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The climate impact of aerosols on the lightning flash rate: is it detectable from long-term measurements?

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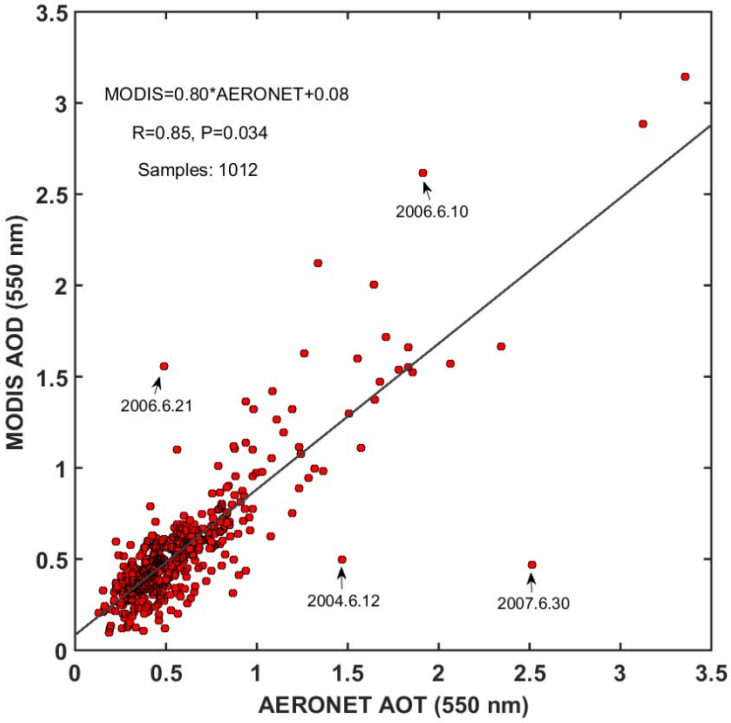

Fig. S1. Daily mean Aqua/MODIS AOD at 550 nm (local time ~13:30) as a function of AERONET AOD (averaged from 12:00–15:00 local time) over the dust-dominant region for the period 2003–2013 (May, June, July of each year). The AERONET site is located at Banizoumbou (2.66ºE, 13.54ºN), and the region covered by MODIS is (2°-3°E,13°-14°N). The four dots marked with dates (yyyy.mm.dd, where yyyy = year, mm = month, and dd = day) have relatively large biases.

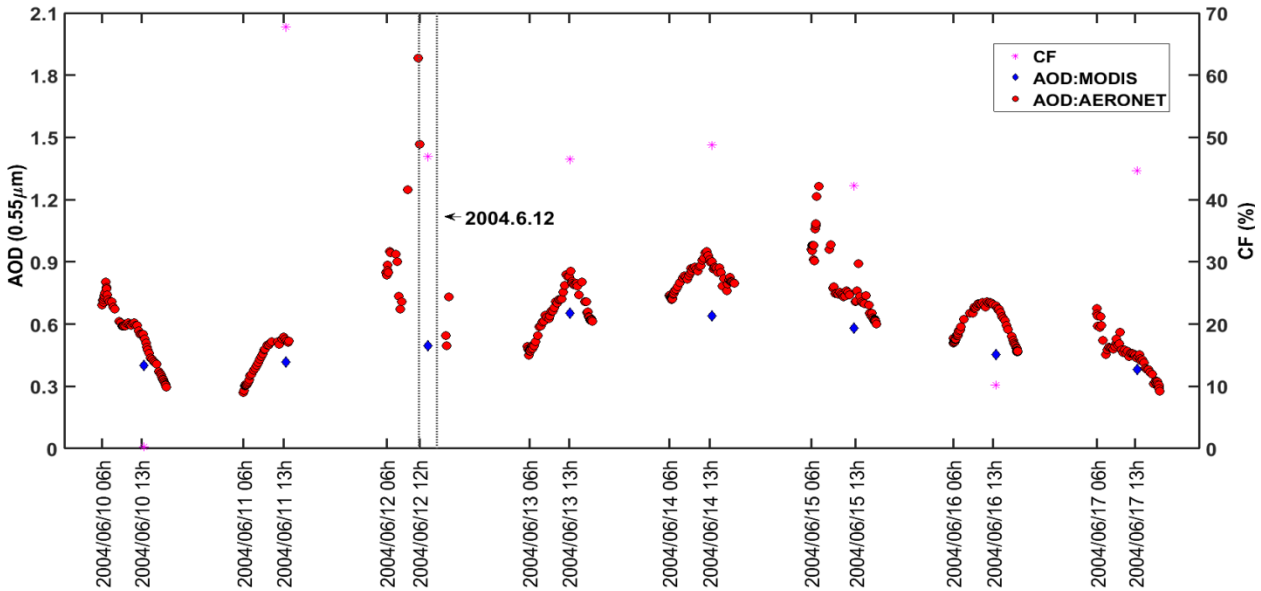

Fig. S1-1. Times series (10–17 June 2004) of daily mean Aqua/MODIS aerosol optical depth (AOD) at 550 nm (local time ~13:30 averaged over (2°-3°E,13°-14°N), blue triangles), high resolution (~7 min) AERONET AOD retrievals made at Banizoumbou (2.66ºE, 13.54ºN, averaged from 12:00–15:00 local time, red dots), and cloud fraction (CF, pink stars). The largest deviation appears on 12 June 2004. The two vertical dotted lines present the period 12:00–15:00 local time.

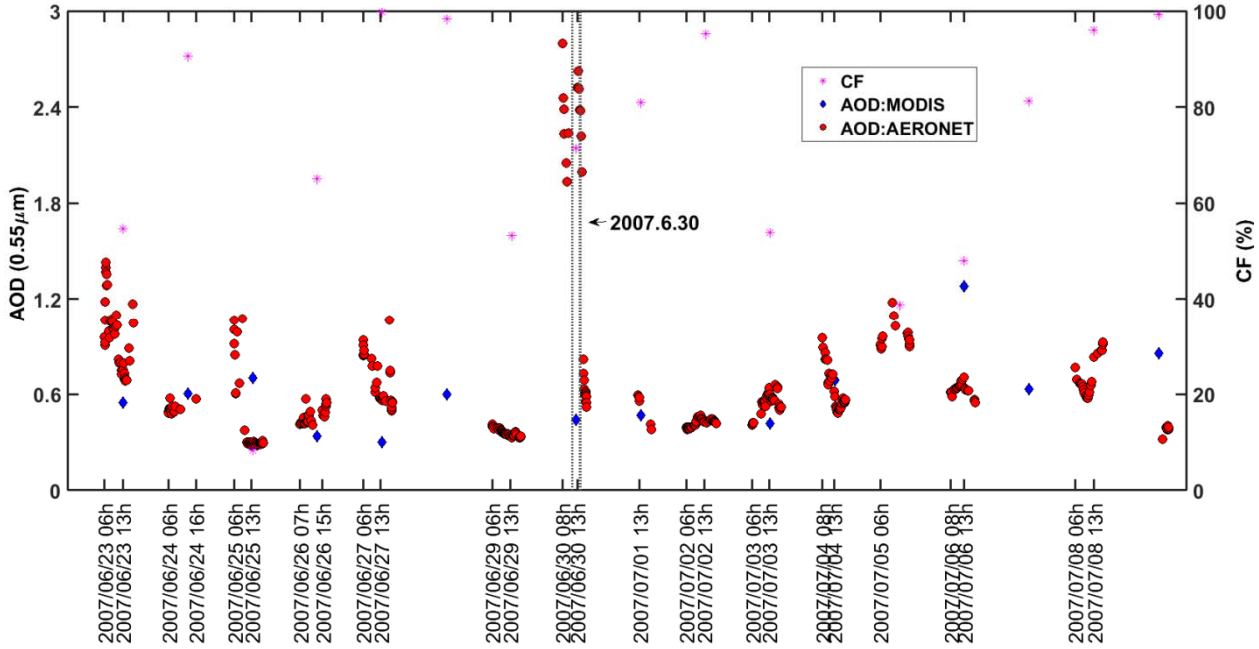

Fig. S1-2. Times series (23 June – 8 July 2007) of daily mean Aqua/MODIS aerosol optical depth (AOD) at 550 nm (local time ~13:30 averaged over (2°-3°E,13°-14°N), blue triangles), high resolution (~7 min) AERONET AOD retrievals made at Banizoumbou (2.66ºE, 13.54ºN, averaged from 12:00–15:00 local time, red dots), and cloud fraction (CF, pink stars). The largest deviation appears on 30 June 2007. The two vertical dotted lines present the period 12:00–15:00 local time.

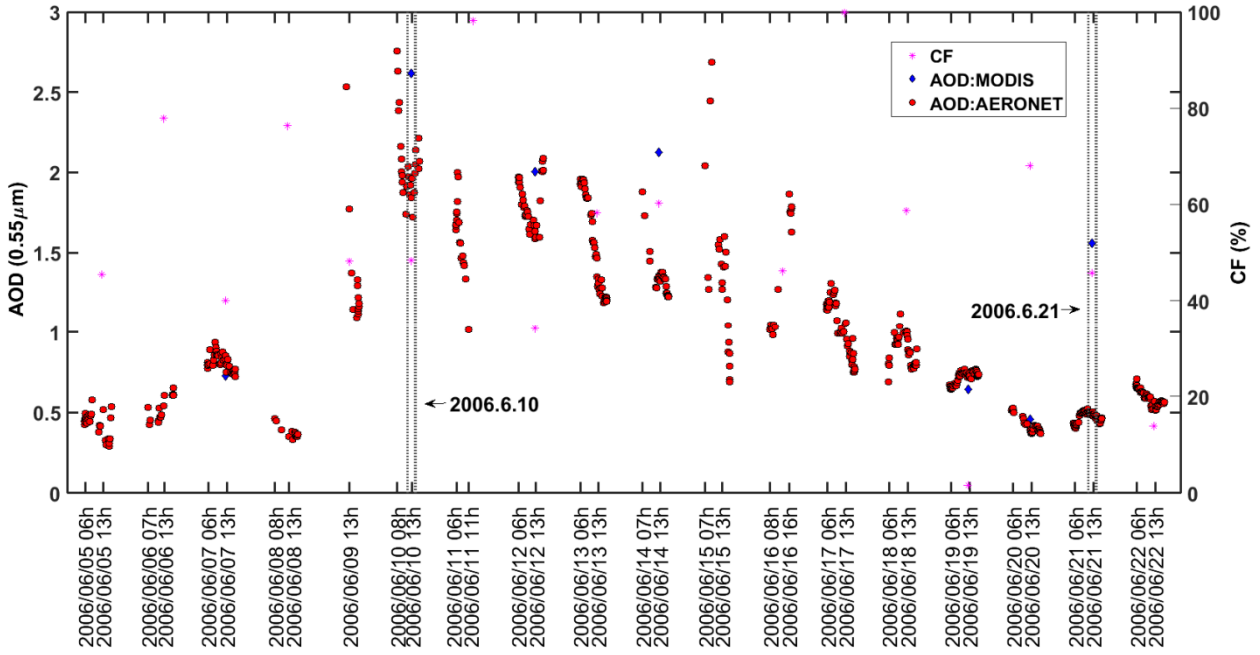

Fig. S1-3. Times series (5–22 June 2006) of daily mean Aqua/MODIS aerosol optical depth (AOD) at 550 nm (local time ~13:30 averaged over (2°-3°E,13°-14°N), blue triangles), high resolution (~7 min) AERONET AOD retrievals made at Banizoumbou (2.66ºE, 13.54ºN, averaged from 12:00–15:00 local time, red dots), and cloud fraction (CF, pink stars). The largest deviations appear on 10 June 2006 and 21 June 2006. The two vertical dotted lines present the period 12:00–15:00 local time on each of these days.

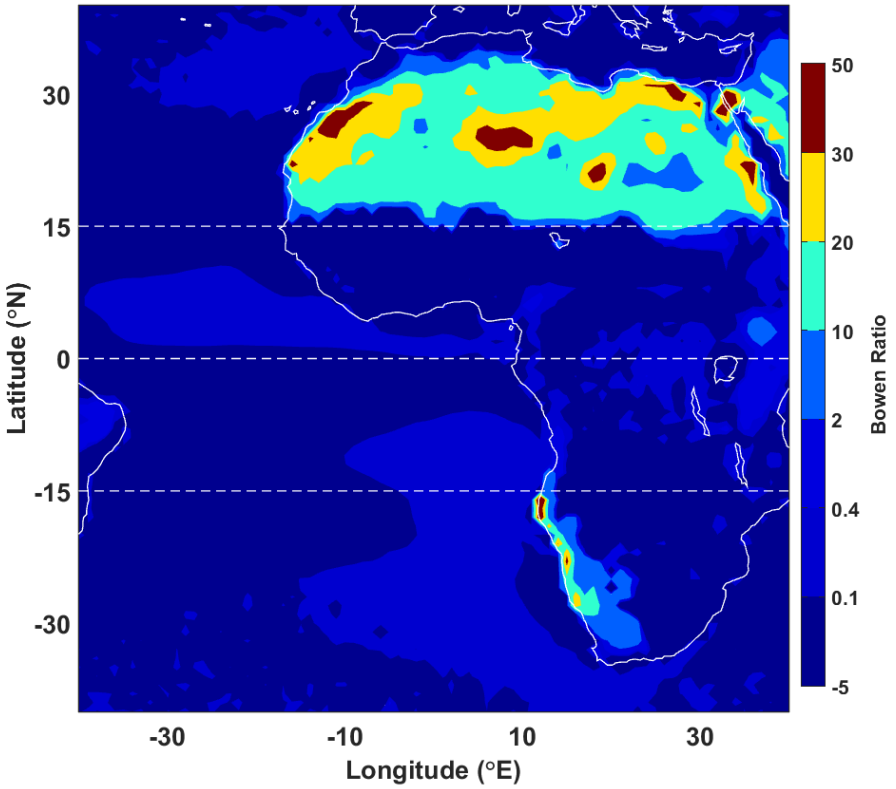

Fig. S2. Spatial distribution of the mean Bowen ratio during the period 2003–2013. Significant regional differences in surface properties over the African landmass are seen.

Table S1-1. The relationship between the sum of squared residuals (Q) and the number of factors (p) and Pearson correlation coefficients (r).

Q \ p / r	1	2	3	4	5	6	7	8	9	10
0.2	0.96	0.93	0.91	0.90	0.89	0.88	0.87	0.87	0.86	0.86
0.3	0.91	0.86	0.83	0.81	0.80	0.78	0.78	0.77	0.76	0.76
0.4	0.84	0.77	0.73	0.71	0.69	0.68	0.67	0.66	0.66	0.65
0.5	0.75	0.67	0.63	0.60	0.58	0.57	0.56	0.56	0.55	0.55
0.6	0.64	0.55	0.51	0.49	0.47	0.46	0.45	0.45	0.44	0.44
0.7	0.51	0.42	0.39	0.37	0.36	0.35	0.34	0.34	0.33	0.33
0.8	0.36	0.29	0.26	0.25	0.24	0.23	0.23	0.22	0.22	0.22
0.9	0.19	0.15	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.11

Note: Here, we assume that the Pearson correlation coefficients between the predictor (y) and factors ($x_1, x_2, \ldots, x_{10}$), and Pearson correlation coefficients between factors are all equal to r.

Table S1-2. The relationship between the sum of squared residuals (Q) and the number of factors (p) and Pearson correlation coefficients (r).

Q \ p / r	1	2	3	4	5	6	7	8	9	10
0.2	0.96	0.93	0.90	0.88	0.86	0.84	0.83	0.81	0.80	0.79
0.3	0.91	0.84	0.79	0.75	0.72	0.69	0.67	0.65	0.63	0.62
0.4	0.84	0.73	0.66	0.60	0.56	0.52	0.49	0.47	0.45	0.43
0.5	0.75	0.6	0.50	0.43	0.38	0.33	0.30	0.27	0.25	0.23
0.6	0.64	0.45	0.33	0.24	0.18	0.14	0.10	0.07	0.05	0.03

Note: Here, we assume that the Pearson correlation coefficients between the predictor (y) and factors ($x_1, x_2, \ldots, x_{10}$) are equal to r, and Pearson correlation coefficients between factors are equal to $r/2$.

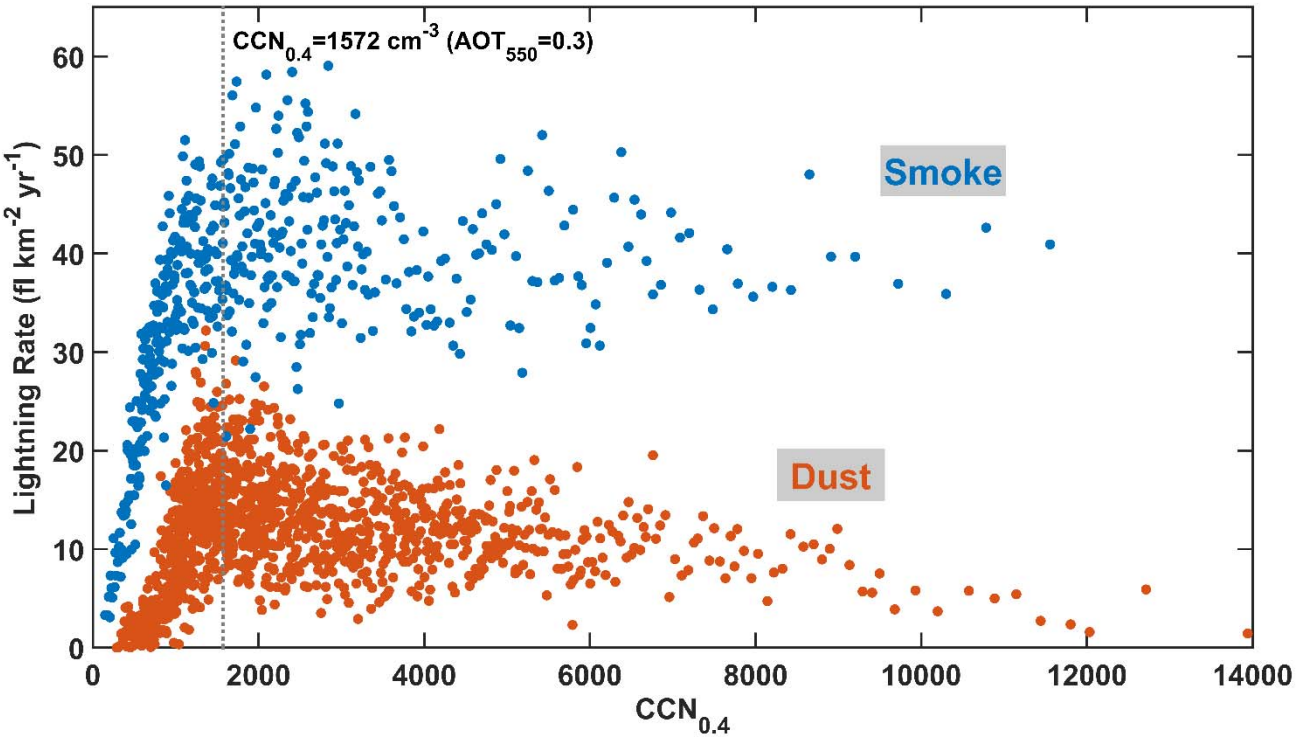

Fig. S3. The response of the lightning flash rate to dust and smoke aerosols in the dust- and smoke-dominant regions. The turning points are around $CCN_{0.4} \approx 1600\ cm^{-3}$.

Table S2: Linear regression correlations between lightning flash rate and dynamic-thermodynamic factors (x_1–x_6) and AOD (x_7) before and after the turning point (AOD = 0.3) for the dust- and smoke-dominant regions.

ROI	Correlation	SLP (x_1)	Θ (x_2)	RH (x_3)	CAPE (x_4)	SHEAR (x_5)	Div (x_6)	AOD (x_7)
dust (AOD<0.3)	Pearson_1	-0.62	0.52	0.96	0.96	-0.51	0.87	0.75
	Pearson_2	-0.74	0.63	0.81	0.76	-0.43	0.74	/
	Partial	0.12	0.02	0.44	0.57	0.02	0.16	-0.04
	Equation	$y = 0.07x_1 + 0.08x_2 + 0.49x_3 + 0.49x_4 + 0.01x_5 + 0.09x_6 - 0.02x_7 - 1.52 \times 10^{-14}$						
	Multiple	0.96 (standardized)						
dust (AOD>0.3)	Pearson_1	0.26	-0.18	0.89	0.91	-0.09	0.76	-0.41
	Pearson_2	-0.66	0.47	-0.51	-0.33	-0.07	-0.53	/
	Partial	0.10	0.16	0.41	0.66	-0.05	0.25	0.04
	Equation	$y = 0.11x_1 + 0.15x_2 + 0.34x_3 + 0.54x_4 - 0.02x_5 + 0.15x_6 + 0.02x_7 - 5.44 \times 10^{-14}$						
	Multiple	0.91 (standardized)						
smoke (AOD<0.3)	Pearson_1	-0.94	-0.37	0.74	0.96	-0.31	0.83	0.86
	Pearson_2	-0.80	-0.43	0.43	0.78	-0.02	0.59	/
	Partial	-0.27	-0.21	0.36	0.50	0.31	-0.10	0.50
	Equation	$y = -0.21x_1 - 0.06x_2 + 0.32x_3 + 0.42x_4 + 0.13x_5 - 0.08x_6 + 0.25x_7 - 5.28 \times 10^{-14}$						
	Multiple	0.96 (standardized)						
smoke (AOD>0.3)	Pearson_1	-0.67	-0.27	0.81	0.87	-0.07	0.82	-0.15
	Pearson_2	0.17	-0.74	-0.24	0	0.5	-0.3	/
	Partial	-0.12	0.11	0.36	0.51	0.04	0.21	0.05
	Equation	$y = -0.07x_1 + 0.09x_2 + 0.31x_3 + 0.51x_4 + 0.02x_5 + 0.17x_6 + 0.04x_7 - 1.02 \times 10^{-14}$						
	Multiple	0.88 (standardized)						

Columns from left to right: (1) Region of interest (ROI). (2) Correlation type: Pearson correlation coefficients of the linear regression relationships between the lightning flash rate and the six dynamic-thermodynamic variables and aerosol optical depth (AOD; Pearson_1), Pearson correlation coefficients of the linear regression relationships between AOD and any given dynamic-thermodynamic variable (Pearson_2), partial correlation coefficients of the relationships between the lightning flash rate and any influential factor (AOD or dynamic-thermodynamic variables) with the others as control variables (Partial). (3) Correlation coefficients, standardized multiple correlation coefficients (R_M), and standardized multiple regression equations of the lightning flash rate (y) to six dynamic-thermodynamic factors ($x_1 - x_6$) and AOD (x_7). The six

dynamic-thermodynamic variables are sea level pressure [SLP (x_1)], potential temperature [θ (x_2)], mid-level relative humidity [RH (x_3)], mean convective available potential energy [CAPE (x_4)], vertical wind shear [SHEAR (x_5)], and 200-hPa divergence [Div (x_6)]. Correlation coefficients are shown in black if they pass the significance test at 99%. They are shown in red if they failed the significance test at the 0.05 level.