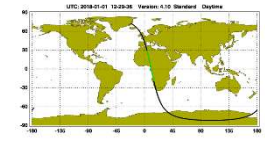
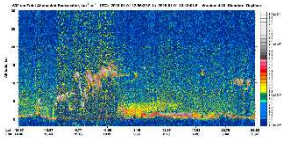
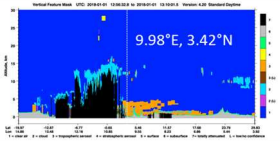
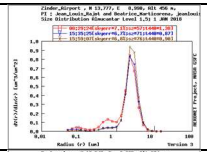
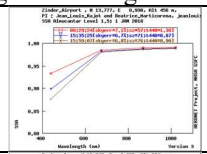
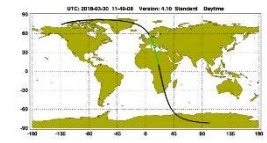
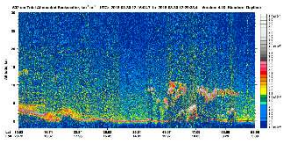
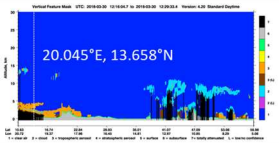
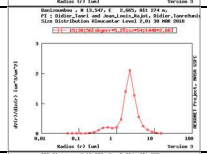
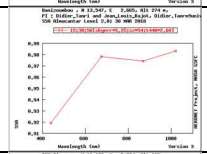
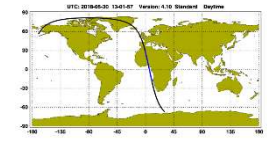
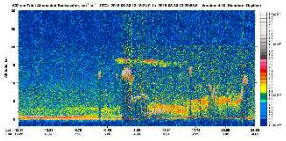
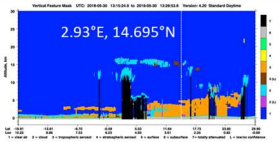
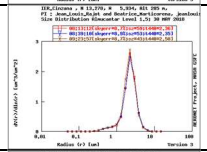
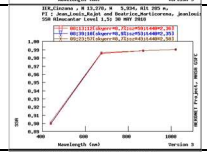
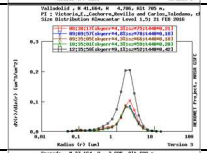
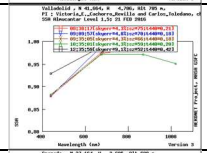
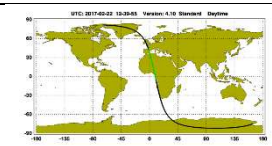
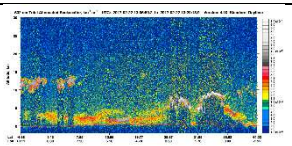
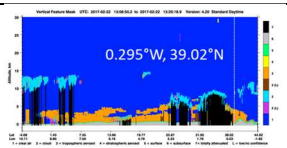
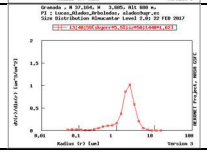
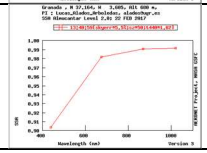
Supplements

Case Number	CALIOP Path	532 nm Total Attenuated Backscatter (km^{-1} sr^{-1})	Vertical Feature Mask	AERONET Inversion: Volume size distribution	AERONET Inversion: Single scattering albedo
Case 1					
Case 2					
Case 3					
Case 4	Not available	Not available	Not available		
Case 5					
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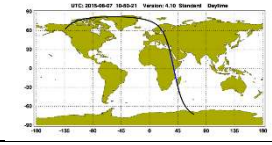
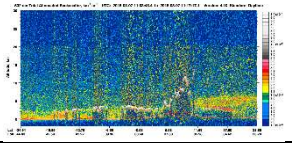
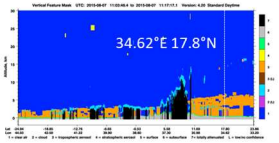
Case 7				Not available	Not available

Fig. S1 Aerosol plume height from CALIOP (CALIOP Path, 532 nm Total Attenuated Backscatter (km^{-1} sr^{-1}), and Vertical Feature Mask), and AERONET inversion data (aerosol volume size distribution and single scattering albedo) for 24 dust cases (Fig. 5, Figs A1–A6, Table 2). CALIOP data available at: https://www-calipso.larc.nasa.gov/products/lidar/browse_images/std_v4_index.php. AERONET data available at: http://aeronet.gsfc.nasa.gov.

Case Number	CALIOP Path	532 nm Total Attenuated Backscatter (km^{-1} sr^{-1})	Vertical Feature Mask	AERONET Inversion: Volume size distribution	AERONET Inversion: Single scattering albedo
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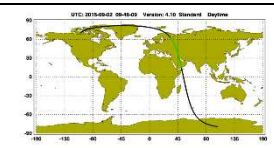
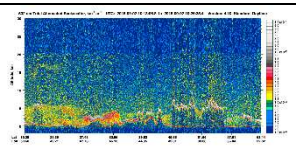
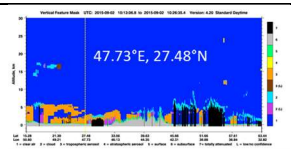
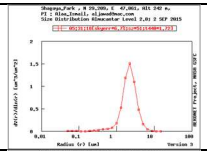
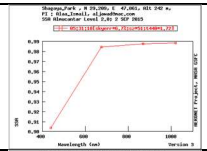
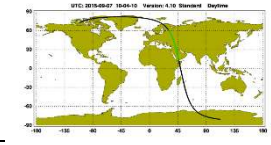
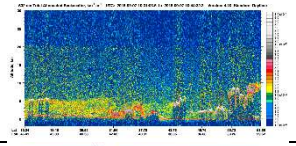
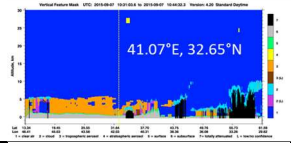
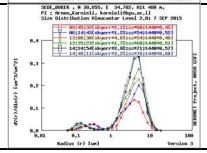
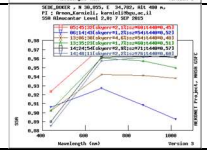
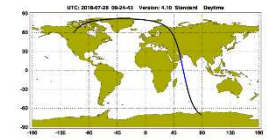
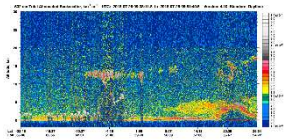
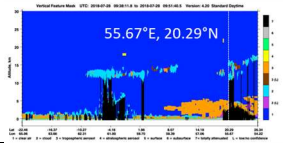
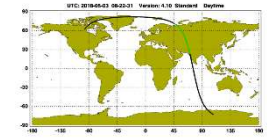
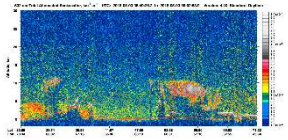
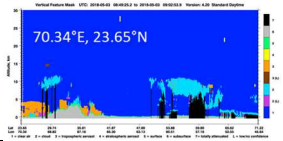
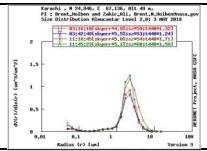
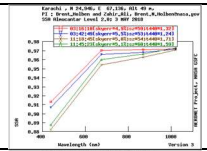
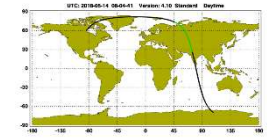
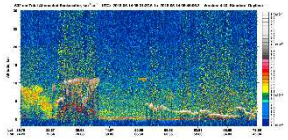
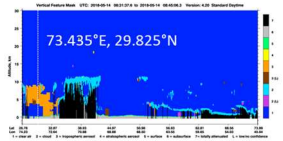
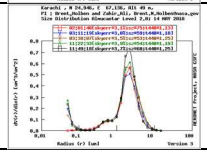
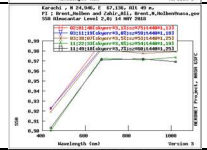
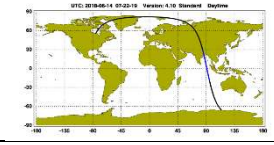
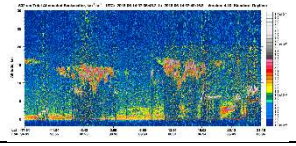
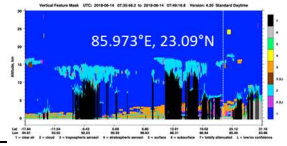
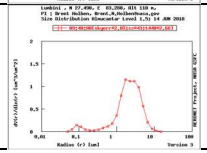
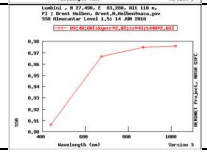
Case 9					
Case 10					
Case 11				Not available	Not available
Case 12					
Case 13					
Case 14					

Fig. S1 Continued.

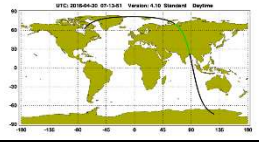
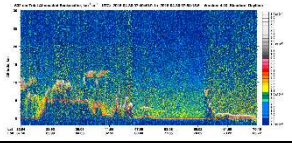
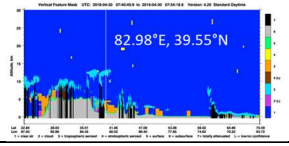
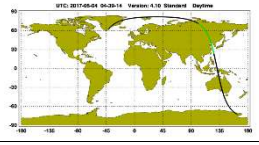
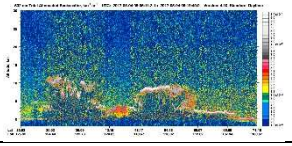
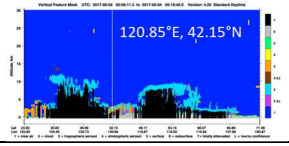
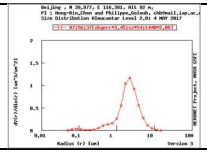
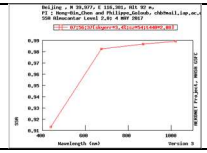
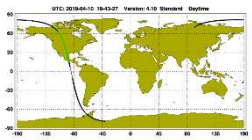
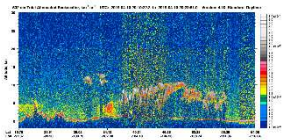
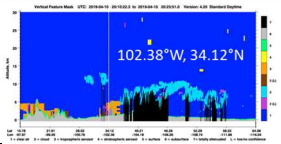
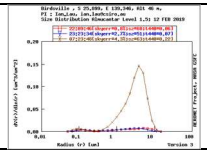
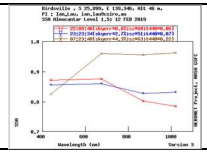
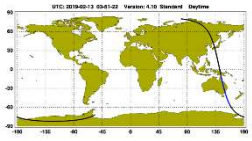
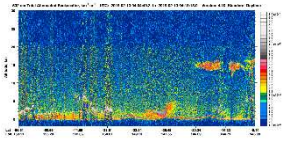
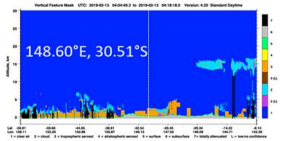
Case Number	CALIOP Path	532 nm Total Attenuated Backscatter (km^{-1} sr^{-1})	Vertical Feature Mask	AERONET Inversion: Volume size distribution	AERONET Inversion: Single scattering albedo
Case 15				Not available	Not available
Case 16	Not available	Not available	Not available	Not available	Not available
Case 17					
Case 18	Not available	Not available	Not available	Not available	Not available
Case 19	Not available	Not available	Not available	Not available	Not available
Case 20				Not available	Not available
Case 21	Not available	Not available	Not available	Not available	Not available
Case 22	Not available	Not available	Not available	Not available	Not available
Case 23	Not available	Not available	Not available		
Case 24				Not available	Not available

Fig. S1 Continued.

15

Table S1 Statistics of monthly variations for Fig. 8. For each site, the number of MAIAC EPIC retrievals (first row of each site) and monthly variations of mass concentration (wt.%) of hematite (second row; 5th, 25th, 50th, 75th and 95th percentiles) and goethite (third row; 5th, 25th, 50th, 75th and 95th percentiles) for 2018 are summarized.

Site	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
1 – Tunisia	6	7	574	1539	450	158	3507	0	5	795	0	0
	1.02/1.11/1.13/1.15/1.17	1.08/1.11/1.22/1.25/1.26	0.72/0.92/1.04/1.22/1.50	0.74/1.00/1.24/1.43/1.87	0.51/0.70/0.87/1.06/1.32	0.34/1.09/1.41/1.63/1.87	1.24/1.87/2.27/2.62/3.07	-	0.21/0.26/0.30/0.34/0.34	0.78/1.03/1.19/1.35/1.61	-	-
	0.71/0.88/1.36/1.39/1.41	1.39/1.41/1.44/1.45/1.46	0.05/0.84/1.21/1.49/1.65	0.0015/0.48/0.92/1.27/1.60	0.39/0.89/1.40/1.55/1.80	0.0015/0.29/0.86/1.21/1.67	0.0015/0.0015/0.05/0.69/1.78	-	0.48/1.32/1.55/1.57/1.57	0.0015/0.46/0.94/1.35/1.92	-	-
2 – Morocco	9	0	19	0	2	5	2118	309	0	1	0	0
	1.19/1.35/1.52/1.61/1.64	-	0.44/0.62/0.71/0.98/1.08	-	-	1.09/1.16/1.21/1.22/1.22	0.90/1.42/1.86/2.35/2.85	0.92/1.17/1.28/1.39/1.56	-	-	-	-
	0.95/0.98/1.04/1.76/1.91	-	0.58/1.31/1.51/1.54/1.62	-	-	0.64/0.66/1.20/1.36/1.36	0.0015/0.0015/0.35/0.88/2.05	0.0015/0.50/0.92/1.26/2.30	-	-	-	-
3 – Libya	0	146	81	2629	2379	2148	15	686	0	12	0	0
	-	0.69/0.88/0.96/1.08/1.21	0.70/0.92/1.22/1.41/3.27	0.53/0.77/0.88/1.07/1.35	0.43/0.77/1.02/1.28/1.84	0.84/1.17/1.49/2.09/2.64	0.90/1.30/1.45/1.53/1.78	0.62/0.86/0.99/1.18/1.38	-	0.36/0.46/0.52/0.70/0.86	-	-
	-	0.44/0.97/1.42/1.59/2.40	0.0015/0.47/0.75/1.29/1.95	0.30/1.08/1.50/1.70/2.67	0.0015/0.68/1.29/1.59/2.37	0.0015/0.0015/0.65/1.33/2.20	0.0015/0.42/0.57/0.79/1.57	0.12/0.71/1.35/1.64/2.57	-	0.89/1.57/2.35/2.56/2.89	-	-
4 – Algeria	26	1	188	779	4109	2080	1457	555	588	0	1	0
	0.37/0.41/0.44/0.50/0.52	-	0.33/0.50/0.65/0.75/0.89	0.41/0.65/0.81/0.96/1.76	0.63/1.12/1.58/1.86/2.35	0.63/0.91/1.24/1.59/1.93	0.67/1.06/1.45/1.86/2.78	0.43/0.61/0.75/1.04/1.53	0.50/0.63/0.75/1.07/1.55	-	-	-
	1.26/2.43/2.59/2.76/2.85	-	0.99/1.46/1.61/2.10/2.57	0.0015/0.94/1.50/2.30/2.90	0.0015/0.0015/0.12/1.13/2.44	0.0015/0.0015/0.71/1.57/2.63	0.0015/0.0015/0.37/1.48/2.55	0.0015/1.15/1.76/2.55/2.91	0.0015/0.90/1.61/2.40/2.87	-	-	-
5 – Mauritania	0	0	412	1488	3025	13892	32416	1293	1075	2298	2	15
	-	-	0.37/0.63/0.88/1.03/1.35	0.54/0.88/1.19/1.64/2.48	1.60/2.37/2.76/3.01/3.38	0.88/1.48/1.86/2.31/3.07	0.93/1.45/1.81/2.14/2.62	0.49/0.65/0.94/1.33/1.86	0.52/0.66/0.80/1.05/1.42	0.62/0.85/1.00/1.13/1.32	-	0.34/0.57/0.63/0.68/1.01
	-	-	0.40/0.97/1.43/1.63/2.54	0.0015/0.67/1.48/1.90/2.74	0.0015/0.0015/0.0015/0.22/1.37	0.0015/0.0015/0.39/1.32/2.42	0.0015/0.0015/0.30/0.99/2.25	0.0015/0.94/1.62/2.20/2.81	0.28/1.06/1.59/2.22/2.85	0.07/0.75/1.38/1.68/2.58	-	0.12/1.34/1.63/2.17/2.48

Table S1 Continued.

Site	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
6 – Niger	1792	3555	2754	2683	7215	5009	1284	24	1386	362	727	350
	0.34/0.58/0.75/0.92/1.15	0.24/0.33/0.42/0.61/0.87	0.33/0.55/0.68/0.82/0.99	0.31/0.53/0.70/0.87/1.15	0.84/1.44/1.86/2.17/3.03	0.56/1.25/1.77/2.22/2.78	0.36/0.86/1.22/1.65/2.44	0.17/0.20/0.28/0.99/1.13	0.25/0.75/1.30/1.56/1.88	0.20/0.35/0.77/0.98/1.16	0.20/0.29/0.35/0.43/0.62	0.25/0.33/0.39/0.47/0.60
	0.38/1.04/1.45/1.67/2.58	0.75/1.20/1.57/1.81/2.48	0.69/1.13/1.44/1.58/1.89	0.37/1.37/1.57/1.89/2.90	0.0015/0.0015/0.18/0.84/1.75	0.0015/0.0015/0.42/1.18/2.24	0.0015/0.2714/1.04/1.54/2.46	0.74/0.88/0.99/1.33/1.61	0.0015/0.29/0.77/1.16/1.72	0.49/0.95/1.18/1.39/1.59	0.69/0.91/1.19/1.48/1.89	0.69/0.85/1.12/1.32/1.88
7 – Mali	1209	314	934	3708	19347	36092	26505	4791	5218	1384	296	95
	0.45/0.58/0.65/0.70/0.86	0.38/0.55/0.65/0.71/0.89	0.57/0.72/1.00/1.32/1.57	0.44/0.64/0.71/0.99/1.77	0.64/1.16/1.74/2.17/2.78	0.72/1.27/1.68/1.95/2.47	0.65/1.20/1.68/2.13/2.78	0.43/0.61/0.69/0.88/1.59	0.46/0.65/0.72/0.89/1.30	0.48/0.62/0.66/0.73/0.90	0.50/0.59/0.64/0.67/0.76	0.49/0.61/0.64/0.66/0.74
	1.53/1.62/2.12/2.40/2.80	1.43/1.59/1.64/2.30/2.80	0.0015/0.66/1.58/2.05/2.78	0.45/1.55/1.63/2.13/2.77	0.0015/0.0015/0.0015/1.36/2.28	0.0015/0.0015/0.17/1.38/2.42	0.0015/0.0015/0.47/1.62/2.61	0.0015/1.54/1.62/2.16/2.83	0.34/1.52/1.61/1.97/2.81	1.44/1.60/1.65/2.28/2.80	1.53/1.61/1.68/2.18/2.56	1.59/1.61/1.68/2.32/2.67
8 – Bodele	221	834	2974	4155	12251	21900	6915	2362	942	2330	125	293
	0.16/0.36/0.44/0.53/0.77	0.23/0.52/0.69/0.85/1.07	0.32/0.54/0.69/0.86/2.17	0.28/0.63/1.11/1.67/2.47	0.38/0.71/0.93/1.25/2.40	0.52/0.73/0.91/1.21/1.82	0.32/0.54/0.64/0.72/0.97	0.29/0.46/0.57/0.66/0.77	0.31/0.51/0.60/0.68/0.86	0.33/0.63/0.79/0.95/1.11	0.19/0.39/0.52/0.66/1.32	0.20/0.44/0.52/0.60/0.71
	0.61/0.83/1.57/2.22/2.59	0.38/0.72/1.40/1.73/2.54	0.0015/1.02/1.57/1.77/2.48	0.0015/0.02/0.75/1.51/2.28	0.0015/0.40/1.10/1.56/2.26	0.0015/0.60/1.43/1.65/2.46	0.45/1.27/1.58/2.05/2.61	0.50/1.42/1.69/2.32/2.72	0.50/1.28/1.63/2.32/2.78	0.15/0.68/1.48/1.64/2.56	0.61/0.76/1.66/2.33/2.89	0.61/1.37/1.89/2.34/2.57
9 – Ethiopia	0	2	0	0	0	149	6	0	0	0	0	0
	-	-	-	-	-	0.85/1.09/1.23/1.37/1.53	0.84/1.19/1.28/1.29/1.41	-	-	-	-	-
	-	-	-	-	-	0.51/0.70/0.87/1.01/1.36	0.43/0.49/0.64/0.92/1.00	-	-	-	-	-
10 – Saudi Arabia	265	52	1670	2028	3796	747	257	29	22	58	0	0
	0.43/0.53/0.63/1.16/1.35	0.28/0.37/0.41/0.46/0.55	0.32/0.66/0.92/1.67/2.17	0.58/0.86/1.05/1.19/1.38	0.59/0.92/1.18/1.52/2.17	0.42/0.61/0.80/0.95/1.16	0.37/0.49/0.56/0.68/0.79	0.39/0.43/0.48/0.56/0.64	0.19/0.31/0.41/0.46/0.60	0.45/0.60/0.66/0.73/0.84	-	-
	0.64/1.08/1.33/1.46/1.82	1.11/1.65/1.80/1.98/2.46	0.0015/0.33/0.98/1.49/1.81	0.29/0.74/1.14/1.48/1.96	0.0015/0.39/0.94/1.49/2.82	0.56/1.01/1.56/2.70/3.21	0.76/1.57/2.44/2.88/3.07	1.62/2.72/2.79/2.90/3.09	0.96/1.54/2.58/2.91/3.10	0.63/0.86/1.16/1.53/1.59	-	-

Table S1 Continued.

Site	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
11 – Kuwait	105	108	686	2799	4743	5779	5194	1918	770	527	9	38
	0.47/0.71/0.78/0.82/0.94	0.52/0.84/0.96/1.10/1.38	0.25/0.38/0.48/0.62/0.88	0.45/0.70/0.85/1.16/1.86	0.52/0.76/0.97/1.28/1.86	0.40/0.57/0.69/0.82/1.26	0.38/0.51/0.64/0.75/0.96	0.36/0.44/0.53/0.64/0.77	0.27/0.37/0.42/0.47/0.61	0.19/0.29/0.37/0.44/0.59	0.27/0.38/0.46/0.63/0.63	0.19/0.26/0.33/0.49/0.56
	0.57/0.92/1.25/1.66/2.57	0.014/0.80/1.37/1.64/2.37	0.69/1.36/1.66/2.32/2.83	0.0015/0.43/1.44/1.63/2.61	0.0015/0.29/1.25/1.62/2.65	0.21/1.33/1.60/2.22/2.82	0.53/1.45/1.67/2.41/2.86	0.96/1.58/2.02/2.48/2.80	0.83/1.65/2.44/2.63/2.90	0.73/1.07/1.61/2.19/2.64	1.01/1.59/1.63/1.63/1.69	0.68/1.17/1.40/1.56/1.62
12 – Gobi	0	0	111	296	50	40	12	15	1	0	7	0
	-	-	0.19/0.30/0.78/0.89/1.02	0.20/0.47/0.61/0.77/1.01	0.43/0.88/0.99/1.16/1.30	0.86/1.05/1.31/1.51/1.86	0.13/0.15/0.17/0.21/0.23	0.14/0.16/0.28/0.31/0.36	-	-	0.15/0.21/0.23/0.23/0.26	-
	-	-	0.25/0.83/1.38/1.66/2.85	0.49/1.02/1.34/1.62/2.98	0.07/0.62/0.99/1.36/1.54	0.0015/0.0015/0.07/1.11/1.94	0.80/0.85/0.86/0.88/1.31	0.50/0.76/0.86/1.02/1.56	-	-	0.80/0.81/0.82/0.87/0.94	-
13 – Taklimakan	0	4	747	2782	9513	1530	538	131	1124	35	0	0
	-	0.31/0.31/0.32/0.58/0.58	0.35/0.51/0.65/0.77/0.94	0.40/0.64/0.74/0.85/1.04	0.48/0.67/0.75/0.85/1.15	0.55/0.71/0.76/0.86/1.08	0.41/0.67/0.76/0.87/1.04	0.52/0.73/0.87/1.18/1.42	0.34/0.53/0.66/0.77/1.01	0.24/0.56/0.64/0.73/0.89	-	-
	-	1.34/1.34/1.64/1.87/1.87	0.45/0.87/1.20/1.56/2.02	0.35/0.84/1.19/1.53/1.78	0.31/0.83/1.15/1.53/1.72	0.34/0.77/1.17/1.53/1.72	0.41/0.86/1.14/1.53/1.71	0.0015/0.80/1.26/1.52/2.50	0.49/0.80/1.09/1.44/1.75	0.55/0.77/0.98/1.54/1.85	-	-
14 – Arizona	0	0	0	3	2	2	0	9	6	3	0	0
	-	-	-	0.26/0.26/0.48/0.48/0.48	-	-	-	0.15/0.25/0.32/0.37/0.49	1.02/1.15/1.27/1.28/1.38	1.46/1.46/1.87/1.87/1.87	-	-
	-	-	-	0.46/0.46/0.77/0.77/0.77	-	-	-	0.69/0.76/0.86/1.25/1.72	0.0015/0.0065/0.54/0.68/1.11	0.58/0.58/0.93/0.93/0.93	-	-
15 – Australia	710	568	615	250	7	18	95	152	192	460	526	1903
	0.57/0.90/1.14/3.53/4.26	0.50/0.74/0.88/0.99/1.10	0.60/0.81/0.93/1.03/1.17	0.70/0.94/1.04/1.11/1.21	0.93/0.99/1.10/1.16/1.19	0.22/0.91/0.96/1.01/1.08	0.37/0.50/0.61/0.74/0.86	0.25/0.74/0.92/1.03/1.21	0.79/0.99/1.10/1.23/1.64	0.70/1.10/1.56/2.41/3.54	0.88/1.17/1.28/1.37/1.54	0.72/1.01/1.13/1.26/1.46
	0.0015/0.34/0.93/1.46/1.92	0.68/1.04/1.39/1.60/2.01	0.57/0.88/1.15/1.51/1.66	0.41/0.67/0.95/1.34/1.56	1.23/1.34/1.41/1.50/1.55	0.50/0.80/0.83/1.06/1.52	0.45/0.59/0.85/1.47/1.57	0.34/0.63/0.91/1.19/1.55	0.04/0.47/0.80/1.26/1.49	0.0015/0.41/0.86/1.40/2.43	0.56/1.00/1.18/1.42/1.82	0.64/1.02/1.26/1.49/1.79

30

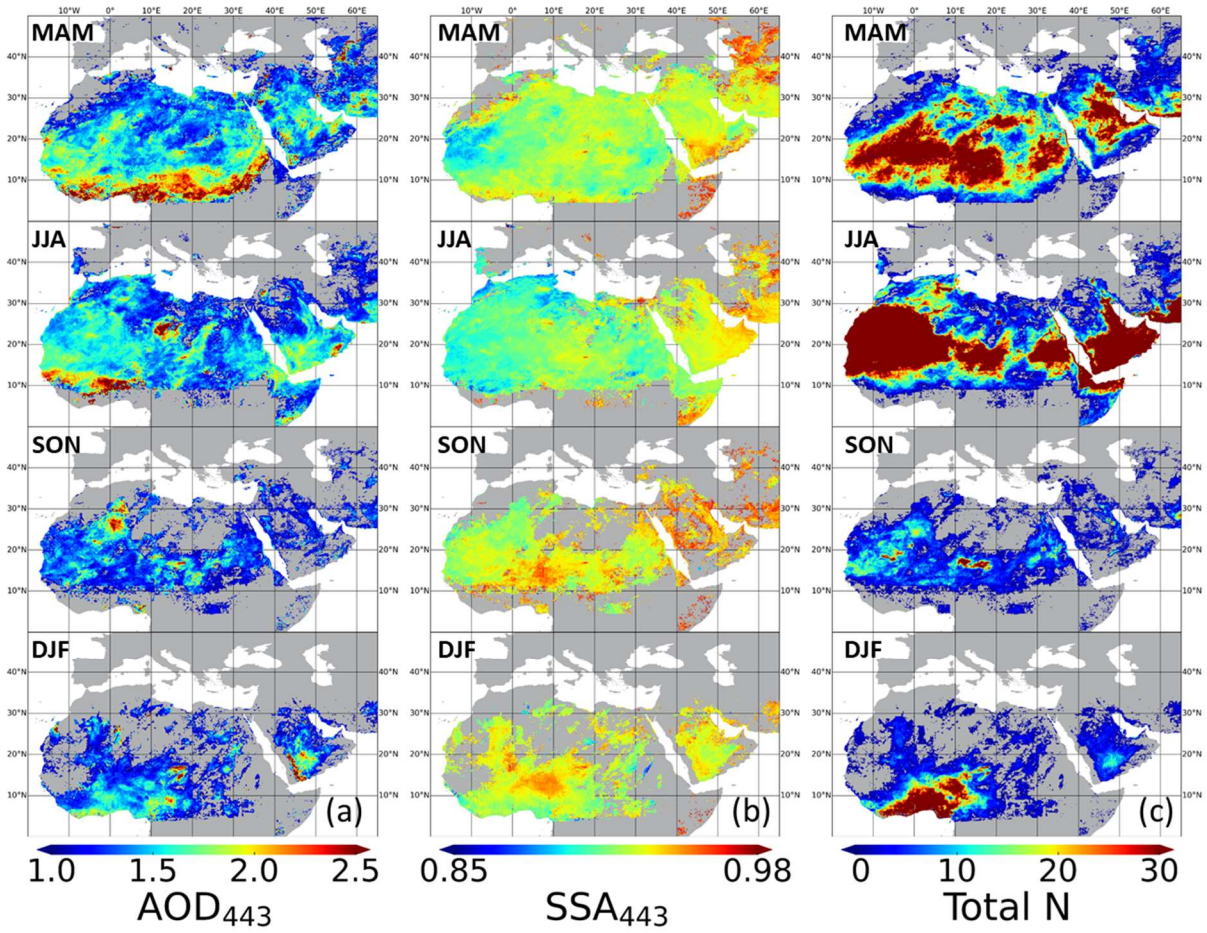


Fig S2 Seasonal average data for Sahara–Sahel dust source region generated from MAIAC EPIC 2018 data: (a) AOD at 443 nm; (b) SSA at 443 nm and (c) total number of datapoints. Climatology data may include some cases of dust/smoke mixtures causing bias relative to pure dust cases (Fig. 5; Figs A1–A6).

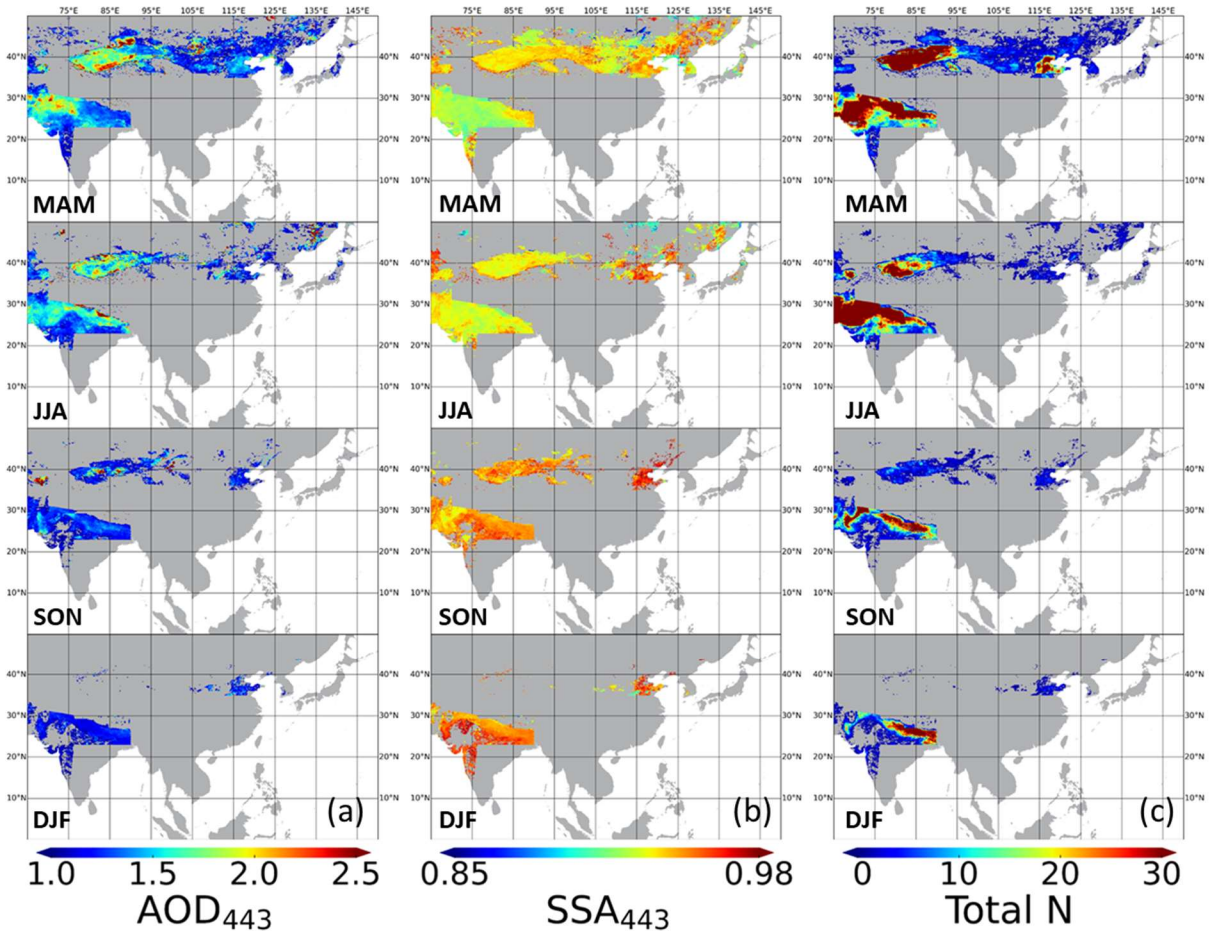


Fig S3 The same as in Fig. S2 but for the Asia dust sources.

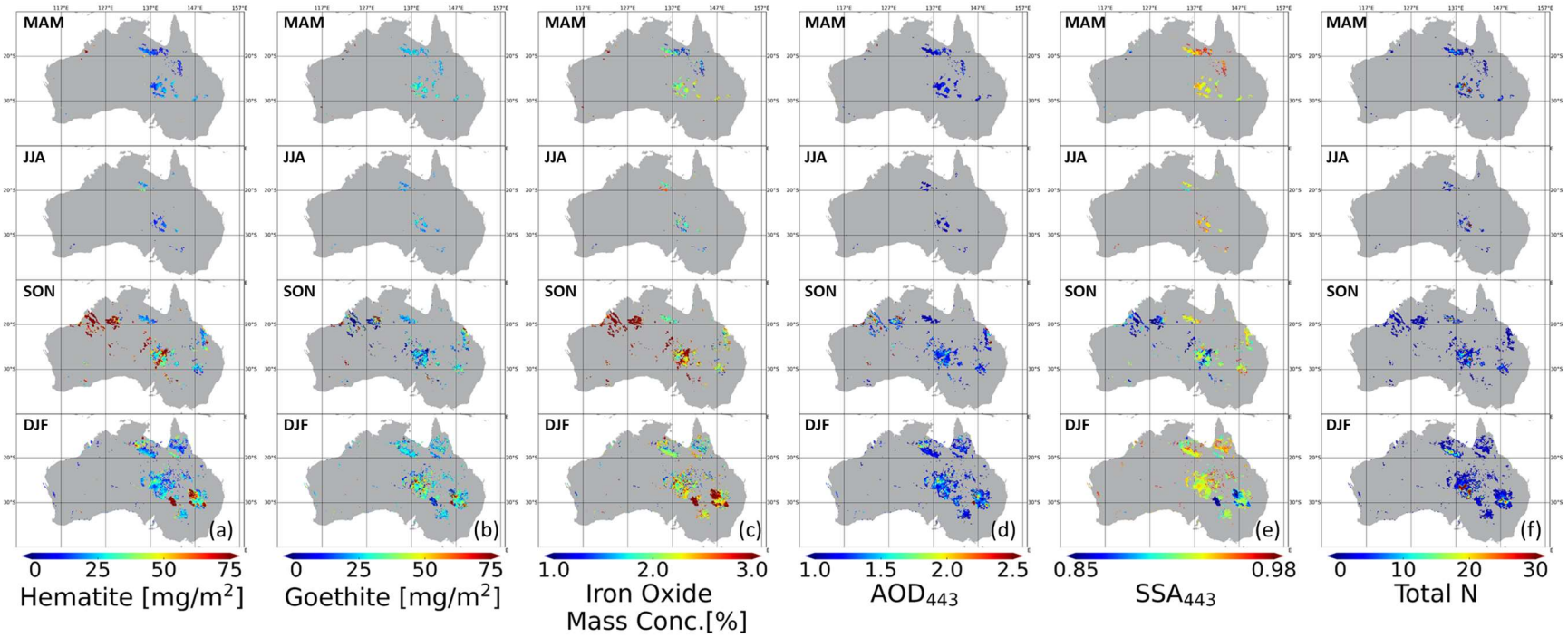


Fig S4 Seasonal average data for Australia dust source areas generated from MAIAC EPIC data: (a) hematite mass concentration (mg m^{-2}); (b) goethite mass concentration (mg m^{-2}); (c) iron-oxide mass concentration (wt.%); (d) AOD at 443 nm; (e) SSA at 443 nm and (f) total number of datapoints.

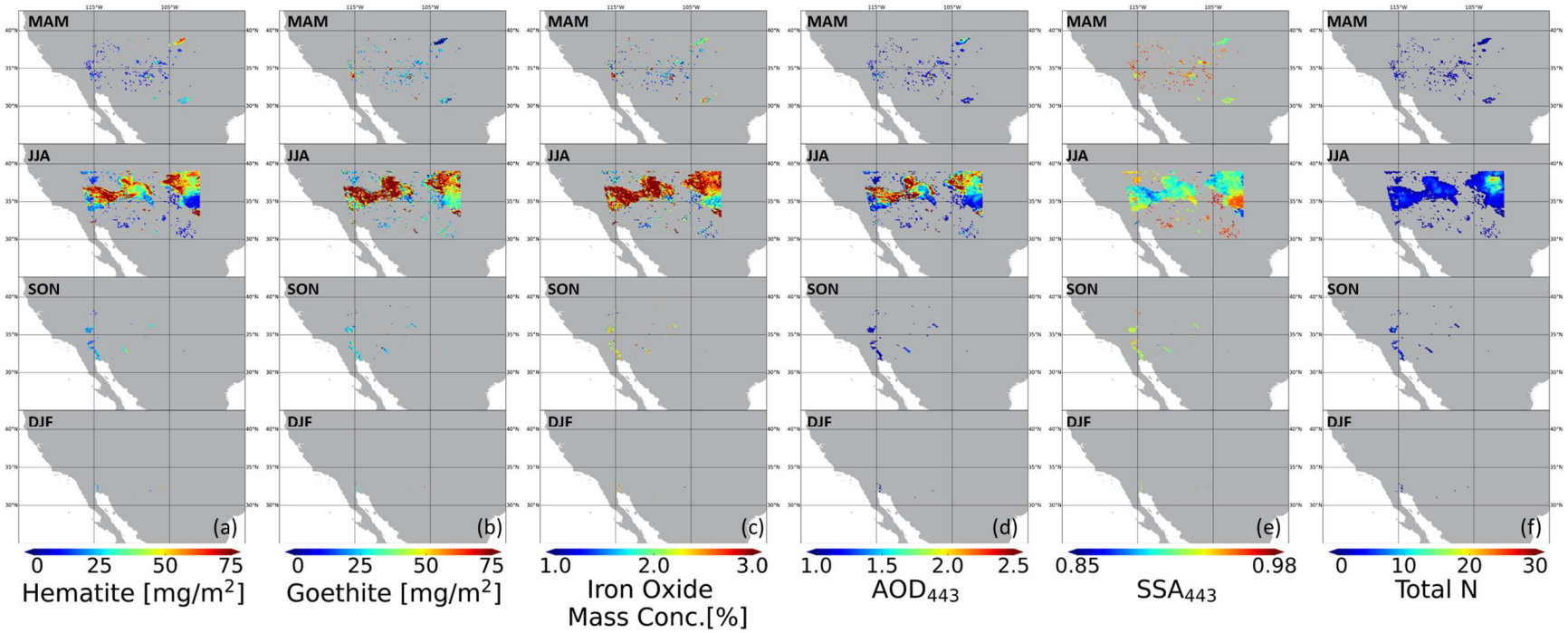


Fig S5 The same as in Fig. S4 but for the North America dust sources.

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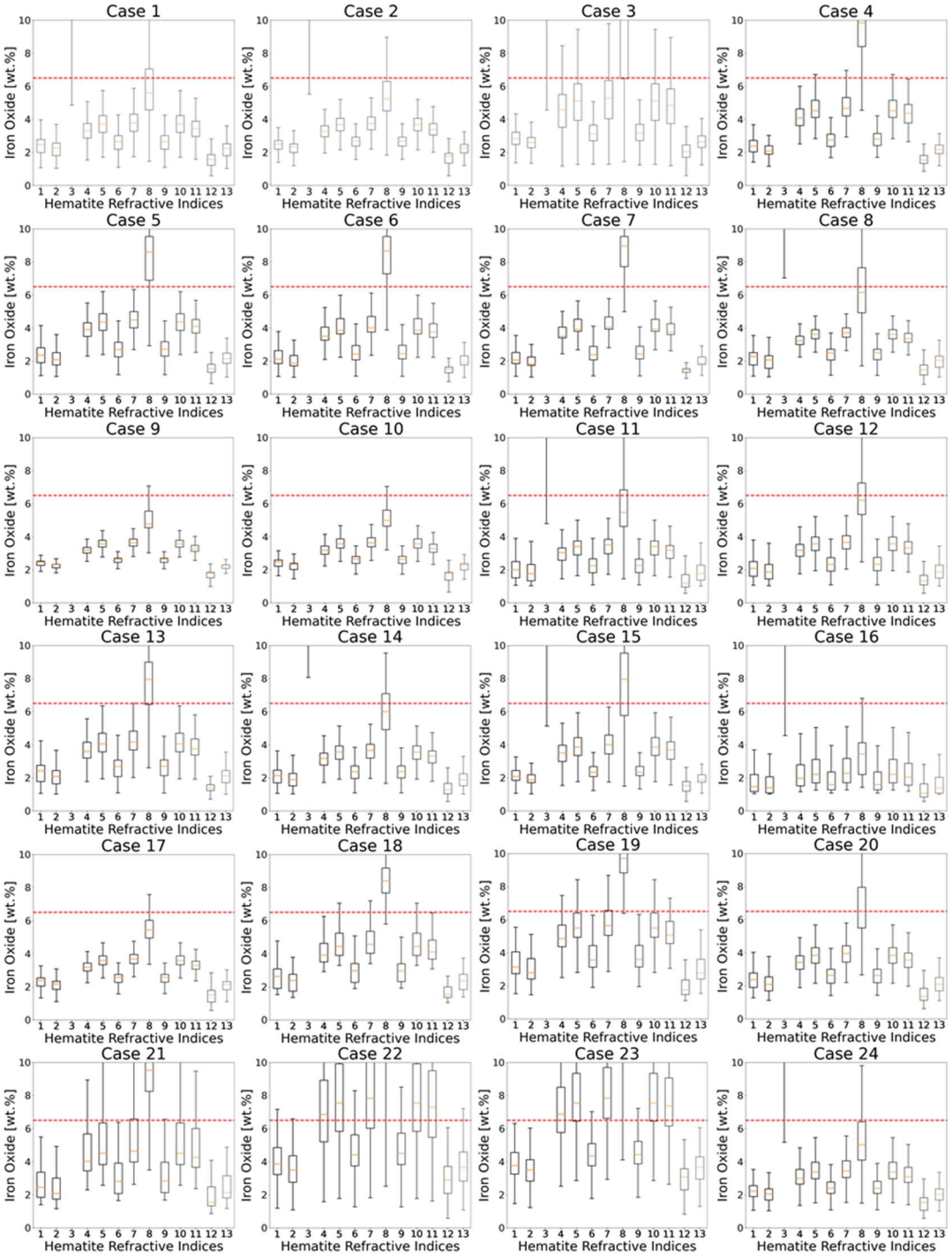

Fig. S6 Box and whisker plot of iron-oxide content by mass (wt.%; y axis) for 13 models of hematite refractive index (x axis; number 1–13, see Table 1) for the 24 dust cases presented in section 3.1. Red horizontal dashed line on each figure indicates the maximum expected iron-oxide content (6.5 wt.%) based on *in situ* measurements.

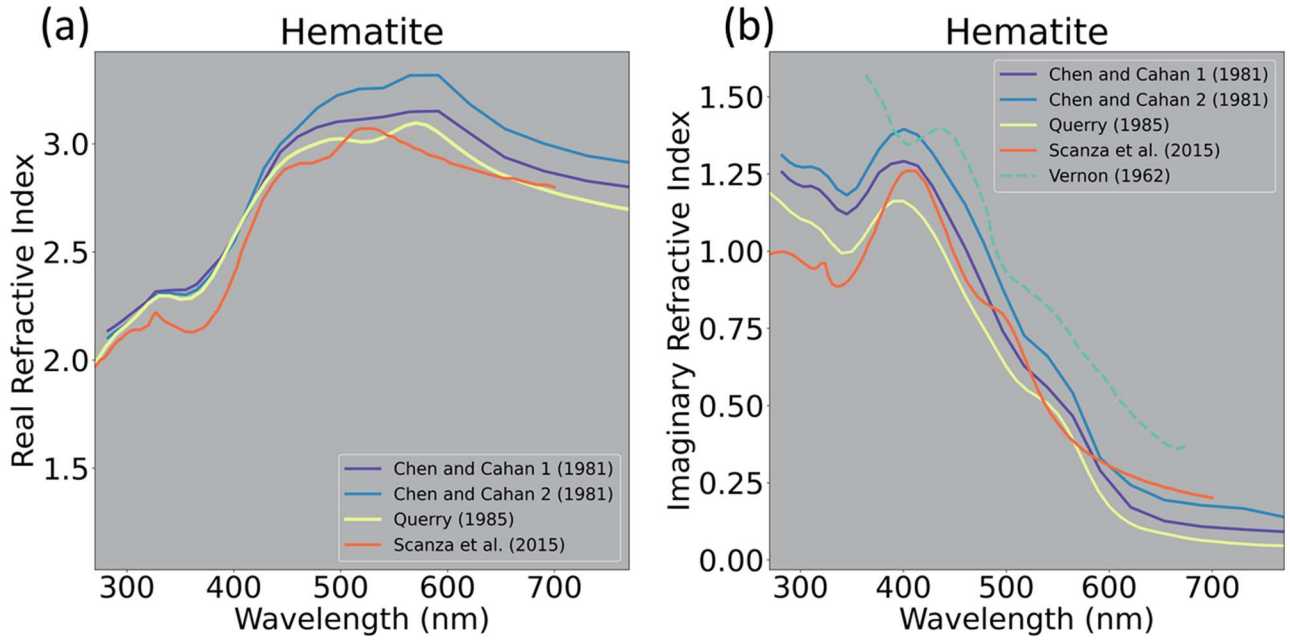

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Fig. S7 Most plausible real (a) and imaginary (b) hematite refractive indices selected in this study.

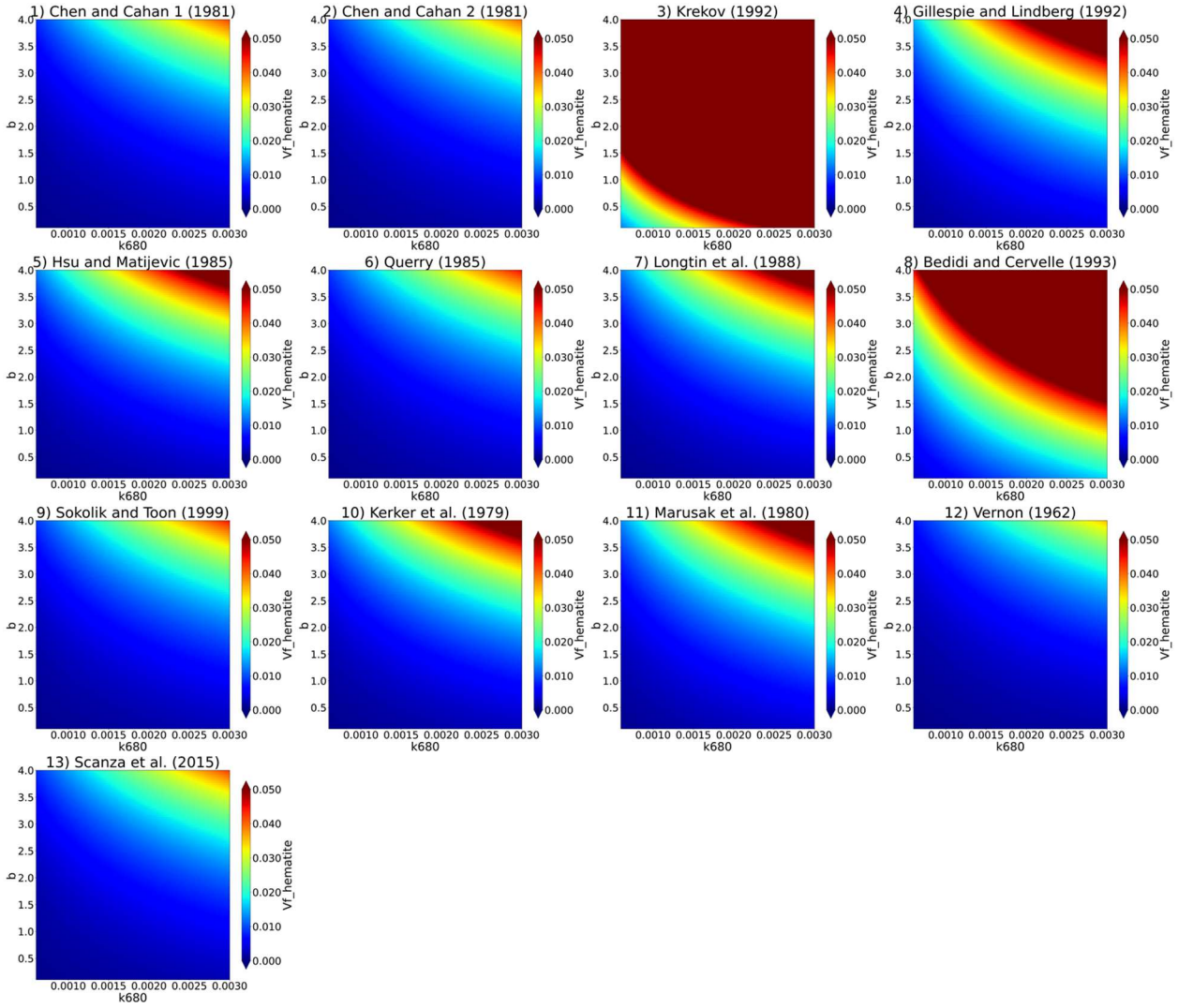

Fig. S8 Theoretical retrieval test. The hematite volume fraction (color bar) as a function of k_0 (x axis) and b (y axis) of MAIAC EPIC parameter using 13 models of hematite refractive index listed in Table 1. The maximum expected volume fraction of hematite and goethite is 3.25% by volume (Schuster et al., 2016).

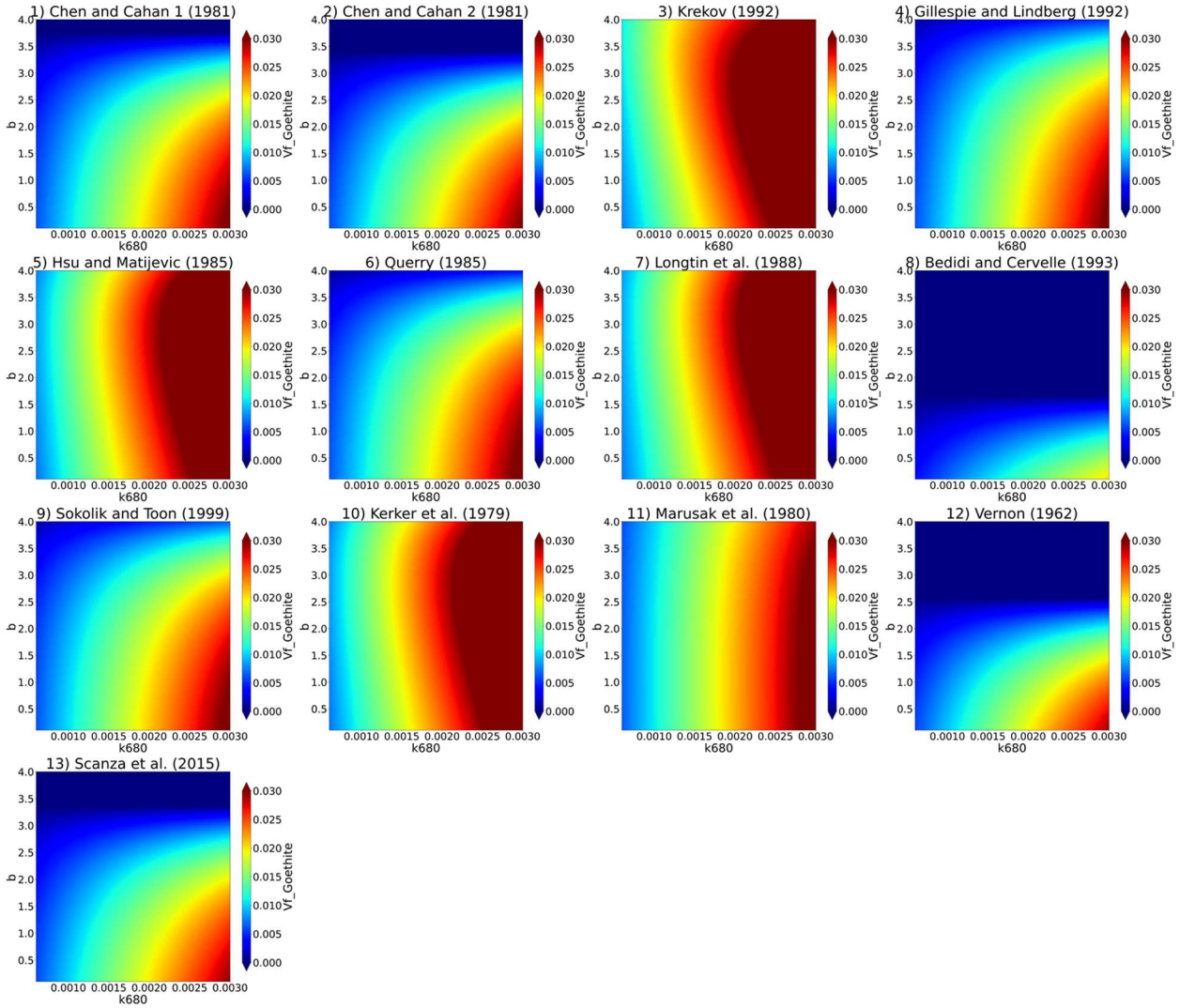

Fig. S9 Theoretical retrieval test. The goethite volume fraction (color bar) as a function of k_0 (x axis) and b (y axis) of MAIAC EPIC parameter using 13 models of hematite refractive indices listed in Table 1. The maximum expected volume fraction of hematite and goethite is 3.25% by volume (Schuster et al., 2016).

60

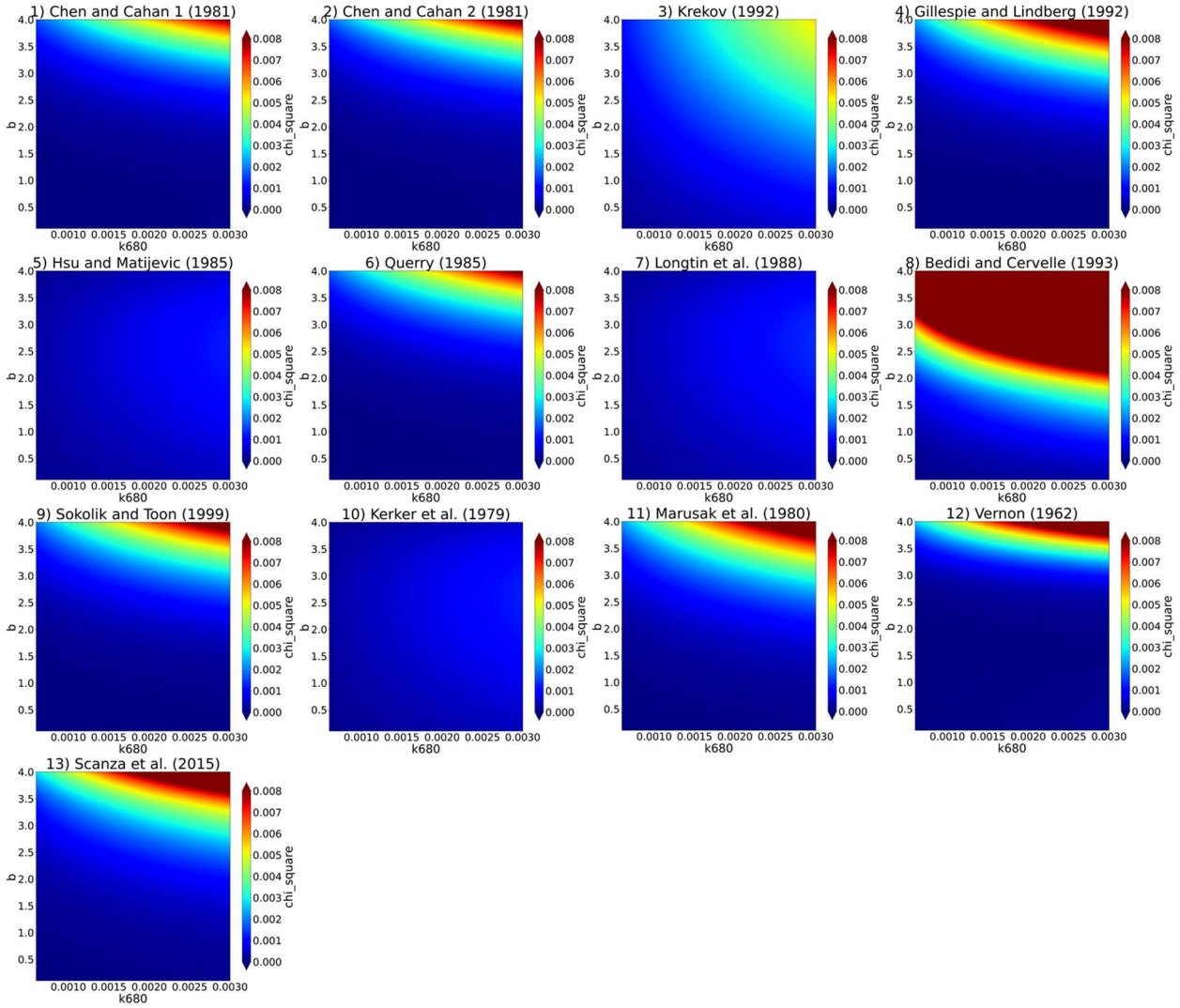

Fig. S10 Theoretical retrieval test. The cost function (color bar) as a function of k_0 (x axis) and b (y axis) of MAIAC EPIC parameter using 13 models of hematite refractive indices listed in Table 1.

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