Supplement

S1. Description of the Dust Emission Parameterization

The dust detrainment and deposition (DEAD) scheme (Zender et al., 2003) is based on a theory studying the transport of dust by winds on Mars by White (1979) to calculate horizontal dust saltation flux H:

$$H = C\frac{\rho}{g}U^{*3}(1-\frac{U_t^*}{U^*})(1+\frac{U_t^*}{U^*})^2 \quad (1)$$

where C is a global tuning factor determining the total dust strength, ρ is the air density, g is the acceleration of gravity, U^* is the friction velocity and U_t^* is the threshold friction velocity. The vertical dust flux, F, is proportional to the horizontal saltation flux. F is parameterized as:

$$F = A_m S \alpha H, \quad (2)$$

where α is the sandblasting mass efficiency, which is a function of the clay fraction in the soil. We use a fixed soil clay fraction of 0.2 as suggested in Zender et al. (2003). S is dust source function, which is an effective factor that favors emissions from specific geographic features. We updated S with a fine resolution dataset without vegetation mask Ginoux et al. (2001). A_m is a factor that suppresses dust emission from snow covered land (A_s), wetlands (A_i) and water bodies (A_w) and vegetated area (A_v),

$$A_m = (1-A_s)(1-A_i-A_w)(1-A_v) \quad (3)$$

The vegetation effect A_v is represented by monthly mean leaf plus stem area index (LAI) following Zender et al. (2003). This feature enables seasonal dust mobilization in the dust emisison scheme. We have not investigated the annual vegetation variation in this study.

Supplemental Figures

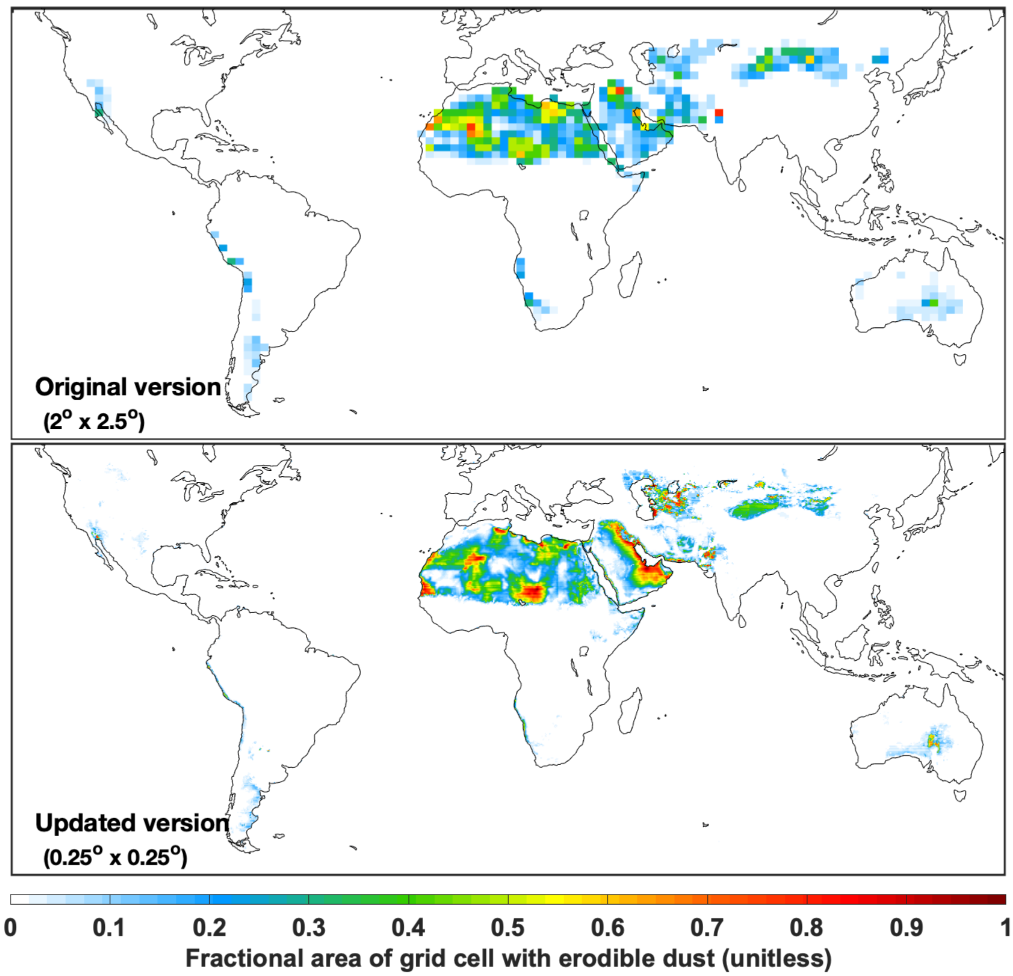

Figure S1. The original and updated versions of the dust source function.

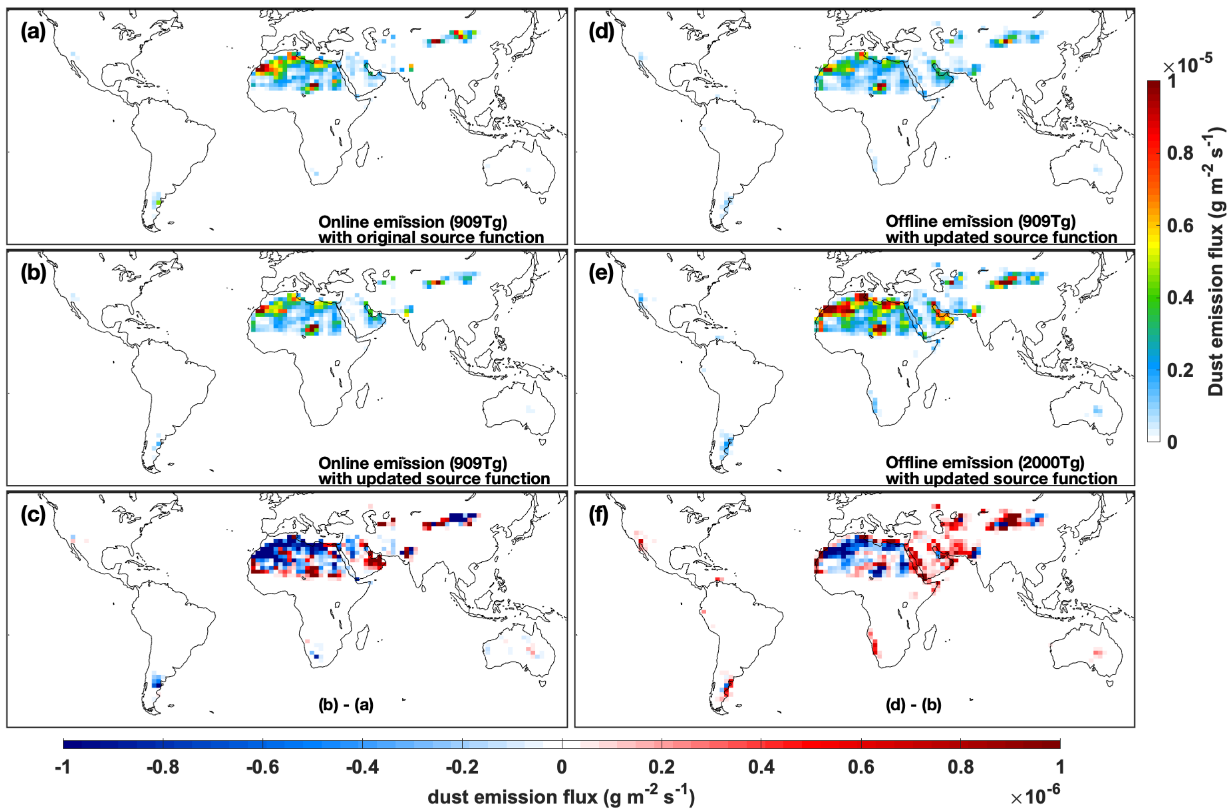

Figure S2. The same as Fig. 2 but averaged over MAM (March, April and May).

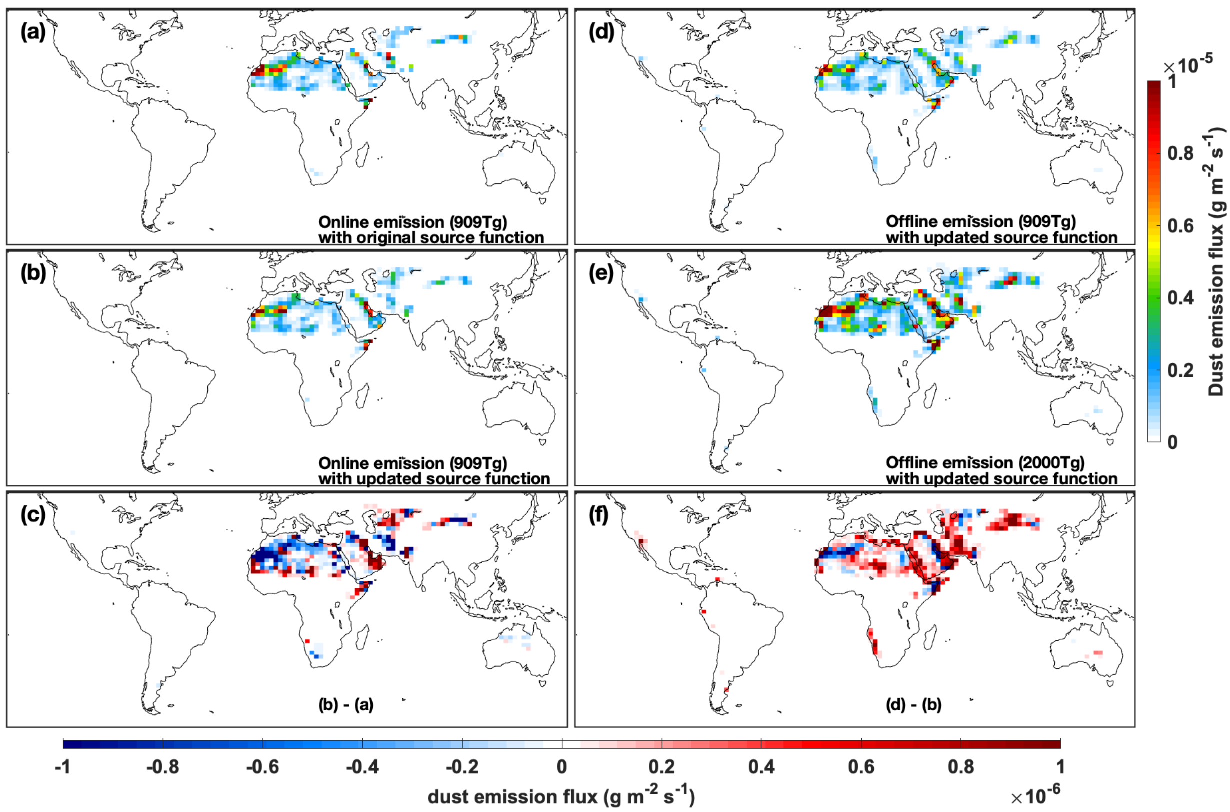

Figure S3. The same as Fig. 2 but averaged over JJA (June, July and August).

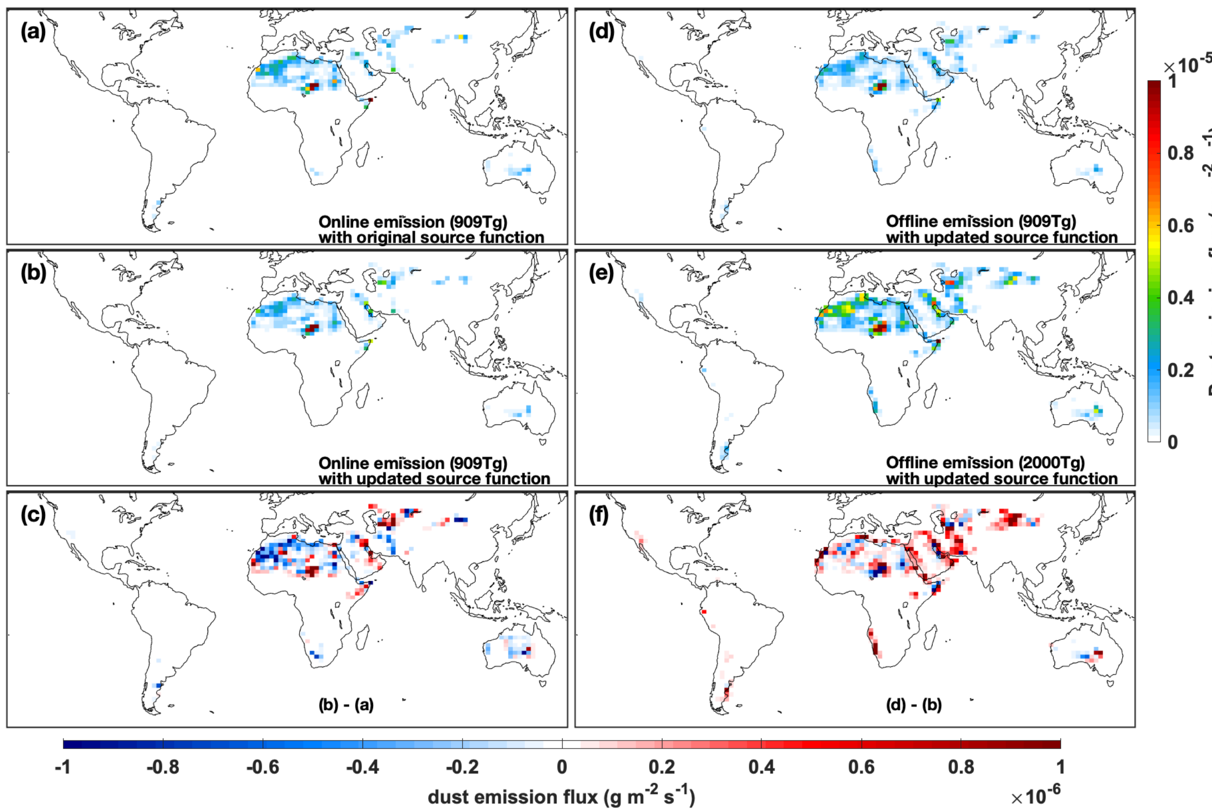

Figure S4. The same as Fig. 2 but averaged over SON (September, October and November).

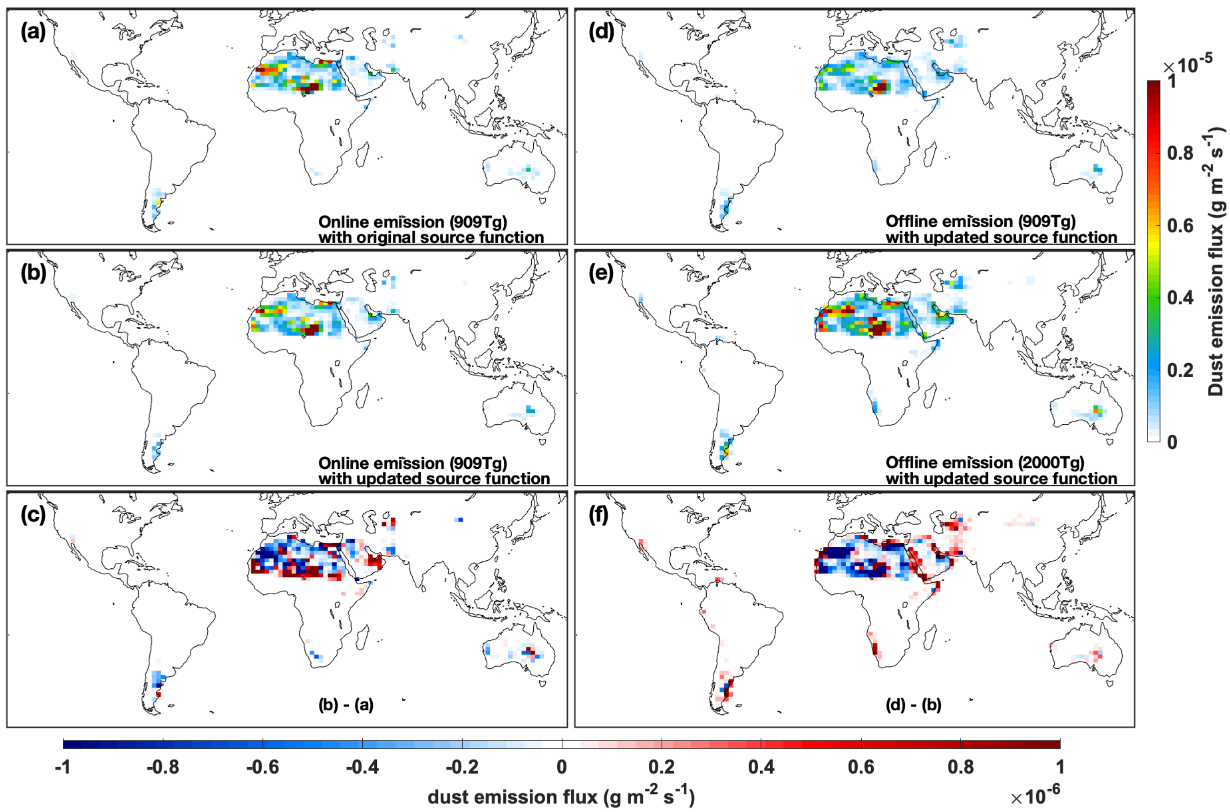

Figure S5. The same as Fig. 2 but averaged over DJF (December, January and February).

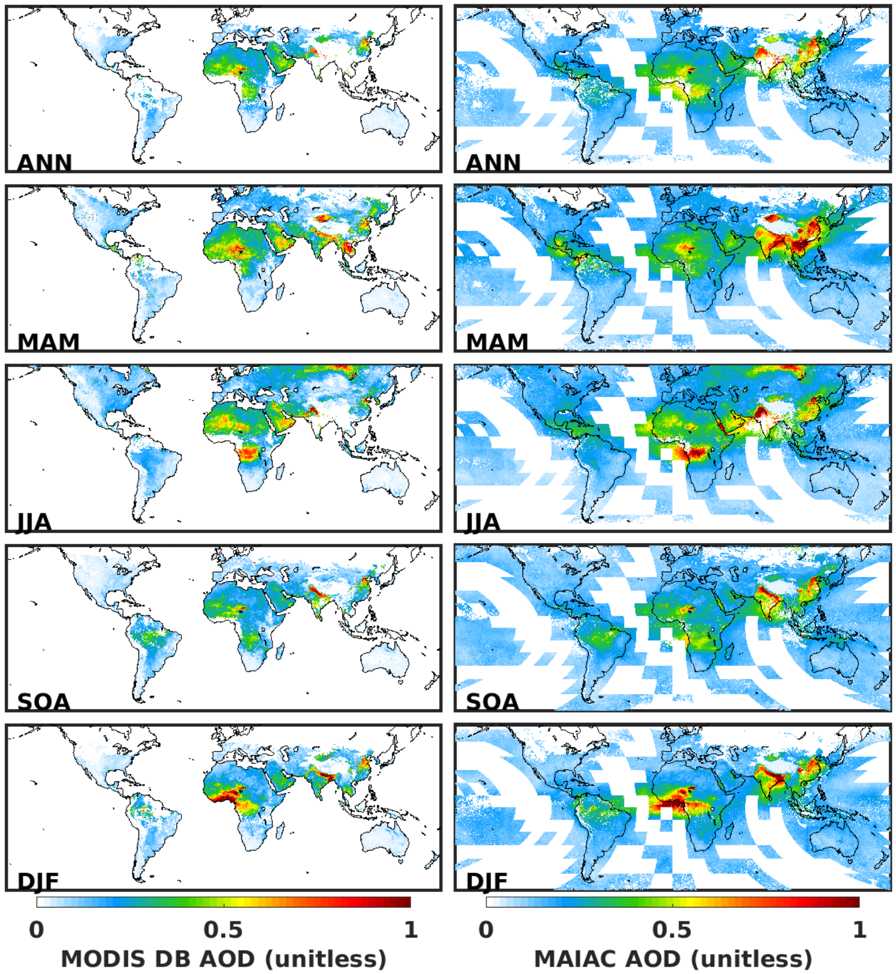

Figure S6. Annual and seasonal satellite AOD from MODIS Deep Blue (DB) and MAIAC algorithms.

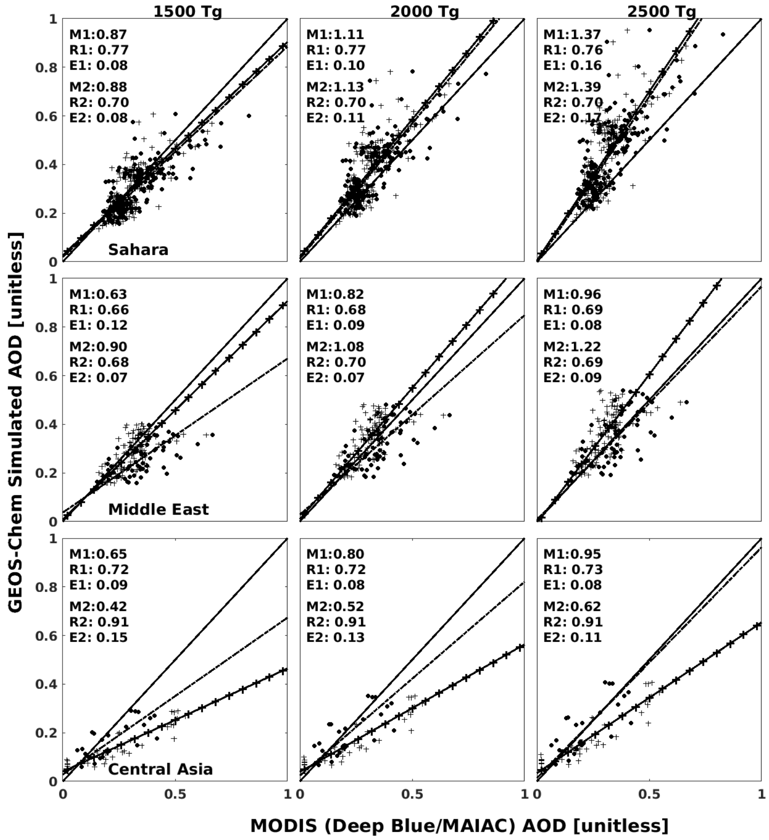

Figure S7. Scatter plots and statistics of comparing GEOS-Chem simulated annual mean AOD with satellite AOD over desert regions. Three columns represent three simulations with total annual dust emissions scaled to the value of 1,500 Tg, 2,000 Tg and 2,500 Tg respectively. The results for the Sahara, Middle East and central Asian deserts are shown in the top, middle and bottom rows respectively. Dots represent the comparison with MODIS Deep Blue AOD; the plus signs represent the comparison with MAIAC AOD. Correlation coefficient (R), root mean square error (E), and Slope (M) are reported, in which R1, E1 and M1 show the results of the comparison with MODIS Deep AOD; R2, E2 and M2 show the results of the comparison with MAIAC AOD. The best fit lines are lines with corresponding marker signs. The 1:1 line solid black line.

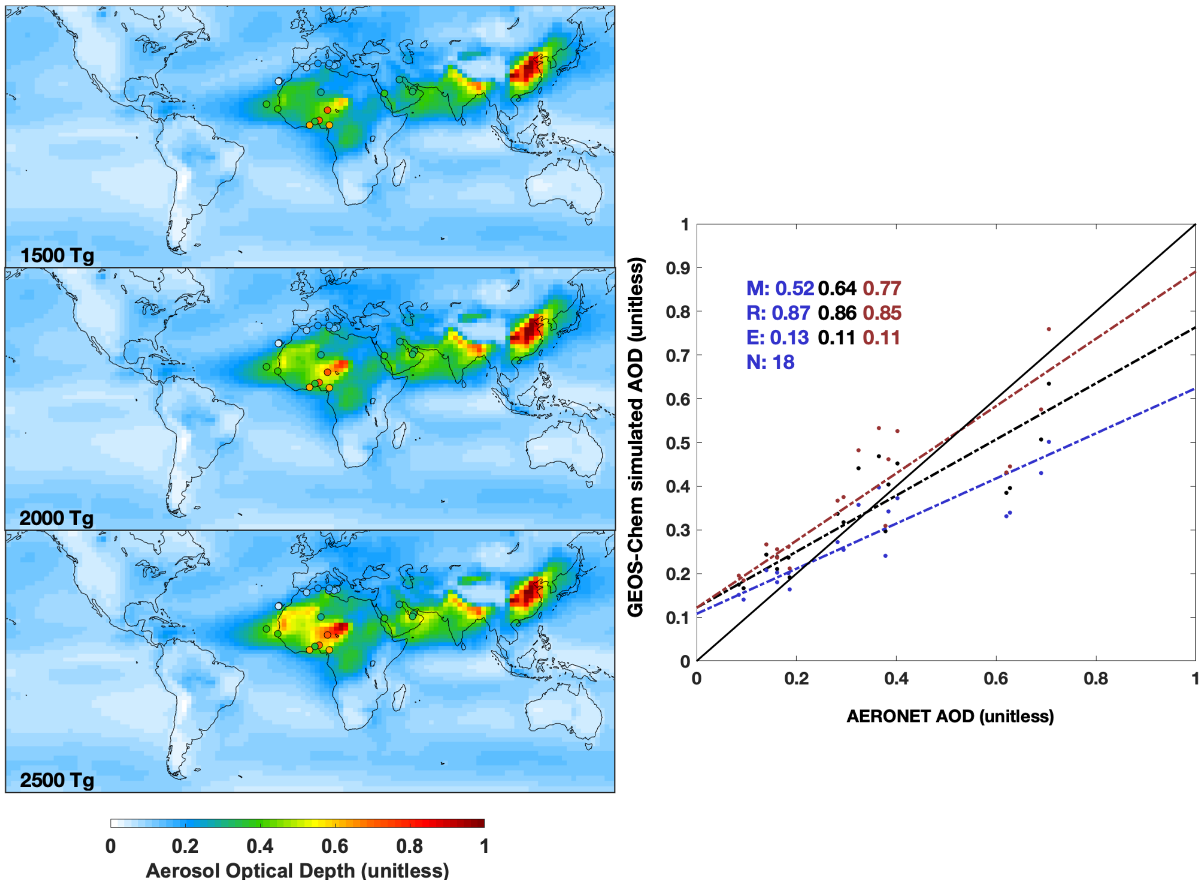

Figure S8. Annual mean simulated aerosol optical depth (AOD) from GEOS-Chem simulations for 2016 for simulations with total annual dust emissions of 1,500 Tg, 2,000 Tg and 2,500 Tg, and the comparison against AERONET measured AOD. Sites, shown as filled circles are chosen by where the ratio of simulated DOD and AOD exceeds 0.5. Corresponding statistics, including root mean square error (E), correlation coefficient(R) and slope (M), are inset. Blue, black and red in the scatter plot represent simulations with total annual dust emissions of 1,500 Tg, 2,000 Tg and 2,500 Tg, respectively.

References

Ginoux, P., Chin, M., Tegen, I., Prospero, J. M., Holben, B., Dubovik, O. and Lin, S.-J.: Sources and distributions of dust aerosols simulated with the GOCART model, Journal of Geophysical Research: Atmospheres, 106(D17), 20255–20273, doi:10.1029/2000JD000053, 2001.

White, B. R.: soil transport by winds on Mars, Journal of Geophysical Research: Solid Earth, 84(B9), 4643–4651, doi:10.1029/JB084iB09p04643, 1979.

Zender, C. S., Bian, H. and Newman, D.: Mineral Dust Entrainment and Deposition (DEAD) model: Description and 1990s dust climatology, Journal of Geophysical Research: Atmospheres, 108(D14), doi:10.1029/2002JD002775, 2003.