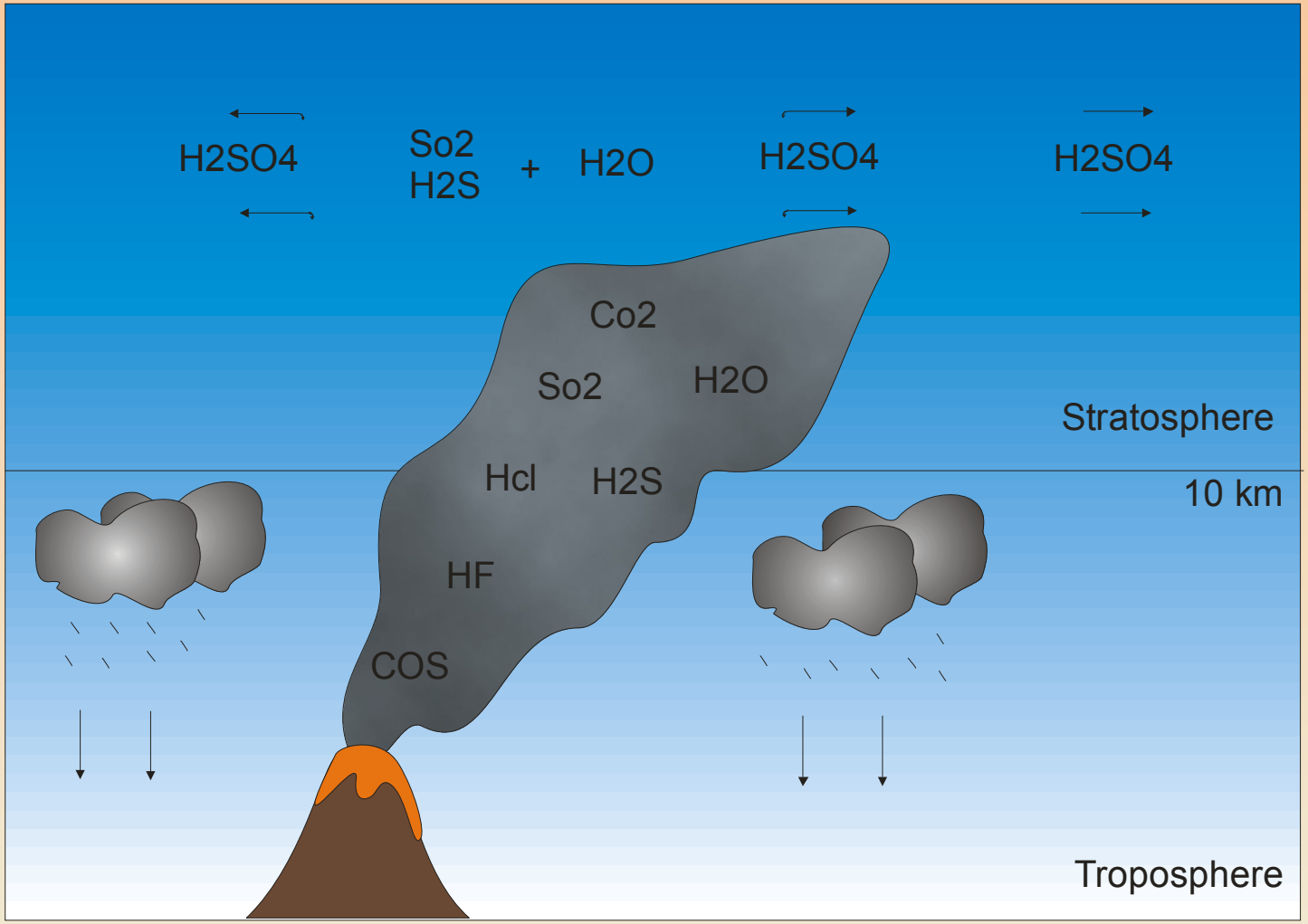
Products of a volcano

- Lava
- Volcanic ash
- Tephra
- Gases:
  - H_2O, COS, CO_2, CO, N_2, SO_2, H_2S, HF, HBr...

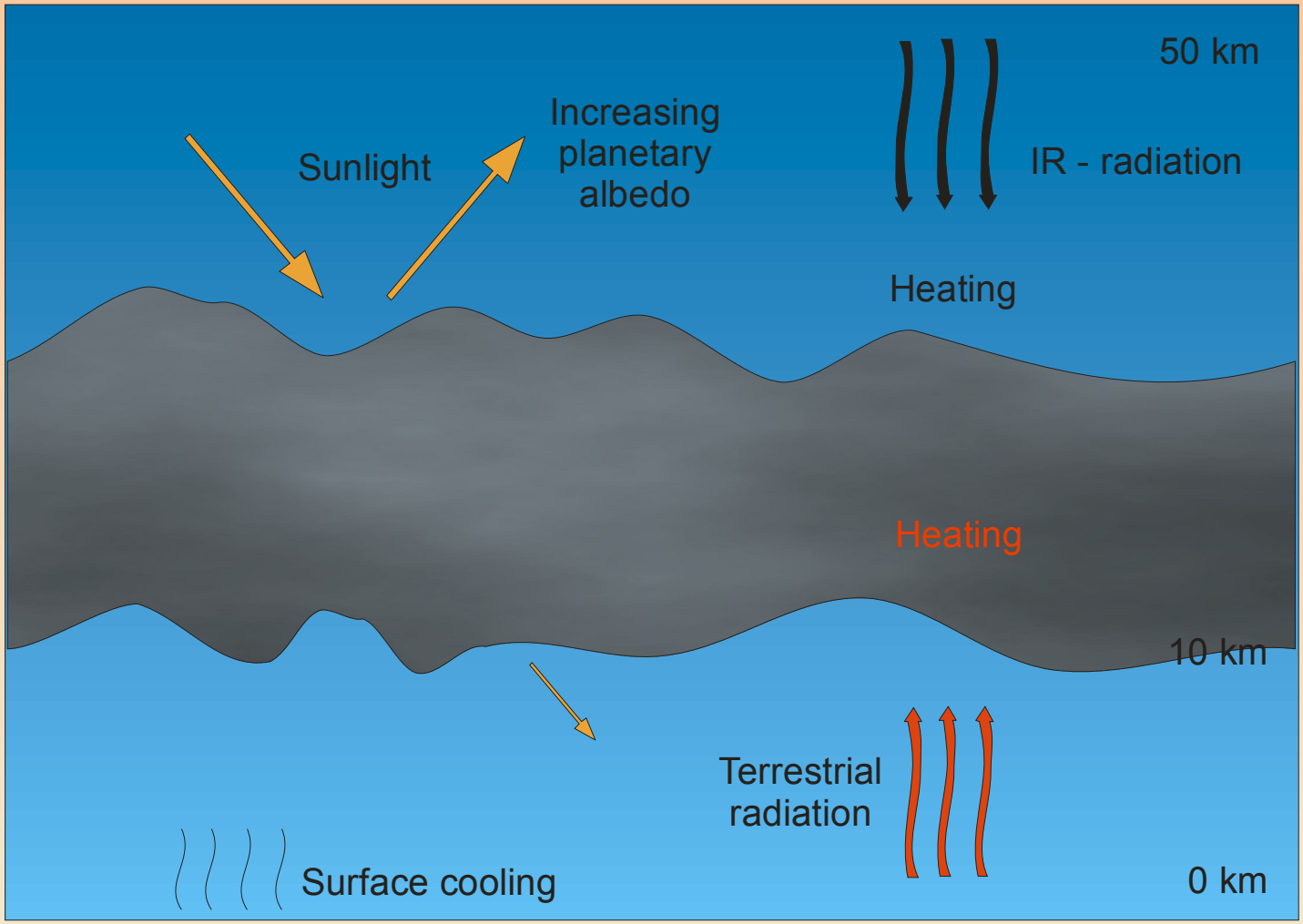
Volcanic ash

- Composition:
  - fine – grained rock
  - mineral fragments
  - glass shards
- Greatly interferes with air traffic
- Damages the aircrafts
- No significant impact on climate

Formation of aerosols



Effects of aerosols



Consequences of H_2SO_4 aerosols

- Sunlight backscatter

  → Decrease in global temperature a year after the eruption
- Stratospheric heating

  → Winter warming effect
- Aircraft problems

Influence of H_2SO_4 aerosols on global temperature

Year*3	Date*3	Volcano*3	VEI*3	Location*3	Latitude *3	H2SO4 metric tons	ΔT°C of annual mean compared to the next year *4
1883	May, 20th	Krakatau	6	Indonesia	6.102 S	2,94 x 10^4*1	-0,08
		Augustine	4	Alaska, USA	59.363 N		
1886	June, 10th	Okataina	5	New Zealand	38.120 S	5,00 x 10^6*1	-0,08
		Niuafo'ou	4	Tonga	15.600 S		
		Tungurahua	4	Ecuador	1.467 S		
1902	October, 24th	Santa Maria	6	Guatemala	14.756 N	1,80 x 10^5*1	-0,06
		Soufriere St. Vincent	4	West Indies	13.330 N	2,40 x 10^5*1	
		Mount Pelee	4	West Indies	14.820 N		
1907	March, 28th	Ksudach	5	Khamchatka, Russia	51.800 N	NIA*5	-0,01
1912	June, 6th	Novarupta	6	Alaska, USA	58.270 N	7,90 x 10^6*1	0,02
1913	January, 13th	Colima	5	Mexico	19.514 N	NIA*5	0,16
1932	April, 21st	Cerro Azul - Quizapu	5	Andes, Chile	35.653 S	NIA*5	-0,15
		Fuego	4	Guatemala	14.473 N		
1955	October, 22nd	Bezymianny	5	Khamchatka, Russia	55.978 N	6,00 x 10^6*1	-0,06
1963	February, 18th	Agung	5	Bali, Indonesia	8.342 S	2,84 x 10^6*1	-0,27
1980	March, 27th	Mount St. Helens	5	Washington, USA	46.200 N	7,90 x 10^4*1	0,05
1982	March, 28th	El Chichon	5	Mexico	17.360 N	7,00 x 10^4*1	0,18
		Galunggung	4	Java, Indonesia	7.250 S		
1991	April, 2nd	Mount Pinatubo	6	Philippines	15.130 N	30,00 x 10^6*2	-0,19
		Mount Hudson	5	Andes, Chile	45.900 S		

*1 Bradley, R.S., Jones, P.D., Records of explosive volcanic eruptions over the last 500 years, Reprinted from 'Climate since A.D. 1500', edited by R.S. Bradley and P.D. Jones, Routledge London, 1992, 606 – 622

*2 Liu, X., Penner, J.E., Effect of Mount Pinatubo H2SO4/H20 aerosol on ice nucleation in the upper troposphere using a global chemistry and transport model, Journal of Geophysical Research, Vol. 107, 2002, (2) 1-16

converted to teragrams from megatons (30 Mt)

*3 Smithsonian Institution, National Museum of Natural History, Global Volcanism program

*4 The calculations have been made using the data from GLOBAL Land-Ocean Temperature Index in 0.01 degrees Celsius, which is a table created by NASA

*5 NIA - no information available

The Tambora eruption, 1815

- Greatest eruption in recorded historical data
- 1816

→ 'A year without a summer'

→ Anomalously high rainfall in Europe during the summer

→ 1 - 2°C cooler temperatures, for the mean of 1810 – 1819

→ red sunsets, 'dry – fogs'

→ agricultural problems throughout the world

Conclusions

- Explosive – volcanic eruptions

  → disrupting the atmosphere

  → affecting the climate
- Eruption greater than VEI 7 – major consequences
- Could the volcanic eruptions be predicted in the future, along with their consequences?

References:

- Fyffe, W. S., McBirney, A. R. (1975): Subduction and the structure of andesitic volcanic belts, American Journal of Science, 275 – A, 285 – 297
- Halmer, M.M., Schminke, H.-U., Graf, H.-F., (2002): The annual volcanic gas input into the atmosphere, in particular into the stratosphere: a global data set for the past 100 years, Journal of volcanology and geothermal research, 115, 511 – 528
- Keppler, H. (1999): Experimental Evidence for the Source of Excess Sulfur in Explosive Volcanic Eruptions, Science, 284, 1652 – 1654
- Kravitz, B., Robock, A. (2011): Climate effects of high - latitude volcanic eruptions: role of the time of year, Journal of Geophysical Research, 116, 1 - 16
- Mason, B. G., Pyle, D. M., Oppenheimer, C.(2004): The size and frequency of the largest volcanic eruptions on Earth, Bulletin of Volcanology, 66, 735 – 748
- Miller, T.P. & Casadevall, T.J. (1999): Volcanic ash: Hazards to aviation. In: Encyclopedia of volcanoes (eds. H. Sigurdsson, B. Houghton, S.R. McNutt, H. Rymer & J. Stix). Volcanic hazards, 7, 914-930, Academic press, San Diego.
- Oppenheimer, C. (2003): Climatic, environmental and human consequences of the largest known historic eruption: Tambora volcano (Indonesia) 1815, Progress In Physical Geography, 27, 230 - 259
- Oreskes, N., Shrader – Frechette, K., Belitz, K., (1994): Verification, validation, and confirmation of numerical models in the earth sciences, Science, 263, 641 – 646

- Perfit, M. R. (2001): Mid-ocean ridge geochemistry and petrology. In: Encyclopedia of Ocean Sciences (eds. J.H. Steele, K.K. Turekian & S.A. Thorpe). 1,778-1,788 Academic Press, San Diego.
- Robock, A. (2000): Volcanic Eruptions and Climate, Reviews of Geophysics, 38, 191 – 219
- Robock, A., Mao, J., (1995): The volcanic signal in surface temperature Observations, Journal of Climate, 8, 1086 – 1103
- Robock, A., Mao, J., (1992): Winter Warming from Large Volcanic Eruptions, Geophysical research letters, 12, 2405 - 2408
- Sleep, N. H. (1992): Hotspot Volcanism and Mantle Plumes, Annual review of Earth and Planetary Sciences, 20, 19 – 43
- Slezin, Yu. B. (2003): The mechanism of volcanic eruptions (a steady state approach), Journal of Volcanology and Geothermal Research, 122, 7 – 50
- Sparks, R.S.J. (2003): Forecasting volcanic eruptions, Earth and Planetary Science Letters, 210, 1 - 15
- Wallace, P.J. (2001): Volcanic SO2 emissions and the abundance and distribution of exsolved gas in magma bodies, Journal of Volcanology and Geothermal Research, 108, 85 – 106
- Wilson, L., (1980): Relationships between pressure, volatile content and ejecta velocity in three types of volcanic eruptions, Journal of Volcanology and Geothermal Research, 8, 297 - 313

THANK

YOU