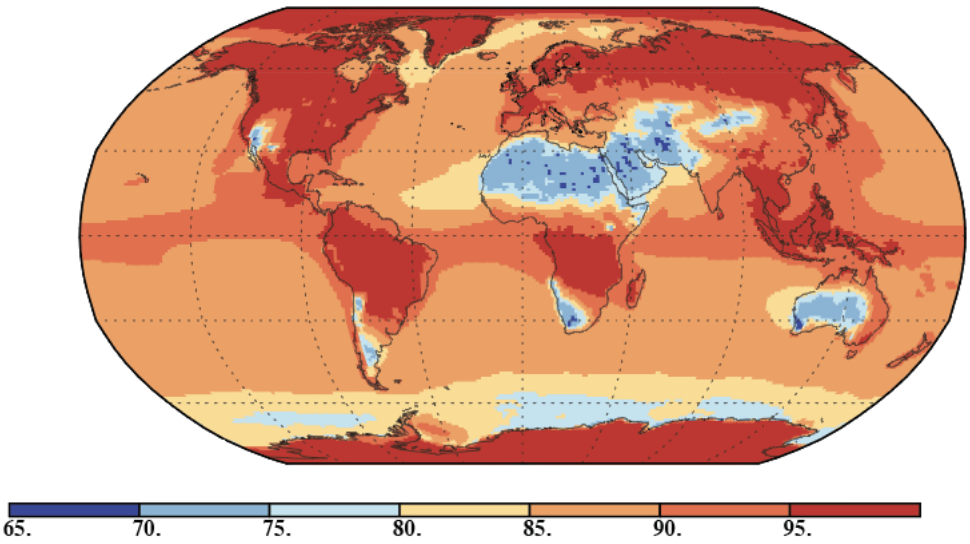

Figure S1: Modeled percentage of PM_{10} concentrations that are within $PM_{6.9}$ for the annual average.

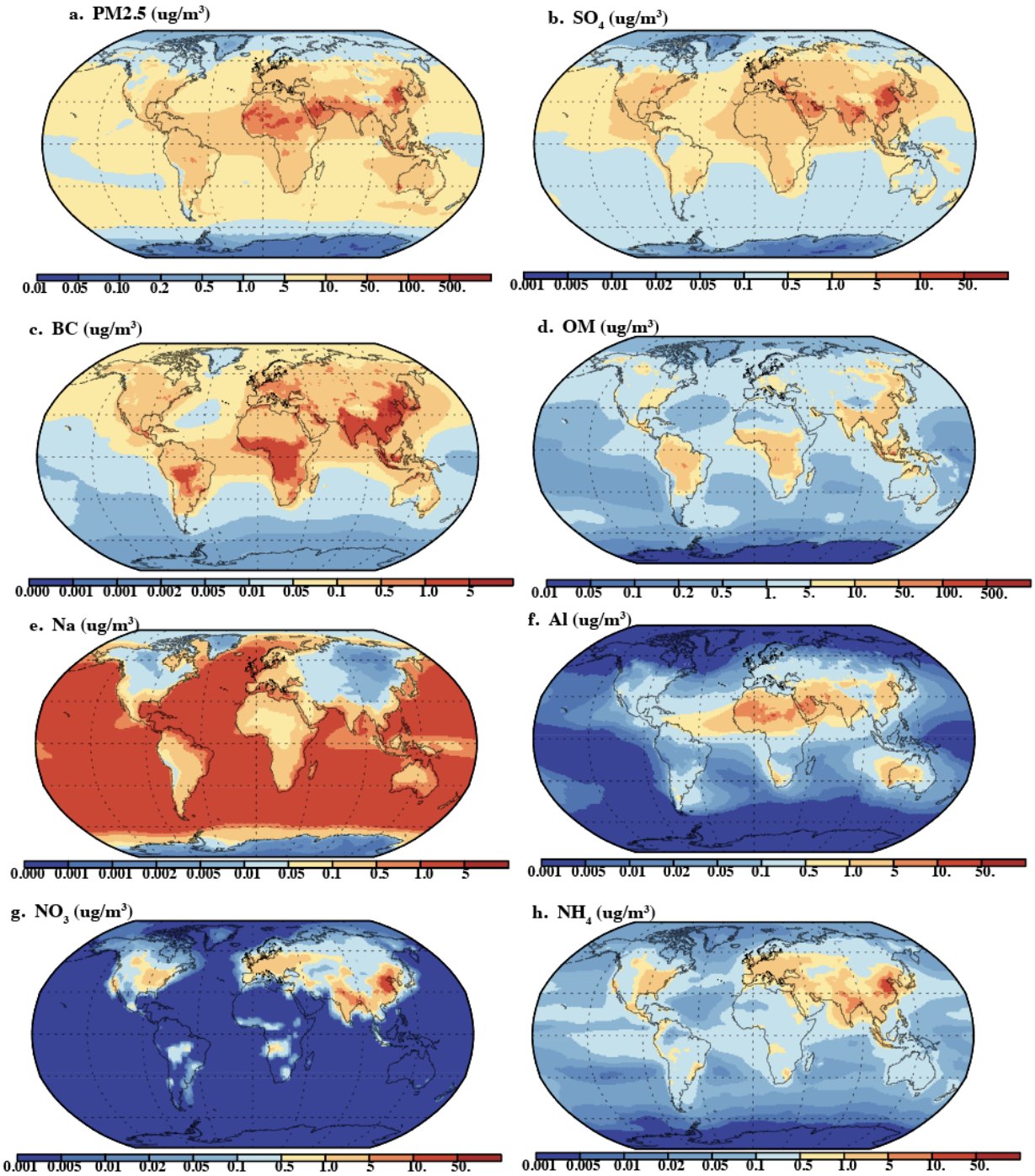

Figure S2: Modeled PM2.5 annual mean concentrations ug/m3 for a) total PM b) SO_4, c) BC, d) OM, e) Na, f) Al, g) NO_3, h) NH_4. These show the same model simulations as Figure 2 and 4, but show only the model simulations.

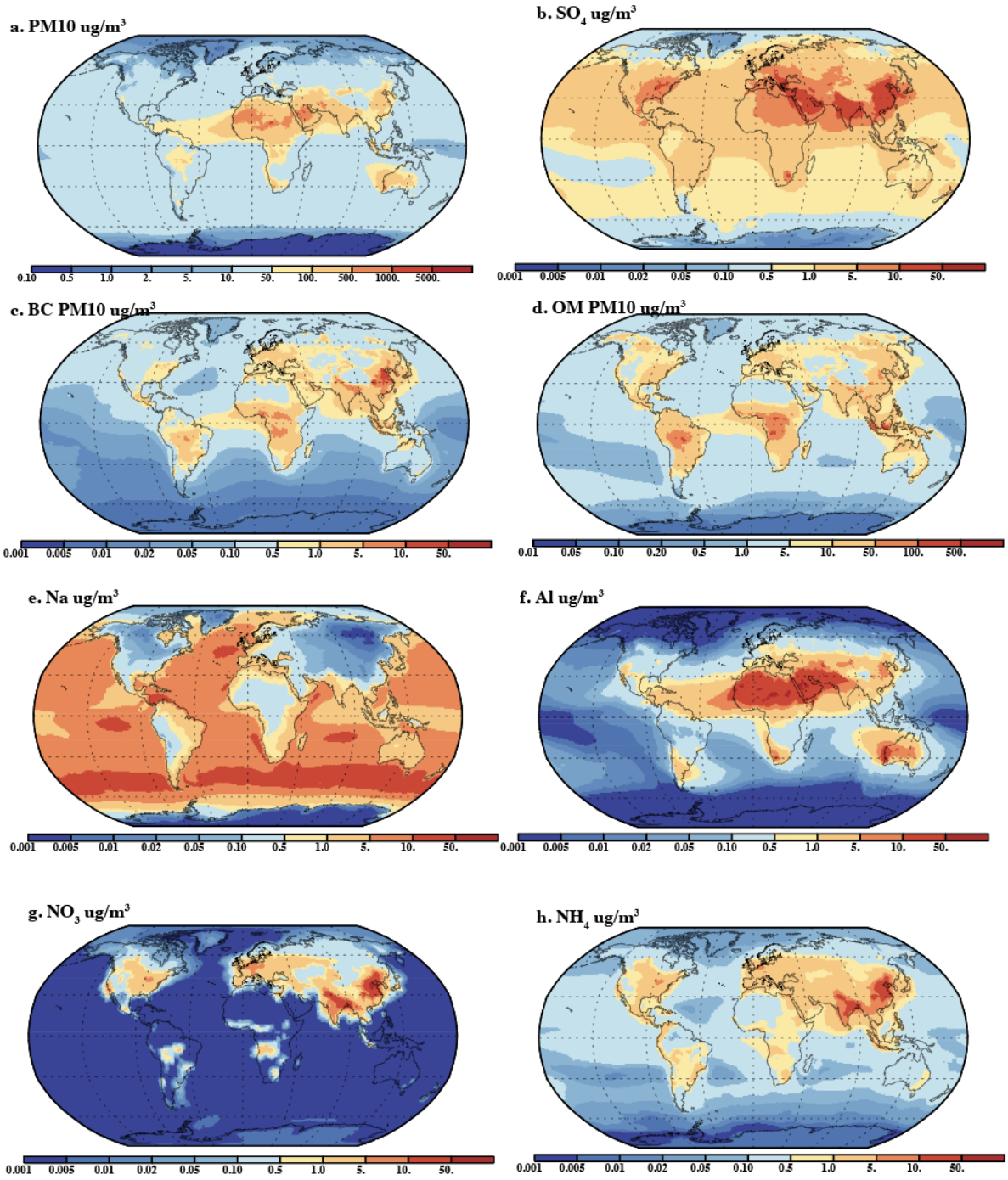

Figure S3: Modeled PM10 annual mean concentrations ug/m3 for a) total PM b) SO_4, c) BC, d) OM, e) Na, f) Al, g) NO_3, h) NH_4. These show the same model simulations as Figure 2 and 4, but show only the model simulations.

Table S1: Anthropogenic Percentage of Dust [a] (Table reproduced from Brodsky et al. (2023)

	North America	South America	North Africa	South Africa	Western Asia	Central Asia	Eastern Asia	Australia
% Anthropogenic Ginoux et al. (2012)	54	41	8.2	54	30	45	40	76[b]
% Anthropogenic - Tuned Run	49	40	8.4	59	32	48	38	15

[a] Average emissions over the regions specified in Ginoux et al. (2012) were calculated and crop area effectiveness as a dust source was modified to create the tuned anthropogenic crop dust source.

[b] Other studies have found a lower percent agricultural dust for Australia (Bullard et al., 2008; Mahowald et al., 2009; Webb and Pierre, 2018)

Table S2: Modelled aerosol composition (rows) and assumed contribution to observed measurements (fractions). Model constituents that are not included in the base CESM are marked with *.

	Measured constituent							
Modeled aerosol composition	PM	SO_4	EC	OM	Na	Al	NO_3	NH_4
SO_4	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Black carbon	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Primary Organic Matter	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00
Secondary Organic Carbon	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00
Seasalts	1.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00
Dust	1.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
NO_3*	0.50	0.00	0.00	0.00	0.00	0.00	0.50	0.00
NH4*	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Agricultural dust*	1.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
Road dust*	1.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
Coarse organic carbon*	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Coarse black carbon*	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Fine and coarse inorganic industrial matter*	1.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
Bacteria and Fungi*	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Other Primary Biogenic Particles from land*	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00

Marine organic aerosols*	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00

Table S3: Measurement variables from the supplemental data which are combined in the comparisons and the factor relation. PM=particulate matter; BC=black carbon; BC=elemental carbon; EC=elemental carbon; OM=organic matter; OC=Organic carbon; Note that the formula from Ash to dust was established by the University of Miami network (Prospero et al., 1996)

Measured reference constituent	Other measured constituents		
PM	PM		
SO_4^{+2}	SO4	(96/32)*S	
BC	BC	EC	
OM	1.8*OC	OM	
Na	Na		
Al	Al	1.4*0.07*Ash	0.07*Dust
NO_3^-	NO_3		
NH_4^+	NH_4		

Table S4: PM2.5 comparison statistics for Figures 2 and 4 model data comparisons including correlation coefficient (r), intercept (A) and slope (B) for linear regression with uncertainties (sigma A and sigma B), root mean square differences (rms), average model during time of the observations (µg/m3) and the number of observations (N).

	r	A	B	sigma A	sigma B	rms (µg/m^3)	avg model (µg/m^3)	avg obs (µg/m^3)	N obs
PM	0.72	-7.96E-01	1.56E+00	1.12E-01	5.15E-03	20	25	17	742
PM (not gridded)	0.78	-2.34E+00	2.17E+00	1.20E-01	3.07E-03	33	38	19	7067
SO_4	0.65	2.15E-01	1.75E+00	1.56E-02	7.65E-03	1.9	2.9	1.6	305
BC	0.25	3.17E-02	8.21E-01	7.44E-03	5.10E-03	3.1	0.6	1.1	207
OM	0.30	6.47E-01	1.08E+00	3.23E-02	6.15E-03	4.4	4.8	4.2	245
Na	0.46	-6.44E-02	3.60E+00	3.30E-03	2.11E-02	0.46	0.35	0.12	296
Al	0.31	-2.87E-02	4.07E+00	3.36E-03	2.48E-02	0.64	0.28	0.10	277
NO_3	0.41	-4.97E-02	1.33E+00	6.76E-03	5.90E-03	1.6	1.0	0.84	271
NH_4	0.30	-4.75E-02	1.64E+00	9.44E-03	8.07E-03	1.5	1.3	0.86	188

Table S5: PM10 comparison statistics for Figures 5 and 6 model data comparisons including correlation coefficient (r), intercept (A) and slope (B) for linear regression with uncertainties (sigma A and sigma B), root mean square differences (rms), average model during time of the observations (µg/m3) and the number of observations (N).

	r	A	B	sigma A	sigma B	rms (µg/m^3)	avg model (µg/m^3)	avg obs (µg/m^3)	N obs
PM	0.67	-5.31E+00	2.04E+00	3.22E-01	7.04E-03	64	64	34	687
PM (not gridded)	0.76	-1.09E+01	2.62E+00	2.19E-01	2.62E-03	84	89	39	6173
SO_4	0.42	0.78	2.77	0.05	0.02	5.71	5.9	2.1	154
BC	0.53	7.61E-02	1.57E+00	3.02E-02	1.72E-02	2.2	2.0	1.3	70
OM	0.50	1.31E+00	1.91E+00	1.61E-01	2.36E-02	12.2	12.3	5.2	54
Na	0.42	2.12E-02	2.80E+00	4.96E-02	1.95E-02	3.5	2.9	1.8	127
Al	0.31	-1.84E-02	4.30E+00	2.45E-02	3.08E-02	4.9	1.9	0.6	129
NO_3	0.48	-3.96E-02	1.55E+00	2.41E-02	1.55E-02	4.6	2.1	1.1	119
NH_4	0.25	-5.91E-02	3.64E+00	2.90E-02	2.93E-02	3.9	2.5	0.7	95