

Mapping the drivers of uncertainty in atmospheric selenium deposition using global sensitivity analysis

Supplementary Material

Aryeh Feinberg, Moustapha Maliki, Andrea Stenke, Bruno Sudret, Thomas Peter,

Lenny H. E. Winkel

S1 Volcanic emissions

Table S1: Comparison of selenium to sulfur ratios in volcanic emissions, extended from Floor and Román-Ross (2012).

Volcano	Period	Se:S ratio ($\times 10^4$)	Reference
Mount Erebus, Antarctica	1986–1991	0.46	Zreda-Gostynska et al. (1997)
	1997–2000	0.11	Wardell et al. (2008)
White Island, New Zealand	2000–2001	0.06	Wardell et al. (2008)
Merapi, Indonesia	1984 (Jan–Feb)	39	Symonds et al. (1987)
Kurile Island, Russia	1990–1993	0.10	Taran et al. (1995)
Kilauea, USA	1983 (Nov)	0.60	Finnegan et al. (1989)
	1983–1984	18	Olmez et al. (1986)
	1984–1996	0.64	Hinkley et al. (1999)
St Helens, USA	1980 (May)	1.3	Vossler et al. (1981)
	1980 (September)	3.6	Phelan et al. (1982)
Augustine, USA	1976	3.1	Lepel et al. (1978)
Soufrière Hills, Montserrat	1996	0.72	Allen et al. (2000)
Stromboli, Italy	1993–1997	0.84	Allard et al. (2000)
Etna, Italy	1976	15	Faivre-Pierret and Le Guern (1983)
(main plume)	1976 (June)	6.8	Buat-Menard and Arnold (1978)
(lava vents)	1976 (June)	32	Buat-Menard and Arnold (1978)
(Bocca Nuova)	1987 (July)	1.2	Andres et al. (1993)
(SE crater)	1987 (July)	0.24	Andres et al. (1993)
(Total)	1987 (July)	0.86	Andres et al. (1993)
(Bocca Nuova)	2001 (3 May)	18	Aiuppa et al. (2003)
(Bocca Nuova)	2001 (18 May)	8.4	Aiuppa et al. (2003)
(Bocca Nuova)	2001 (5 June)	9.3	Aiuppa et al. (2003)
(Bocca Nuova)	2001 (29 June)	51	Aiuppa et al. (2003)
(Bocca Nuova)	2001 (12 July)	5.8	Aiuppa et al. (2003)
(Lava flow)	2001 (19 July)	15	Aiuppa et al. (2003)
(Monti Carcazzi)	2001 (19 July)	1.1	Aiuppa et al. (2003)
(Vent)	2001 (25 July)	2.0	Aiuppa et al. (2003)
(Vent)	2001 (1 Aug)	14	Aiuppa et al. (2003)
(Crater rims)	2004–2007	0.25	Calabrese et al. (2011)
El Chichón, Mexico	-	0.12	Kotra et al. (1983)
Nasudake, Japan	-	0.24	Suzuoki (1964)

S2 Dummy aerosol emission and radius relationship

Table S2: AEROCOM I (Dentener et al., 2006) aerosol types and the corresponding effective radius.

Aerosol Type	Effective radius (μm)
Coarse sea salt	2.50
Coarse dust	2.09
Fine mode dust	0.37
Fine mode sea salt	0.22
Biomass burning-derived particulate organic matter	0.095
Biomass burning-derived black carbon	0.095
Biofuel-derived particulate organic matter	0.095
Biofuel-derived black carbon	0.095
Ultrafine mode sea salt	0.037
Fossil fuel-derived particulate organic matter	0.036
Fossil fuel-derived black carbon	0.036

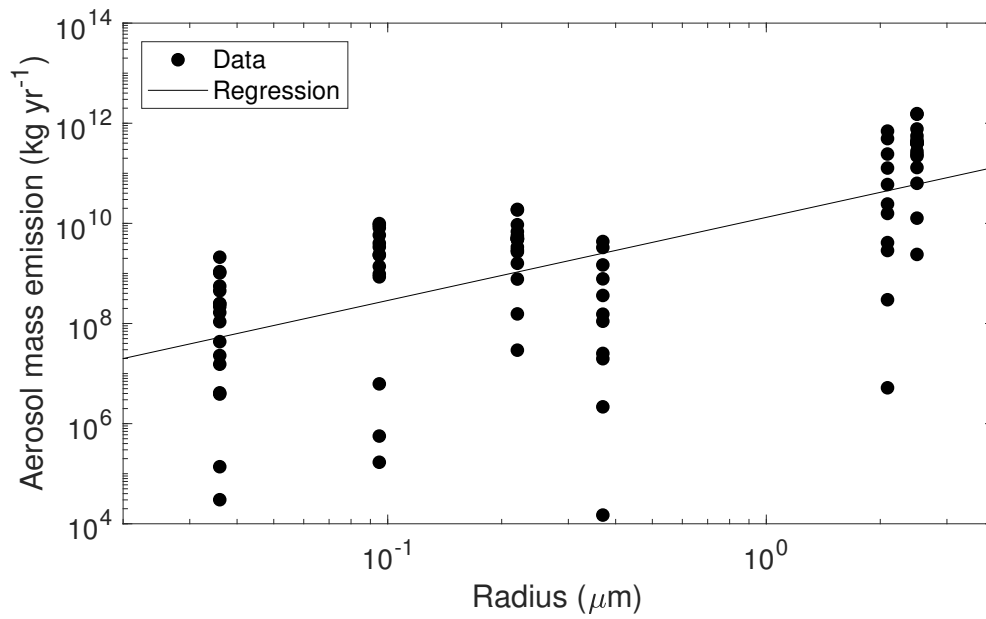


Figure S1: Relationship between aerosol radius and mass emissions in AEROCOM I inventory (Dentener et al., 2006). Emissions are aggregated to 10° latitude bands, to reflect the dummy latitude input parameter in this study.

S3 Leave-one-out error of PCE

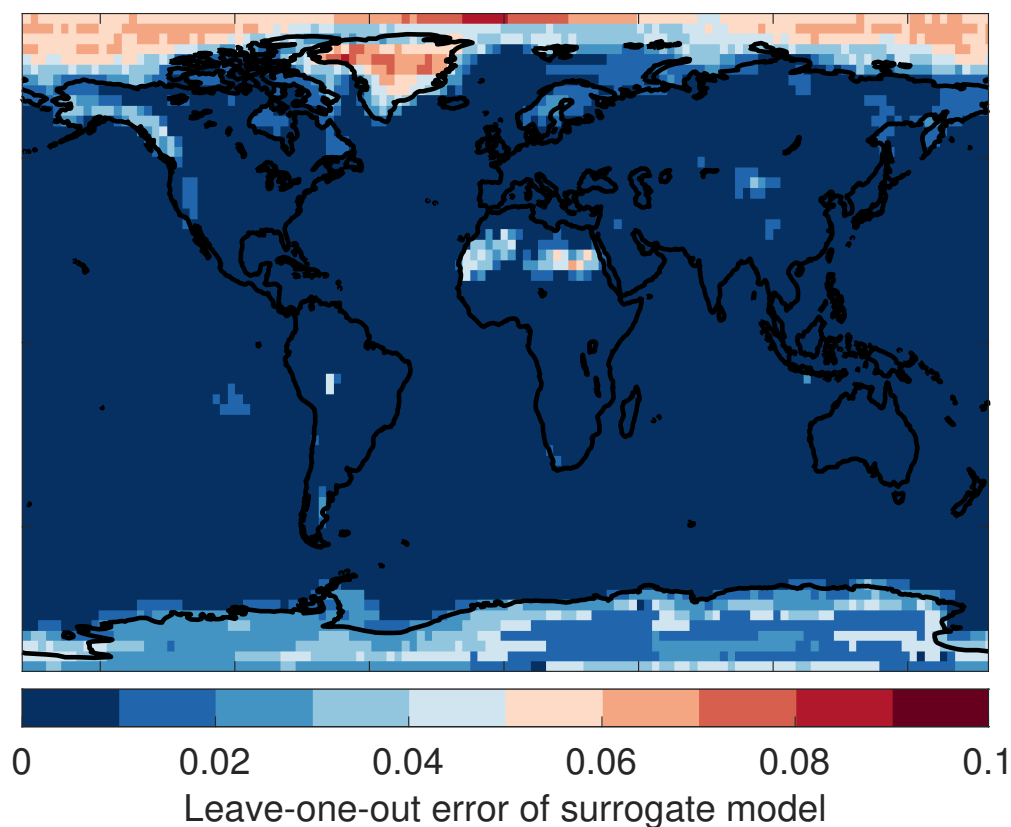


Figure S2: Leave-one-out error of PCE models used to represent the total Se deposition fluxes from SOCOL-AER. The colorbar is chosen to highlight values that are above 0.05, which are shown in shades of red.

S4 References

- Aiuppa, A., Dongarrà, G., Valenza, M., Federico, C., and Pecoraino, G.: Degassing of trace volatile metals during the 2001 eruption of Etna, Washington DC American Geophysical Union Geophysical Monograph Series, 139, 41–54, URL <https://doi.org/10.1029/139GM03>, 2003.
- Allard, P., Aiuppa, A., Loyer, H., Carrot, F., Gaudry, A., Pinte, G., Michel, A., and Dongarrà, G.: Acid gas and metal emission rates during long-lived basalt degassing at Stromboli volcano, Geo-

- physical Research Letters, 27, 1207–1210, URL <https://doi.org/10.1029/1999GL008413>, 2000.
- Allen, A. G., Baxter, P. J., and Ottley, C. J.: Gas and particle emissions from Soufrière Hills Volcano, Montserrat, West Indies: characterization and health hazard assessment, *Bulletin of Volcanology*, 62, 8–19, URL <https://doi.org/10.1007/s004450050287>, 2000.
- Andres, R., Kyle, P., and Chuan, R.: Sulphur dioxide, particle and elemental emissions from Mount Etna, Italy during July 1987, *Geologische Rundschau*, 82, 687–695, URL <https://doi.org/10.1007/BF00191496>, 1993.
- Buat-Menard, P. and Arnold, M.: The heavy metal chemistry of atmospheric particulate matter emitted by Mount Etna Volcano, *Geophysical Research Letters*, 5, 245–248, URL <https://doi.org/10.1029/GL005i004p00245>, 1978.
- Calabrese, S., Aiuppa, A., Allard, P., Bagnato, E., Bellomo, S., Brusca, L., DAlessandro, W., and Parello, F.: Atmospheric sources and sinks of volcanogenic elements in a basaltic volcano (Etna, Italy), *Geochimica et Cosmochimica Acta*, 75, 7401–7425, URL <https://doi.org/10.1016/j.gca.2011.09.040>, 2011.
- Dentener, F., Kinne, S., Bond, T., Boucher, O., Cofala, J., Generoso, S., Ginoux, P., Gong, S., Hoelzemann, J., and Ito, A.: Emissions of primary aerosol and precursor gases in the years 2000 and 1750 prescribed data-sets for AeroCom, *Atmospheric Chemistry and Physics*, 6, 4321–4344, URL <https://doi.org/10.5194/acp-6-4321-2006>, 2006.
- Faivre-Pierret, R. and Le Guern, F.: Health risks linked with inhalation of volcanic gases and aerosols, 1983.
- Finnegan, D. L., Kotra, J. P., Hermann, D. M., and Zoller, W. H.: The use of 7 LiOH-impregnated filters for the collection of acidic gases and analysis by instrumental neutron activation analysis, *Bulletin of Volcanology*, 51, 83–87, URL <https://doi.org/10.1007/BF01081977>, 1989.

- Floor, G. H. and Román-Ross, G.: Selenium in volcanic environments: a review, *Applied Geochemistry*, 27, 517–531, URL <https://doi.org/10.1016/j.apgeochem.2011.11.010>, 2012.
- Hinkley, T. K., Lamothe, P. J., Wilson, S. A., Finnegan, D. L., and Gerlach, T. M.: Metal emissions from Kilauea, and a suggested revision of the estimated worldwide metal output by quiescent degassing of volcanoes, *Earth and Planetary Science Letters*, 170, 315–325, URL [https://doi.org/10.1016/S0012-821X\(99\)00103-X](https://doi.org/10.1016/S0012-821X(99)00103-X), 1999.
- Kotra, J. P., Finnegan, D. L., Zoller, W. H., Hart, M. A., and Moyers, J. L.: El Chichón: Composition of plume gases and particles, *Science*, 222, 1018–1021, URL <https://doi.org/10.1126/science.222.4627.1018>, 1983.
- Lepel, E., Stefansson, K., and Zoller, W.: The enrichment of volatile elements in the atmosphere by volcanic activity: Augustine volcano 1976, *Journal of Geophysical Research: Oceans*, 83, 6213–6220, URL <https://doi.org/10.1029/JC083iC12p06213>, 1978.
- Olmez, I., Finnegan, D., and Zoller, W.: Iridium emissions from Kilauea volcano, *Journal of Geophysical Research: Solid Earth*, 91, 653–663, URL <https://doi.org/10.1029/JB091iB01p00653>, 1986.
- Phelan, J. M., Finnegan, D. L., Ballantine, D. S., Zoller, W. H., Hart, M. A., and Moyers, J. L.: Airborne aerosol measurements in the quiescent plume of Mount St. Helens: September, 1980, *Geophysical Research Letters*, 9, 1093–1096, URL <https://doi.org/10.1029/GL009i009p01093>, 1982.
- Suzuoki, T.: A geochemical study of selenium in volcanic exhalation and sulfur deposits, *Bulletin of the Chemical Society of Japan*, 37, 1200–1206, URL <https://doi.org/10.1246/bcsj.37.1200>, 1964.
- Symonds, R. B., Rose, W. I., Reed, M. H., Lichte, F. E., and Finnegan, D. L.: Volatilization, transport and sublimation of metallic and non-metallic elements in high temperature gases at

- Merapi Volcano, Indonesia, *Geochimica et Cosmochimica Acta*, 51, 2083–2101, URL [https://doi.org/10.1016/0016-7037\(87\)90258-4](https://doi.org/10.1016/0016-7037(87)90258-4), 1987.
- Taran, Y. A., Hedenquist, J., Korzhinsky, M., Tkachenko, S., and Shmulovich, K.: Geochemistry of magmatic gases from Kudryavy volcano, Iturup, Kuril Islands, *Geochimica et Cosmochimica Acta*, 59, 1749–1761, URL [https://doi.org/10.1016/0016-7037\(95\)00079-F](https://doi.org/10.1016/0016-7037(95)00079-F), 1995.
- Vossler, T., Anderson, D. L., Aras, N. K., Phelan, J. M., and Zoller, W. H.: Trace element composition of the Mount St. Helens plume: Stratospheric samples from the 18 May eruption, *Science*, 211, 827–830, URL <https://doi.org/10.1126/science.211.4484.827>, 1981.
- Wardell, L., Kyle, P., and Counce, D.: Volcanic emissions of metals and halogens from White Island (New Zealand) and Erebus volcano (Antarctica) determined with chemical traps, *Journal of Volcanology and Geothermal Research*, 177, 734–742, URL <https://doi.org/10.1016/j.jvolgeores.2007.07.007>, 2008.
- Zreda-Gostynska, G., Kyle, P. R., Finnegan, D., and Prestbo, K. M.: Volcanic gas emissions from Mount Erebus and their impact on the Antarctic environment, *Journal of Geophysical Research: Solid Earth*, 102, 15 039–15 055, URL <https://doi.org/10.1029/97JB00155>, 1997.