

**Table S1: Variability (defined as the standard deviation over the mean) at each station for the monthly mean concentration for 1990-2005 (a) and AOD (b) from the model and observations for each station (Figure 3 and 4). Variability from the observations is also shown (in parenthesis variability from the entire observed period, which may not overlap 1990-2005).**

a. Surf. Conc.	Banizo umbou	Barbad os	Bermu da	Cinzan a	Izana	Mace-head	Mbour	Miami	Midwa y
CAM4 (MERRA)	0.72	0.89	1.59	0.65	1.47	1.93	0.50	1.53	1.38
CAM4 (NCEP)	0.72	1.02	1.85	0.71	1.28	2.15	0.46	1.75	1.41
CAM4 (ERAI)	0.55	0.77	1.11	0.53	1.39	1.03	0.49	1.14	0.84
CAM4 (AMIP)	0.70	0.37	0.97	0.55	0.82	1.00	0.45	0.94	0.83
GCHEM (MERRA)	0.83	0.90	1.56	0.72	1.61	1.50	0.79	1.54	1.32
MATCH (NCEP)	0.86	0.80	1.72	0.80	1.56	2.16	0.77	1.52	1.04
CAM5 (AMIP)	0.78	0.88	1.64	0.71	1.14	2.70	0.83	1.70	1.13
Obs.	0.71 (0.90)	2.02 (0.77)	(1.96)	0.84	1.09 (1.08)	(1.19)	0.75 (0.75)	1.33 (1.14)	1.49 (1.20)

b. AOD	Bahrain	Dahkla	Dalanzadga d	Dhabi	Ilorin	Sede Boker
CAM4 (MERRA)	0.50	0.50	0.67	0.70	0.53	0.58
CAM4 (NCEP)	0.52	0.73	0.71	0.71	0.50	0.70
CAM4 (ERAI)	0.48	0.60	0.67	0.60	0.42	0.57
CAM4 (AMIP)	0.60	0.29	0.72	0.63	0.66	0.79
GCHEM (MERRA)	0.62	0.74	0.78	0.64	0.89	0.89
MATCH (NCEP)	0.48	0.69	0.62	0.52	0.84	0.80
CAM5 (AMIP)	0.70	0.67	0.83	0.70	0.82	0.62
Obs.	0.30 (0.29)	0.58 (0.58)	0.58 (0.58)	0.25 (0.39)	0.52 (0.39)	0.28 (0.32)

**Table S2: Fraction of the variability from seasonal cycle for the model and observations at each station for 1990-2005 for concentrations (a) and AOD (b) (Figure 3 and 4). Fraction of the variability from the seasonal cycle in the observations is also shown (in parenthesis fraction of the variability from the seasonal cycle from the entire observed period, which may not overlap 1990-2005).**

a. Surf. Conc.	Banizo umbou	Barbad os	Bermu da	Cinzan a	Izana	Mace-head	Mbour	Miami	Midwa y
CAM4 (MERRA)	0.90	0.69	0.80	0.94	0.70	0.41	0.78	0.91	0.83
CAM4 (NCEP)	0.91	0.76	0.79	0.91	0.67	0.41	0.73	0.88	0.83
CAM4 (ERAI)	0.89	0.89	0.88	0.88	0.69	0.51	0.82	0.96	0.86
CAM4 (AMIP)	0.95	0.45	0.82	0.94	0.74	0.24	0.91	0.91	0.89
GCHEM(MERRA)	0.86	0.57	0.70	0.78	0.65	0.54	0.70	0.71	0.80
MATCH (NCEP)	0.89	0.71	0.80	0.89	0.68	0.53	0.83	0.88	0.82
CAM5 (AMIP)	0.93	0.81	0.76	0.85	0.69	0.36	0.84	0.78	0.78
Obs.		0.82 (0.72)	0.70 (0.68)	0.66 (0.66)	0.50 (0.78)	0.53 (0.53)	0.61 (0.61)	0.68 (0.68)	0.94 (0.71)

b. AOD	Bahrain	Dahkla	Dalanzadga d	Dhabi	Ilorin	Sede Boker
CAM4 (MERRA)	0.94	0.75	0.83	0.96	0.80	0.71
CAM4 (NCEP)	0.91	0.82	1.00	0.94	0.67	0.71
CAM4 (ERAI)	0.91	0.92	0.75	0.93	0.73	0.75
CAM4 (AMIP)	0.89	0.55	0.85	0.88	0.81	0.87
GCHEM (MERRA)	0.85	0.65	0.86	0.82	0.88	0.75
MATCH (NCEP)	0.79	0.75	0.88	0.83	0.81	0.79
CAM5 (AMIP)	0.97	0.88	0.89	0.94	0.85	0.62
Obs.	0.82 (0.82)	0.94 (0.94)	0.86 (0.71)	1.0 (0.82)	0.94 (0.97)	0.80 (0.67)

**Table S3: Correlation of monthly mean concentration between model and observed values for each case and station for 1990–2005 for concentrations (Figure 3) (a) and AOD (Figure 4) (b). Correlations which are statistically significant at the 95 percentile level are in bold. Correlations of the seasonal cycle (climatology of 12 months) shown in parenthesis. Note that only the stations with overlapping time periods with the model runs are included in this analysis. CAM4-RE is the average of the model CAM4 (MERRA), CAM4 (NCEP) and CAM4(ERA).**

a. Surf. Conc.	Barbados	Bermuda	Izana	Mace Head	Miami	Midway
CAM4 (MERRA)	<b>0.62</b> (0.90)	<b>0.79</b> (0.98)	-0.03 (-0.49)	0.36 (0.30)	<b>0.76</b> (0.98)	<b>0.74</b> (0.96)
CAM4 (NCEP)	<b>0.71</b> (0.98)	<b>0.83</b> (0.97)	0.08 (-0.45)	0.36 (0.39)	<b>0.81</b> (0.99)	<b>0.69</b> (0.83)
CAM4 (ERA)I	<b>0.80</b> (0.95)	<b>0.75</b> (0.96)	0.02 (-0.46)	0.31 (0.42)	<b>0.86</b> (0.98)	<b>0.69</b> (0.90)
CAM4 (AMIP)	-0.03 (0.15)	<b>0.34</b> (0.78)	-0.15 (-0.54)	-0.18 (0.29)	<b>0.53</b> (0.77)	<b>0.10</b> (0.28)
GCHEM (MERRA)	<b>0.55</b> (0.83)	<b>0.72</b> (0.95)	0.06 (-0.39)	0.31 (0.55)	<b>0.77</b> (0.94)	<b>0.82</b> (0.95)
MATCH (NCEP)	<b>0.66</b> (0.87)	<b>0.88</b> (0.95)	0.11 (-0.41)	0.34 (0.48)	<b>0.81</b> (0.9 7)	<b>0.62</b> (0.88)
CAM5 (AMIP)	<b>0.49</b> (0.79)	<b>0.44</b> (0.95)	-0.15 (-0.46)	0.38 (0.61)	<b>0.55</b> (0.95)	<b>0.27</b> (0.56)
CAM4 (RE)	<b>0.77</b> (0.94)	<b>0.81</b> (0.97)	0.01 (-0.46)	0.38 (0.38)	<b>0.84</b> (0.98)	<b>0.74</b> (0.92)
b. AOD	Bahrain	Dahkla	Dhabi	Dalanzadg ad	Ilorin	Sede Boker
CAM4 (MERRA)	<b>0.73</b> (0.89)	<b>0.91</b> (0.89)	<b>0.71</b> (0.93)	<b>0.50</b> (0.80)	<b>0.58</b> (0.83)	<b>0.22</b> (0.20)
CAM4 (NCEP)	<b>0.76</b> (0.84)	<b>0.90</b> (0.92)	<b>0.82</b> (0.93)	<b>0.47</b> (0.70)	<b>0.69</b> (0.89)	<b>0.29</b> (0.38)
CAM4 (ERA)I	<b>0.72</b> (0.77)	<b>0.92</b> (0.95)	<b>0.82</b> (0.95)	<b>0.69</b> (0.95)	<b>0.62</b> (0.75)	<b>0.25</b> (0.35)
CAM4 (AMIP)	<b>0.60</b> (0.82)	<b>0.42</b> (0.76)	<b>0.66</b> (0.81)	<b>0.42</b> (0.70)	<b>0.72</b> (0.91)	<b>0.23</b> (0.40)
GCHEM (MERRA)	<b>0.64</b> (0.84)	<b>0.89</b> (0.84)	<b>0.68</b> (0.66)	<b>0.61</b> (0.89)	<b>0.87</b> (0.98)	0.19 (0.21)
MATCH (NCEP)	<b>0.65</b> (0.55)	<b>0.77</b> (0.84)	<b>0.68</b> (0.59)	<b>0.41</b> (0.61)	<b>0.77</b> (0.96)	<b>0.22</b> (0.33)
CAM5 (AMIP)	<b>0.42</b> (0.71)	<b>0.74</b> (0.93)	0.42 (0.58)	<b>0.53</b> (0.82)	<b>0.78</b> (0.94)	<b>0.26</b> (0.41)
CAM4 (RE)	<b>0.75</b> (0.86)	<b>0.93</b> (0.93)	<b>0.79</b> (0.90)	<b>0.56</b> (0.82)	<b>0.66</b> (0.84)	<b>0.25</b> (0.31)

**Table S4: Correlation of annual mean concentration between model and observed values for each case and station for 1990-2005 for concentrations (a) and AOD (b). Correlations which are statistically significant at the 95 percentile level are in bold. Note that only the stations with overlapping time periods with the model runs with multiple years are included in this analysis. CAM4-Re is the mean time series from the CAM4 (MERRA), CAM4 (NCEP) and CAM4 (ERA1) model simulations.**

a. Surf. Conc.	Barbados	Bermuda	Izana	Mace Head	Miami	Midway
CAM4 (MERRA)	0.16	0.64	0.08	0.26	-0.25	-0.72
CAM4 (NCEP)	0.15	<b>0.78</b>	0.33	0.63	-0.17	-0.66
CAM4 (ERA1)	0.19	0.14	0.28	0.66	0.37	-0.79
CAM4 (AMIP)	0.21	-0.011	0.12	-0.62	-0.20	-0.33
GCHEM (MERRA)	0.16	0.36	0.28	-0.27	-0.20	-0.53
MATCH (NCEP)	0.14	<b>0.92</b>	0.31	0.23	-0.20	-0.73
CAM5 (AMIP)	0.23	0.14	0.06	-0.08	-0.34	-0.37
CAM4-RE	0.20	0.43	0.21		-0.02	-0.71
b. AOD	Bahrain	Dalanzad gad	Ilorin	Sede Boker		
CAM4 (MERRA)	-0.12	0.55	0.47	-0.35		
CAM4 (NCEP)	0.22	0.37	0.60	-0.36		
CAM4 (ERA1)	-0.32	0.10	0.28	-0.39		
CAM4 (AMIP)	0.12	-0.12	-0.78	-0.59		
GCHEM(MERRA)	-0.73	0.25	<b>0.78</b>	-0.23		
MATCH (NCEP)	0.23	0.51	0.56	-0.12		
CAM5 (AMIP)	0.10	-0.09	0.63	0.33		
CAM4-RE	-0.11	0.48	0.47	-0.37		

**Table S5: Meteorological drivers of CAM4 model results in the Western Sahel and North Africa. Correlation between IAV in mobilization (source) and different meteorological variables (statistically significant values at 95% bold face),in the Western Sahel (13 to 22°N and -20 to 13°E). Only gridboxes which are active in each model are included in the calculation for that model.**

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	Precip.	Soil moisture	LAI	Sfc. Wind
CAM4 (MERRA)	<b>-0.20</b>	<b>-0.21</b>	<b>-0.20</b>	<b>0.78</b>
CAM4 (NCEP)	<b>-0.50</b>	<b>-0.47</b>	<b>-0.62</b>	<b>0.87</b>
CAM4 (ERA1)	-0.15	-0.16	<b>-0.41</b>	<b>0.63</b>
CAM4 (AMIP)	-0.13	-0.12	-0.15	<b>0.94</b>

**Table S6: Meteorological drivers of CAM4 model results in the Western Sahel region (13 to 22°N and -20 to 13°E). Slope of the normalized annual mean values from 1982 to 2008 (or time period available, shown in Table 1) for each region and model (statistically significant values are in bold). Values are normalized by dividing by the mean, so that slopes represent relative change per year. Only gridboxes which are active in each model are included in the calculation for that model.**

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	Precip.	Soil moisture	LAI	Sfc. Wind
CAM4 (MERRA)	0.0005	-0.001	<b>-0.0073</b>	<b>-0.0036</b>
CAM4 (NCEP)	<b>0.0443</b>	<b>0.016</b>	<b>0.057</b>	<b>-0.0036</b>
CAM4 (ERA1)	0.0010	<b>-0.0027</b>	-0.0001	<b>-0.0007</b>
CAM4 (AMIP)	<b>0.0194</b>	<b>0.0079</b>	<b>0.015</b>	<b>-0.0016</b>

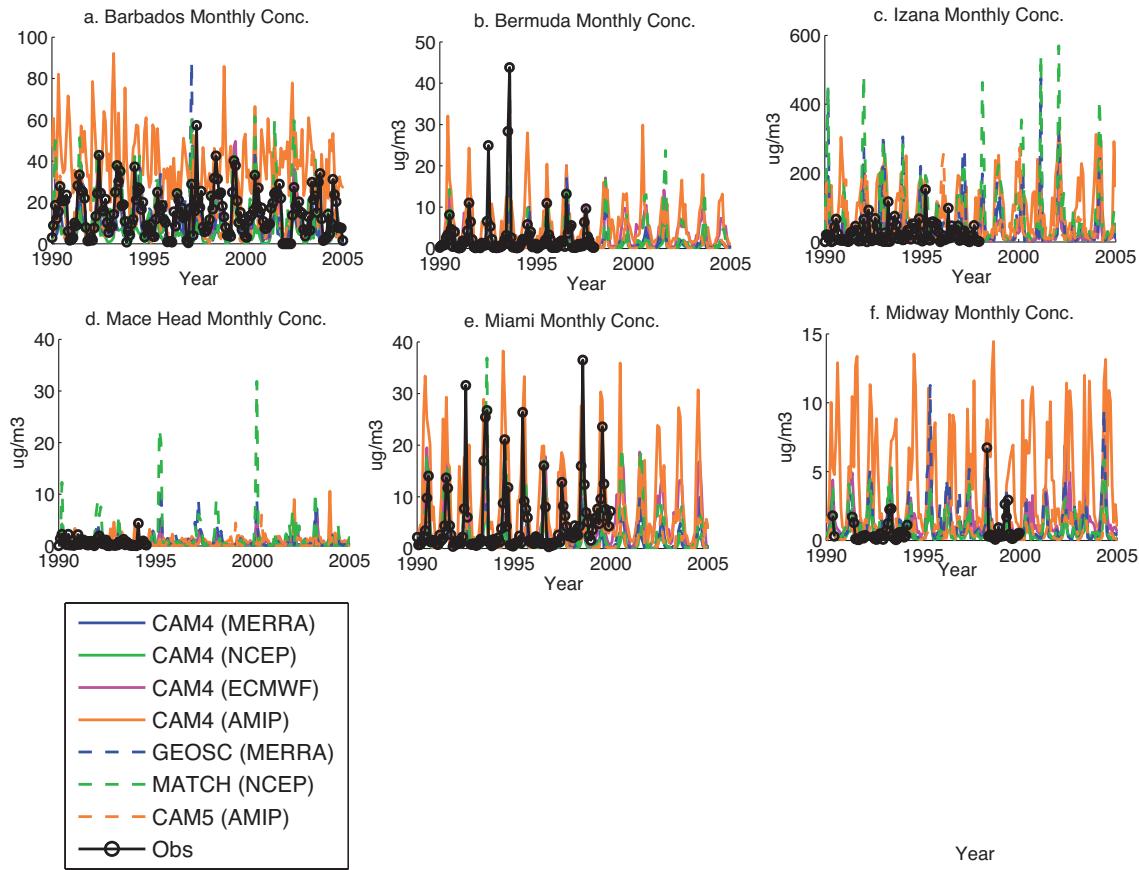
**Table S7: Correlation of variables for South American (Argentinian) dust sources in different model versions (statistically significant values at 95% bold face). The values are the correlation across time series averaged over the grid-boxes which are active sources in each model (which is different between different versions).**

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	Precip.	Soil moisture	LAI	Sfc. Wind
CAM4 (MERRA)	-0.04	0.04	<b>-0.56</b>	<b>-0.27</b>
CAM4 (NCEP)	<b>0.31</b>	<b>0.49</b>	<b>-0.63</b>	<b>-0.51</b>
CAM4 (ERA1)	<b>0.23</b>	<b>0.29</b>	<b>-0.33</b>	<b>-0.22</b>
CAM4 (AMIP)	-0.06	0.04	<b>-0.47</b>	<b>0.45</b>

**Table S8: Slopes in mobilization and meteorological variables in different regions for the annual average over 1990-2005 in each region (only including gridboxes which are active at any time in that model simulation).** Values shown are the averages of the slopes across the CAM4-Reanalysis models (CAM4(MERRA), CAM4(NCEP) and CAM4(ERA5)). The regions are defined as in Table 5. Bold values represent slopes that are larger than the average across the models of the one sigma error in the regression.

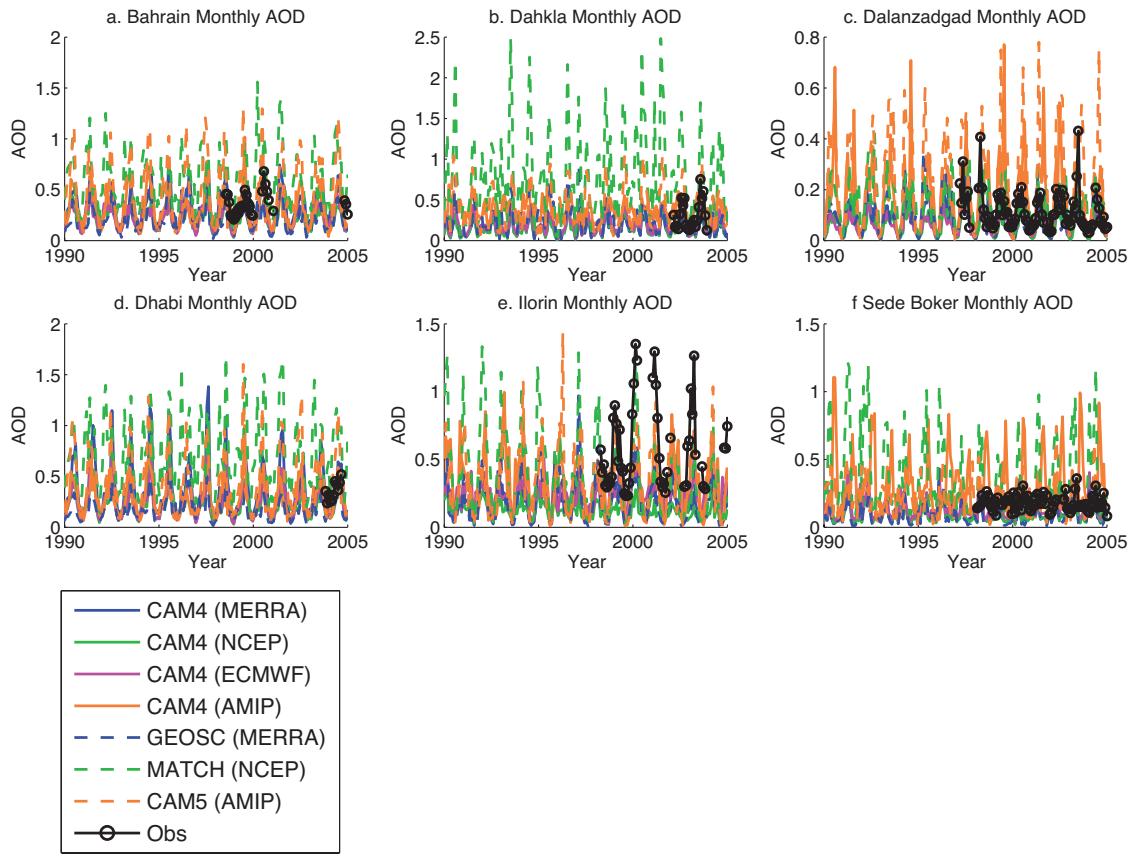
	Source.	Precipitation	Leaf Area Index	Sfc. Wind
Australia	<b>0.051</b>	-0.013	<b>-0.032</b>	<b>-0.0026</b>
East Asia	-0.0035	<b>0.006</b>	-0.0025	-0.0011
Middle East	-0.0012	-0.0022	0.0066	0.0001
North Africa	-0.0003	-0.0015	0.0024	<b>-0.0018</b>
North America	0.0024	-0.0069	<b>-0.0172</b>	-0.0001
Sahel (Western)	<b>-0.0087</b>	<b>0.0135</b>	<b>0.0239</b>	<b>-0.0039</b>
South Africa	<b>-0.011</b>	<b>0.0243</b>	<b>0.0392</b>	0.0012
South America (Argentina)	<b>-0.13</b>	0.001	0.0107	0.0016
Globe	-0.0005	0.0012	<b>0.0035</b>	<b>-0.0011</b>



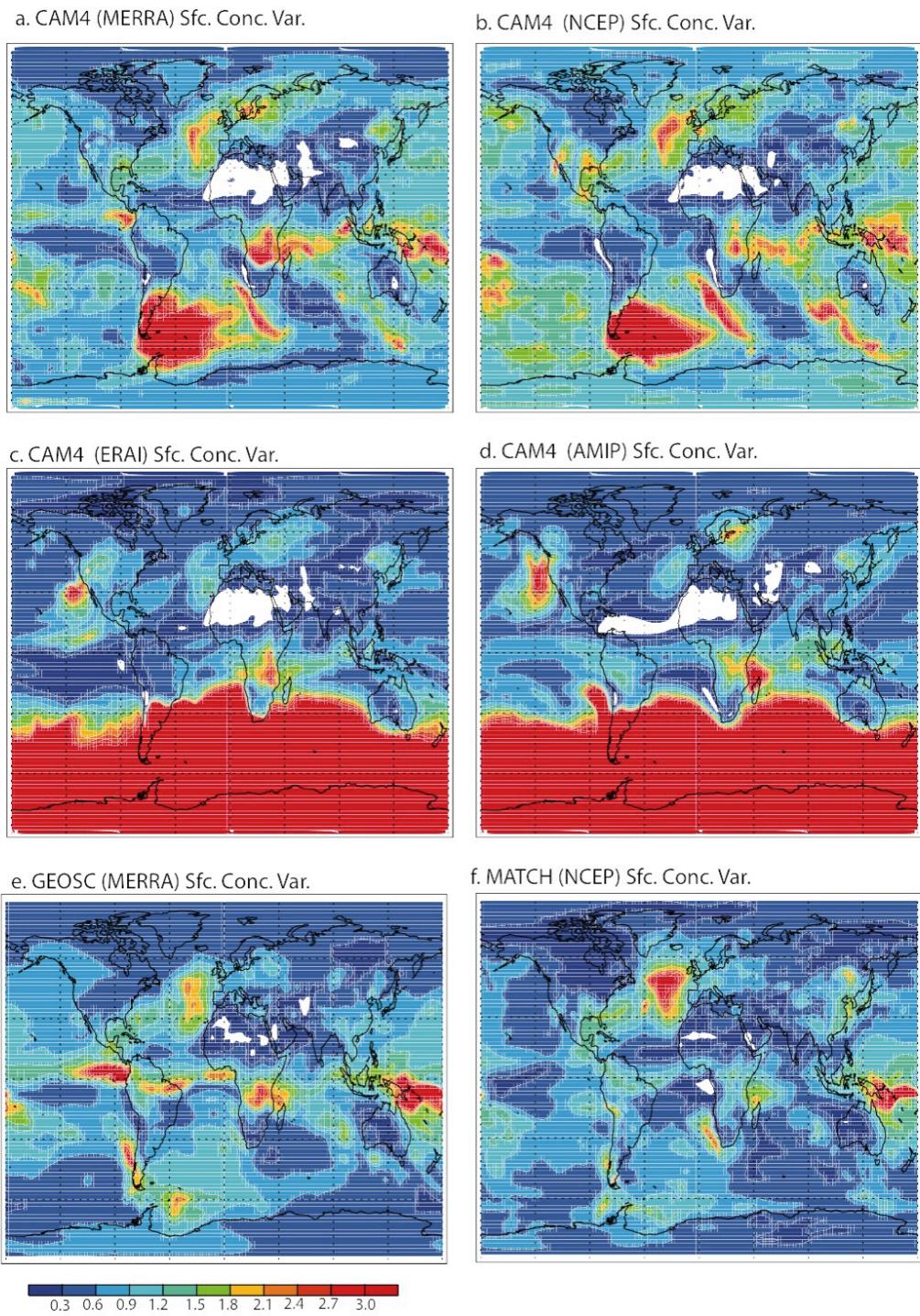
**Figure S1: Monthly mean time series of dust concentration ( $\mu\text{g}/\text{m}^3$ ) at stations with multiple years of data overlapping with the model simulations: a) Barbados ( $13^\circ\text{N}$ ,  $60^\circ\text{W}$ ), b) Bermuda ( $32^\circ\text{N}$ ,  $65^\circ\text{W}$ ), c) Izana ( $28^\circ\text{N}$ ,  $16^\circ\text{W}$ ), d) Mace Head ( $53^\circ\text{N}$ ,  $10^\circ\text{W}$ ), e) Miami ( $26^\circ\text{N}$ ,  $80^\circ\text{W}$ ), and f) Midway ( $28^\circ\text{N}$ ,  $177^\circ\text{W}$ ). Data from U. of Miami network sites (e.g. Prospero, 1990; Prospero, 1996). Observations are in black: if no observations shown, observations are from a different time period, and only used for variability and seasonal cycle calculations. Different colors and line styles indicate the different model versions: CAM4 (MERRA) (blue solid), CAM4 (NCEP) (green solid), CAM4 (ERA1) (pink solid), CAM4 (AMIP) (orange solid), GEOSC (MERRA) (blue dashed), MATCH (NCEP) (green dashed), CAM5 (AMIP) (orange dashed) (colors the same as Figure 1).**

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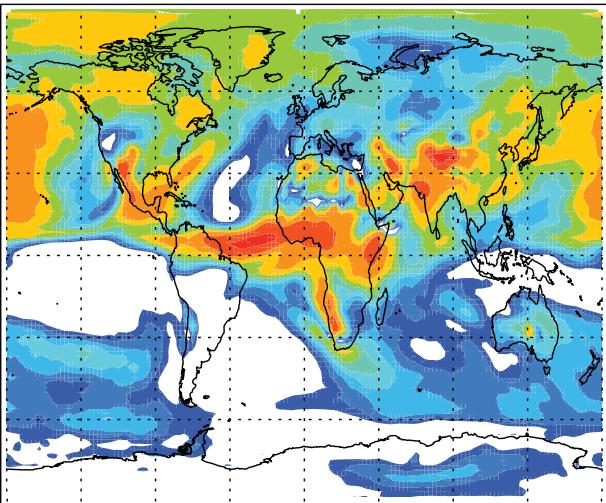


5 **Figure S2: Timeseries of monthly mean AOD for model simulations (based on dust only), compared with AERONET observations (Holben et al., 2000) for: a) Bahrain ( $26.208^{\circ}\text{N}$ ,  $50.609^{\circ}\text{E}$ ), b) Dahkla ( $23.717^{\circ}\text{N}$ ,  $15.950^{\circ}\text{W}$ ), c) Dhabi ( $24.481^{\circ}\text{N}$ ,  $54.383^{\circ}\text{E}$ ), d) Ilorin ( $8.320^{\circ}\text{N}$ ,  $4.340^{\circ}\text{E}$ ), e) Sede Boker ( $30.855^{\circ}\text{N}$ ,  $34.782^{\circ}\text{E}$ ), and f) Dalanzadgad ( $43.577^{\circ}\text{N}$ ,  $104.419^{\circ}\text{E}$ ) for each of the different model versions (Colors are the same as in Figure 1 and S7). Observational data from AERONET stations (listed in Table 2).**

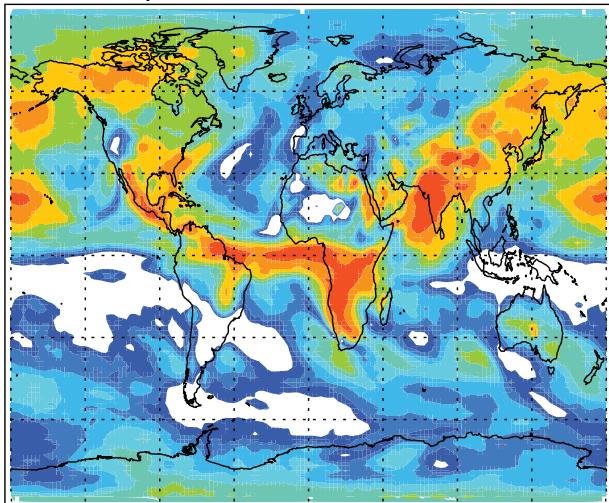


**Figure S3: Spatial plot of the variability (standard deviation over mean) of the monthly mean surface concentration for CAM4 (MERRA) (a), CAM4 (NCEP) (b), CAM4 (ERA1) (c), CAM4 (AMIP) (d), GEOSC (MERRA) (e), MATCH (NCEP) (f).**

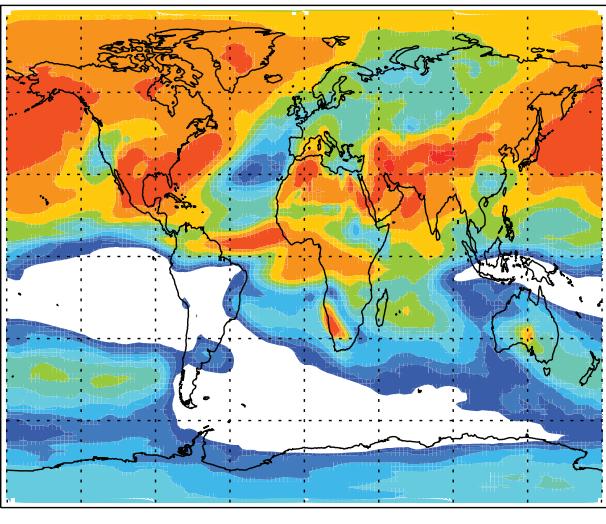
a. Corr. Sfc. Conc (AMIP runs)



b. Corr. Deposition (AMIP runs)

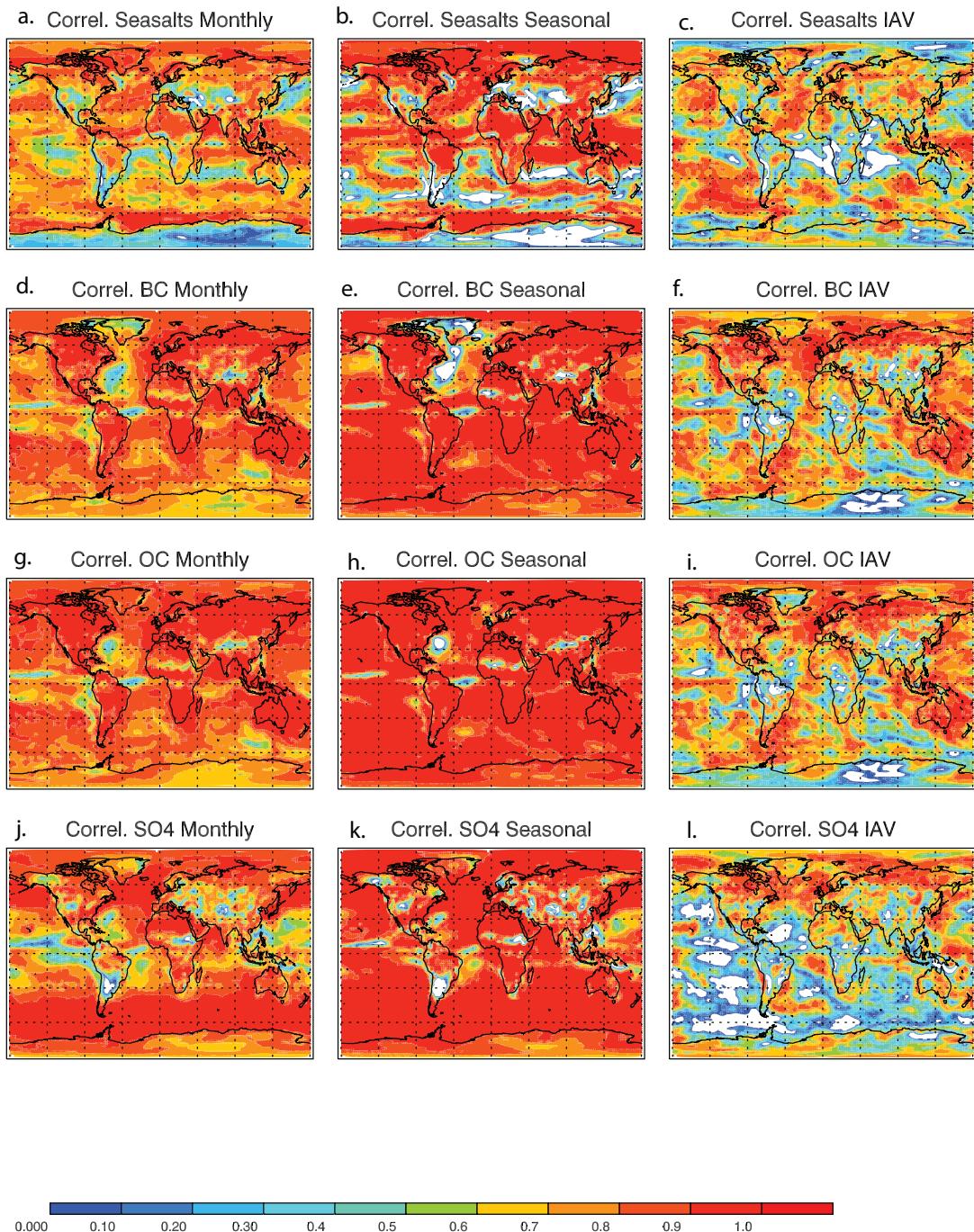


c. Corr. AOD (AMIP runs)



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Figure S4: Spatial plot of the temporal rank correlation of the monthly mean modeled values for the average correlation between the CAM4-AMIP and CAM5-AMIP simulation for surface concentration (a), deposition (b) and AOD (c).



**Figure S5: Correlation maps for the CAM4 (MERRA) and CAM4 (NCEP) simulations for additional aerosol species (Seasalts (a, b, c), black carbon (BC) (d,e,f), organic carbon (OC) (g, h, i), and sulfate (SO4) (j,k,l), for monthly mean (left hand column: a,d,g,j), seasonal climatological monthly means (b,e,h,k) and IAV (interannual variability) (c,f,i,l).**

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Albani S, Mahowald N, Perry A, Scanza R, Zender C, Flanner MG (2014) Improved representation of dust size and optics in the CESM. Journal of Advances in Modeling of Earth Systems, **6**, doi:10.1002/2013MS000279.

Holben BN, Tanre D, Smirnov A *et al.* (2001) An emerging ground-based aerosol climatology: Aerosol optical depth from AERONET. Journal of Geophysical Research, **106**, 12067-12097.