Clumping Together of Aerosol Paricles Deceases Optical Depth

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We discuss how we expect the optical depth of an aerosol cloud to change, were the particles within it to clump together.

Stothers (1997) compiles observations of wavelength-dependent optical depth for aerosol clouds from several large volcanic eruptions. Optical depth D is shown to vary with wavelength λ as approximately $D \propto 1/\lambda$ (see Figure). This behavior implicitly includes the effect of the particle size distribution, since the measurements are for natural clouds containing particles of many sizes.

To first order, light scattering is only sensitive the ratio of particle radius R and wavelength λ; that is, to (R/λ). Thus, if we were somehow able to double the radius of all the particles in the cloud by a factor, say, of two, but hold the number of particles fixed, then for fixed wavelength, the optical depth would decrease by a factor of two.

However, if the increase in particle size were accomplished by clumping-together groups of eight particles of the same size, then radius of all the particles in the cloud would double and the number of particles in every size range would decrease by a factor of eight. The overall particle density would drop by a factor of eight. Since, in the single scattering approximation, optical thickness depends linearly on the particle density, the decrease in density would cause the optical thickness (at fixed wavelength) to decrease by a factor of eight.

Overall, we expect that a doubling of particle radii by a clumping-together mechanism would cause optical thickness (at fixed wavelength to decrease by a factor of $2 \times 8 = 16$.

Stothers' (1997) Table 1.

Table 1. Wavelength-Dependent Optical Depth Perturbations (Multiplied by 1000) due to the Eruptions of Santa Maria, Ksudach, and Katmai

			Wavelength, μm									
Year	Month	N_{obs}	0.35	0.40	0.45	0.50	0.60	0.70	0.80	1.00	1.20	1.60
1903–1904	Jan.–Dec.	20		84	98	85	71	66	51	38	26	5
				37	22	20	20	14	11	8	7	5
1907	May	2		78	163	111	105	63	57	16	2	0
				82	38	28	6	23	17	33	22	49
1908	June–Oct.	97		37	28	33	27	25	24	22	17	15
				6	6	5	4	3	2	2	1	1
1912	July–Aug.	53	223	161	145	138	116	105	88	62	48	39
			9	9	9	8	8	8	7	6	5	4
1913	Aug.–Oct.	67	110	51	45	50	43	33	25	15	7	3
			6	5	5	4	4	3	2	2	1	1
1914	June–Oct.	85	74	13	5	12	9	7	5	1	0	0
			6	5	5	4	4	3	2	2	1	1

N_{obs} is the number of observations. First row for each year gives the mean optical depth perturbation, while second row gives the standard error of the mean.

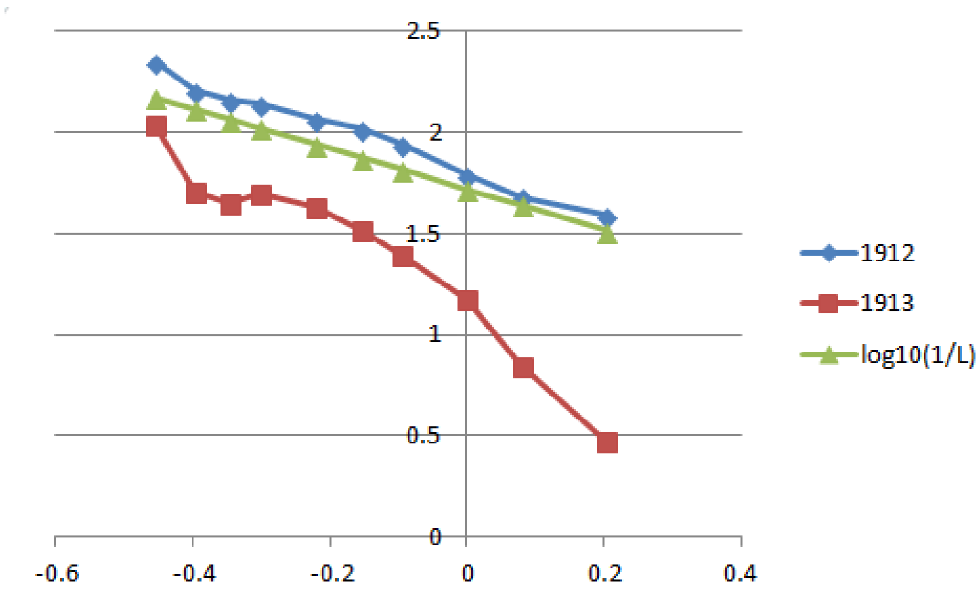

Figure. Log-log plot of optical depth D vs. wavelength λ for selected data from Stother (1997, his Table 1). The 1912 (blue) and 1913 (red) data are shown, together with the comparison curve $150 \times (0.35/\lambda)$.

Reference

Stothers, R.B, Stratospheric aerosol clouds due to very large volcanic eruptions of the earthy twentieth century: Effective particle sizes and conversion from pyrheliometric to visual optical depth, J. Geophysical Research 102, 6143-6151, 1997.