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Supplement of

An observationally constrained estimate of global dust aerosol optical depth

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Supplementary Materials

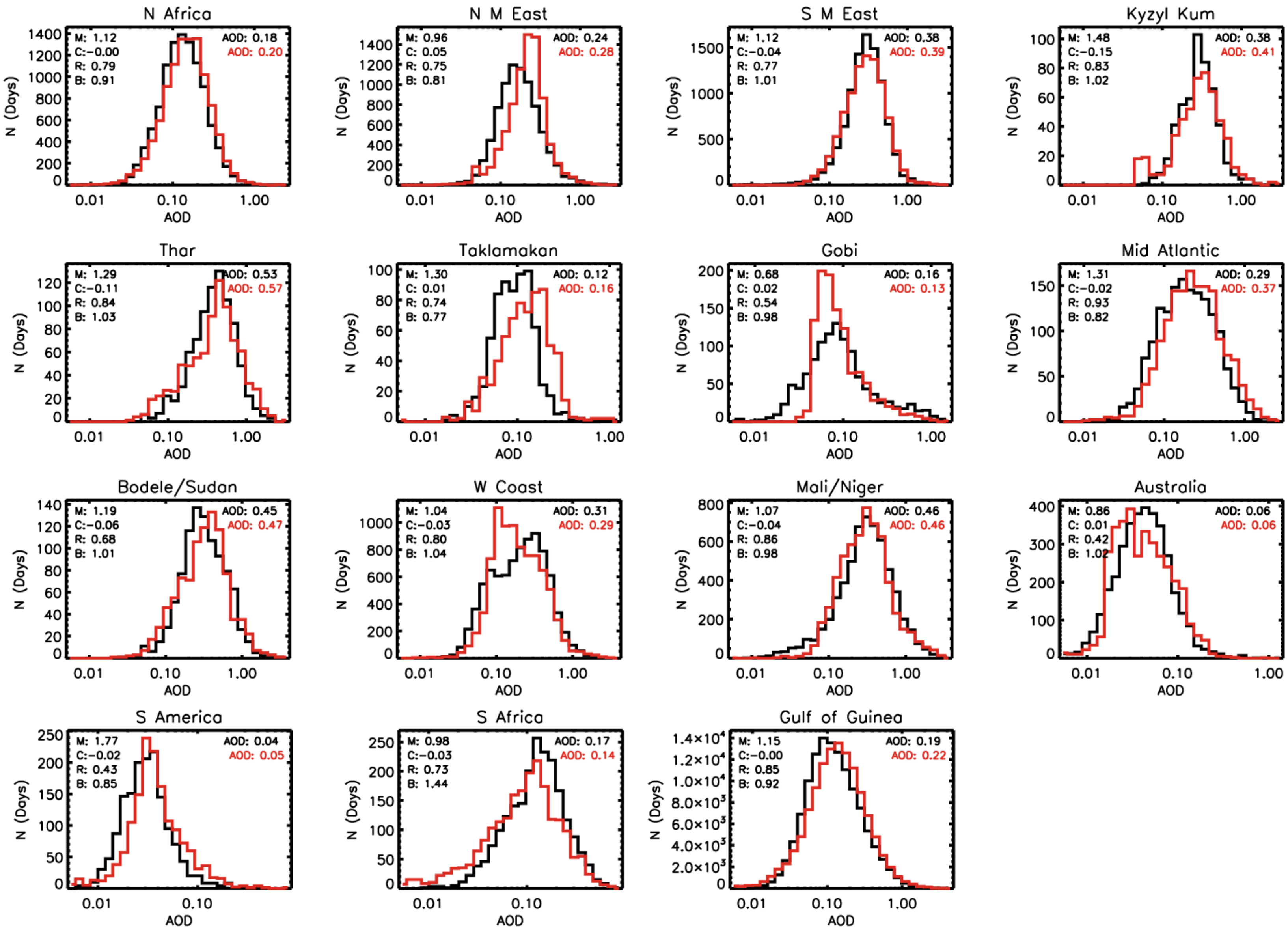

Figure S1 – Histograms of coincident daily AOD from MODIS Aqua (red) and AERONET (black) at AERONET site locations within each of the regions defined in Figure 1. Data is aggregated for all available days between 2003 and 2013. The mean AOD for AERONET and MODIS Aqua in each region is shown in the top right of each panel. Statistics of the regression between the modeled and the observed AOD are shown for the slope (M), y-intercept (C), correlation (R), and the fractional normalized mean bias (B; B>1 indicates the scaling factor by which the AERONET AOD exceeds the modeled AOD).

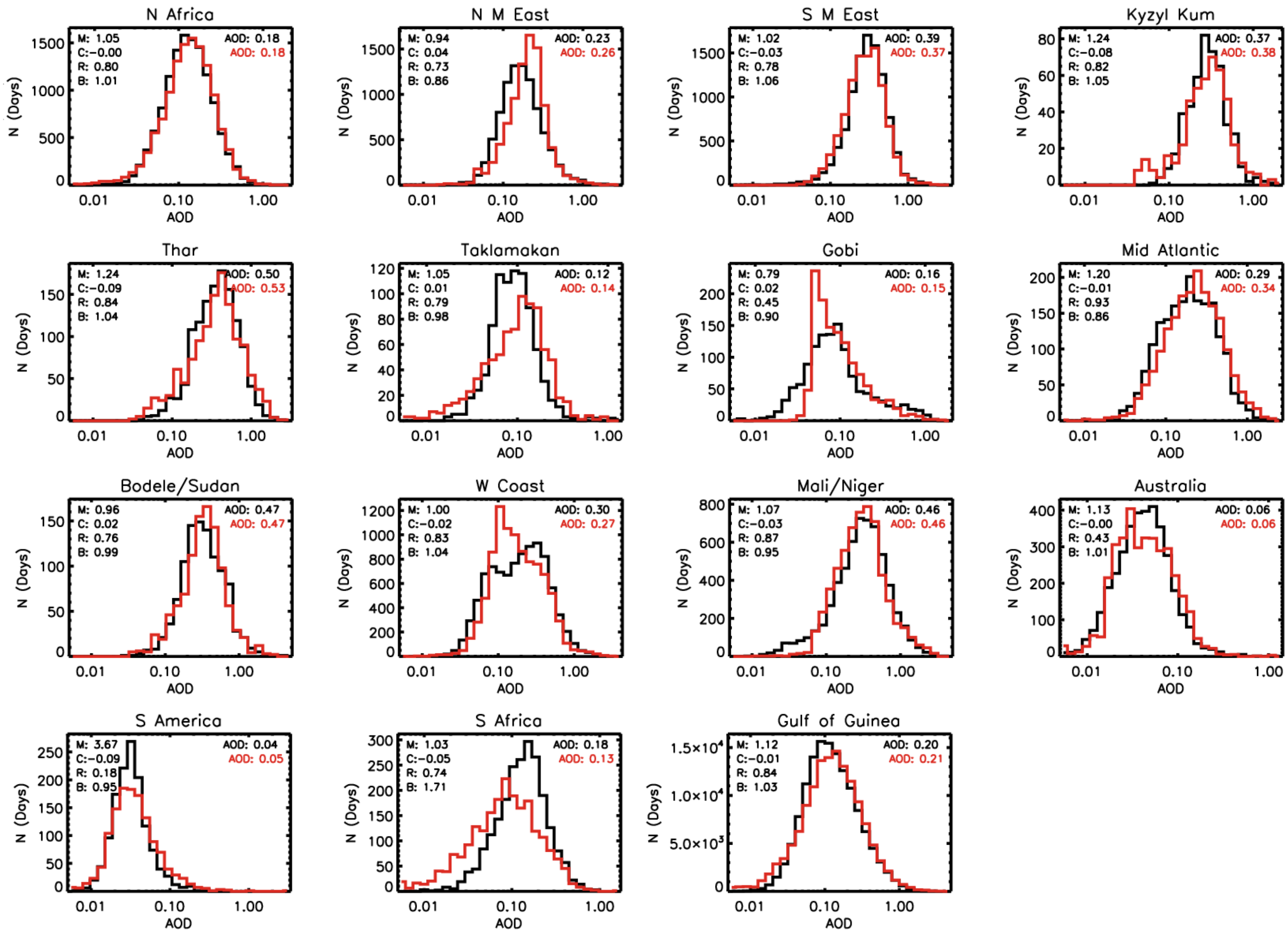

Figure S2 – Same as S1 but for AERONET (black) and MODIS Terra (red).

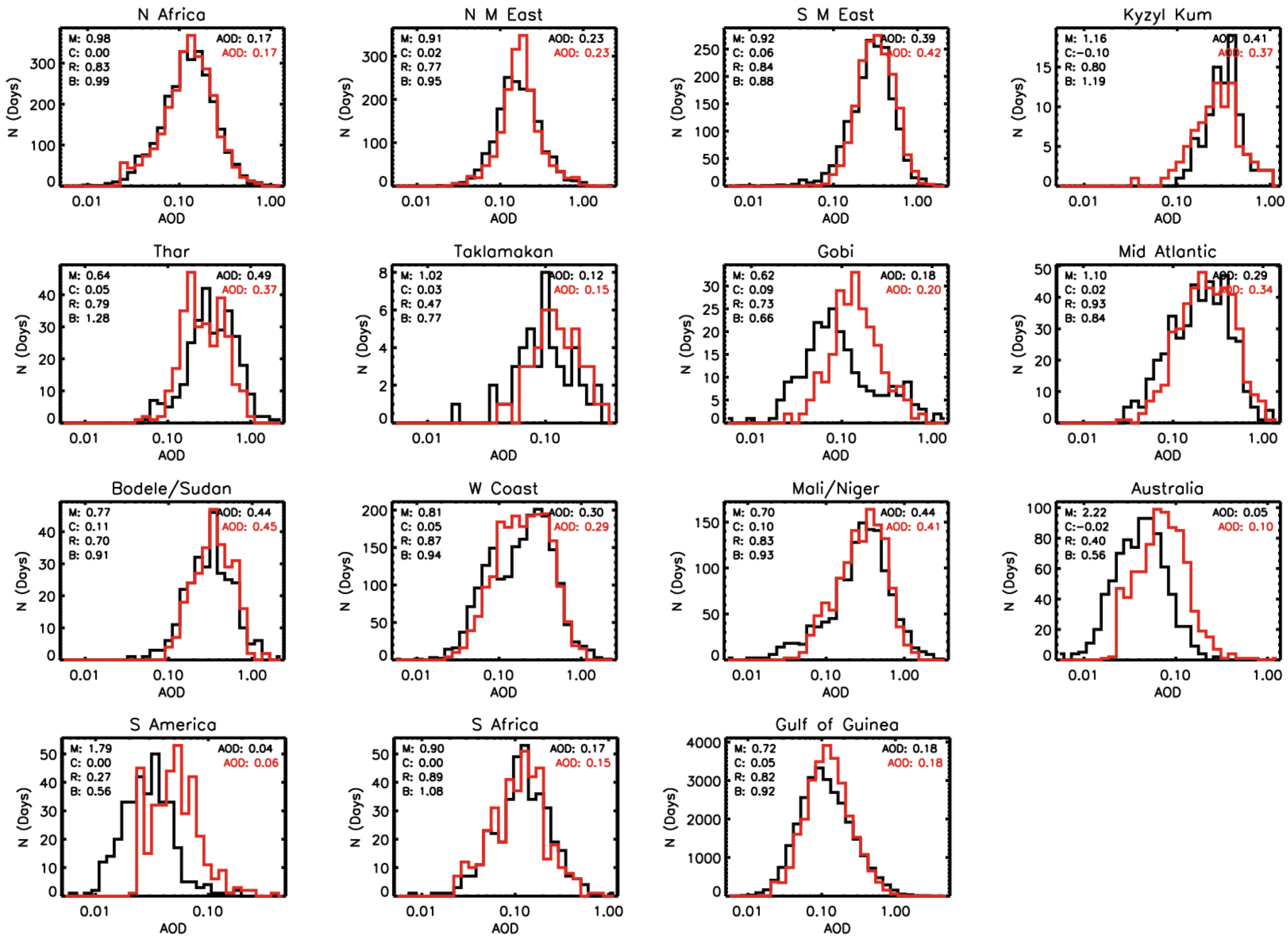

Figure S3 – Same as S1 but for AERONET (black) and MISR (red).

Exploring potential model biases

Biases in the model estimate of non-dust AOD will yield a bias in the observational estimate of dust AOD. To identify these, we compare the model AOD bias relative to AERONET AOD for days when model dust AOD accounts for more than 60% of the AOD versus days when the dust AOD accounts for less than 60% of the total AOD (Figure S4). We find that there is a bias between these two cases where CESM and GEOS-Chem both underestimate the AOD relative to AERONET in low dust cases and overestimate the AOD in high dust cases. WRF-Chem and MERRAero show a smaller bias in the opposite direction. Relative to AERONET, the models are biased by -23%, -20%, +3%, +10% (GEOS-Chem, CESM, WRF-Chem and MERRAero, respectively) for the low dust cases, and biased +33%, +12%, +14% and +6% for the high dust cases. The days with low dust AOD in the models are biased low most at AERONET sites in the Thar Desert and Kyzyl Kum, that have limited AERONET data, in the Middle East, and across Africa. This suggests that the non-dust AOD in the models may be biased low on average, which would lead to a high bias in the observational estimate of the dust AOD.

If we re-run the analysis including a regional bias correction factor for the models, we find that the mean estimate of the global dust AOD is reduced to 0.028, a 7% decrease but still well within our uncertainty estimate. However, with the bias correction applied, the observational estimate of dust AOD in the Mid-Atlantic is unrealistically close to zero in winter and can end up being consistently negative in the Thar desert, suggesting the bias correction is overcompensating. The agreement in seasonal dust AOD between different satellite-model realizations is also worsened, rather than improved. Finally, there is no guarantee that the model dust AOD is an adequate filter to partition the data into low/high dust days, the filter may simply select for seasons when less dust present, which might not tell us much about the non-dust AOD in seasons when dust is present. For this reason, we do not bias-correct the model non-dust AOD for the observational estimate of global dust AOD presented in this work. However, we highlight this potential source of uncertainty in the main text and included a reference to this supplementary text in the summary of explored biases and uncertainty (Table 2).

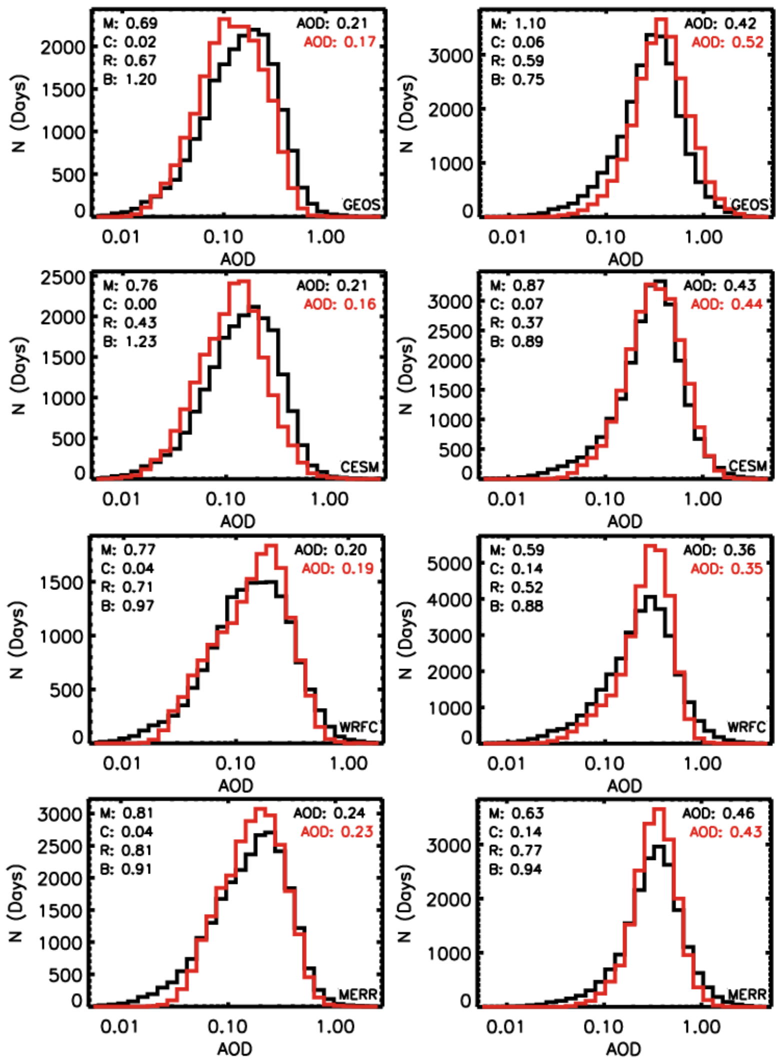

Figure S4 - Histograms of coincident daily AOD from AERONET (black) and model (red) for the case of model dust AOD < 60% of the model total AOD (left) and model dust AOD > 60% of the model total AOD (right).

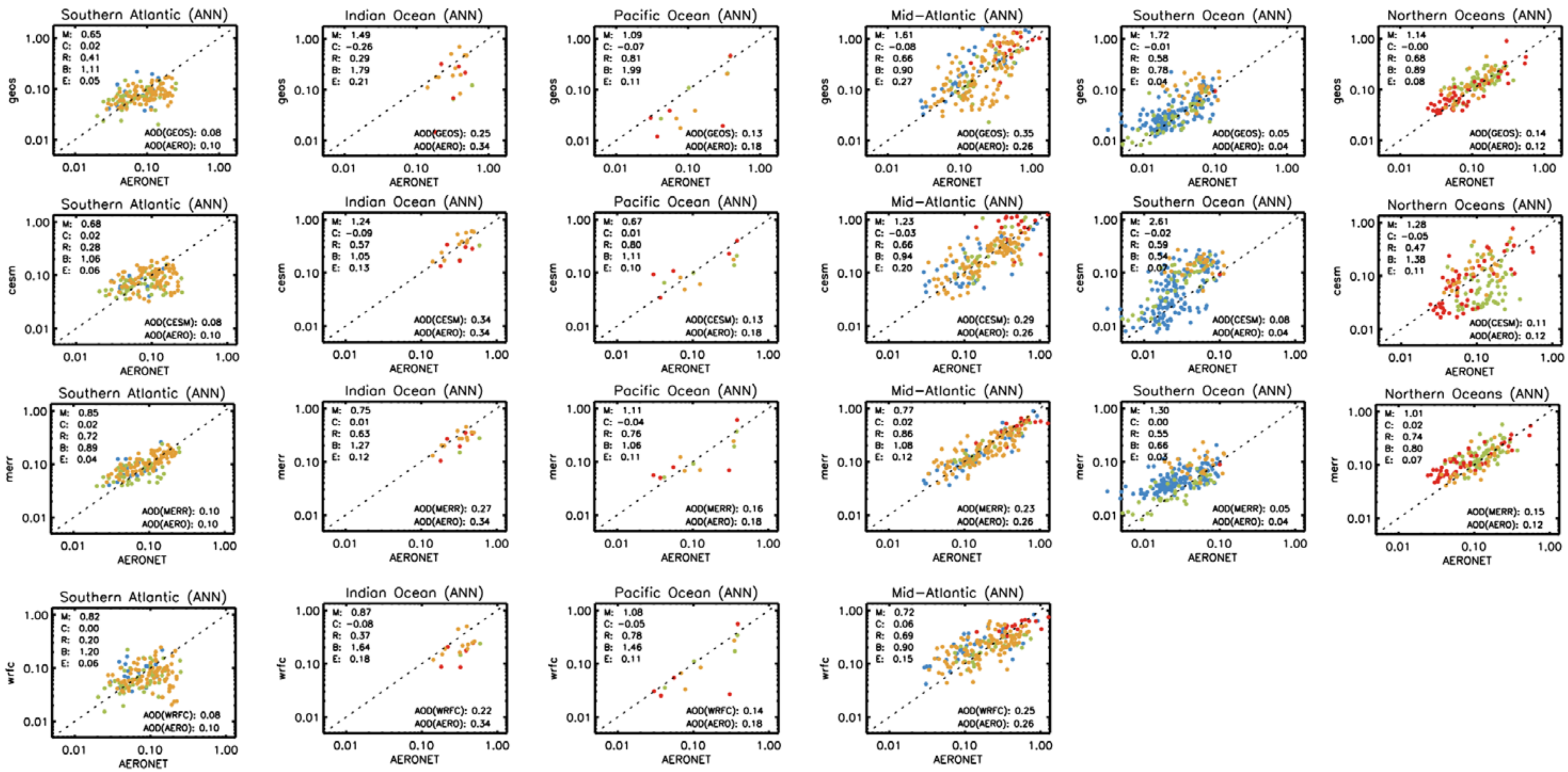

Figure S5 – Scatter plots of coincident daily AOD from the AERONET Marine Aerosol Network and corresponding modeled daily AOD from GEOS-Chem (upper), CESM (upper middle), WRF-Chem (lower-middle), and MERRAero (bottom). Data is aggregated for all available days between 2004 and 2008. The (boreal) season of the day of comparison is indicated with color for winter (blue), spring (green), summer (red) and fall (orange). The mean AOD for AERONET and the model in each region is shown in the bottom right of each panel. Statistics of the regression between the modeled and the observed AOD are shown for the slope (M), y-intercept (C), correlation (R), RMS error (E), and the fractional normalized mean bias (B; B>1 indicates the scaling factor by which the AERONET AOD exceeds the modeled AOD).

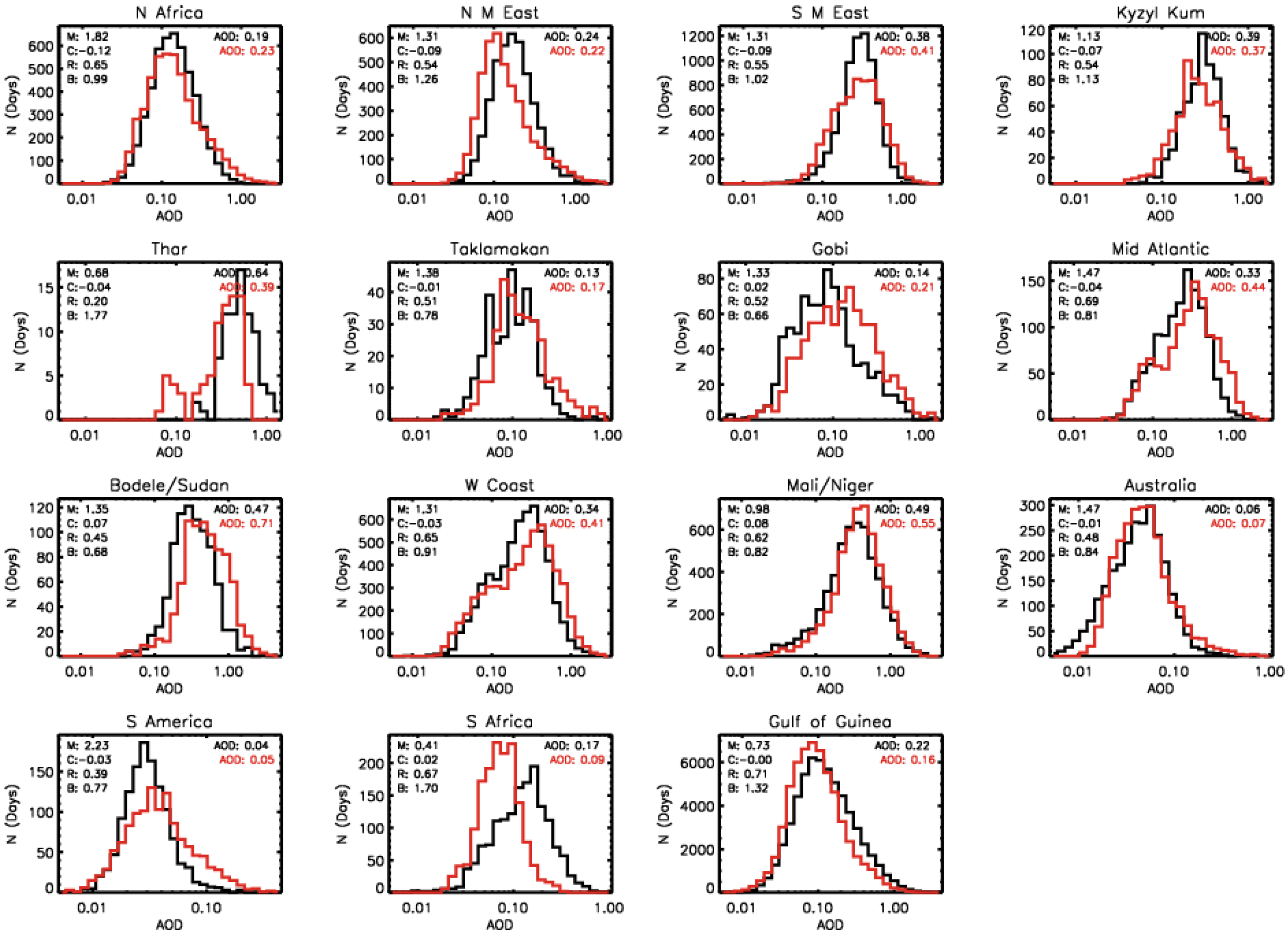

Figure S6 – Histograms of coincident daily AOD from the GEOS-Chem model (red) and AERONET (black) at AERONET site locations within each of the regions defined in Figure 1. Data is aggregated for all available days between 2004 and 2008. The mean AOD for all coincident AERONET and the model data in each region is shown in the top right of each panel. Statistics of the regression between the modeled and the observed AOD are shown for the slope (M), y-intercept (C), correlation (R), and the fractional normalized mean bias (B; B>1 indicates the scaling factor by which the AERONET AOD exceeds the modeled AOD).

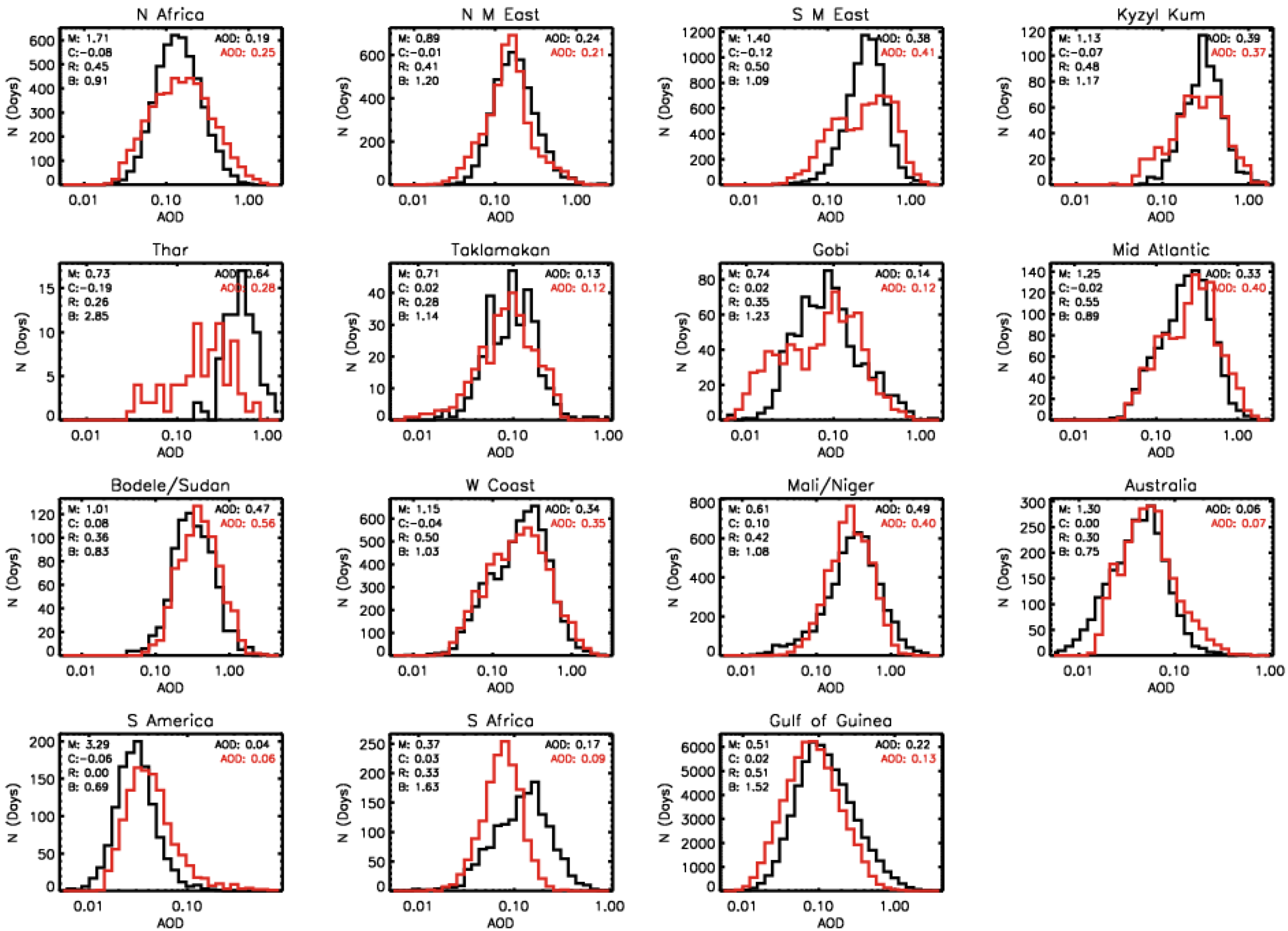

Figure S7 – Same as S6 but for CESM modeled AOD.

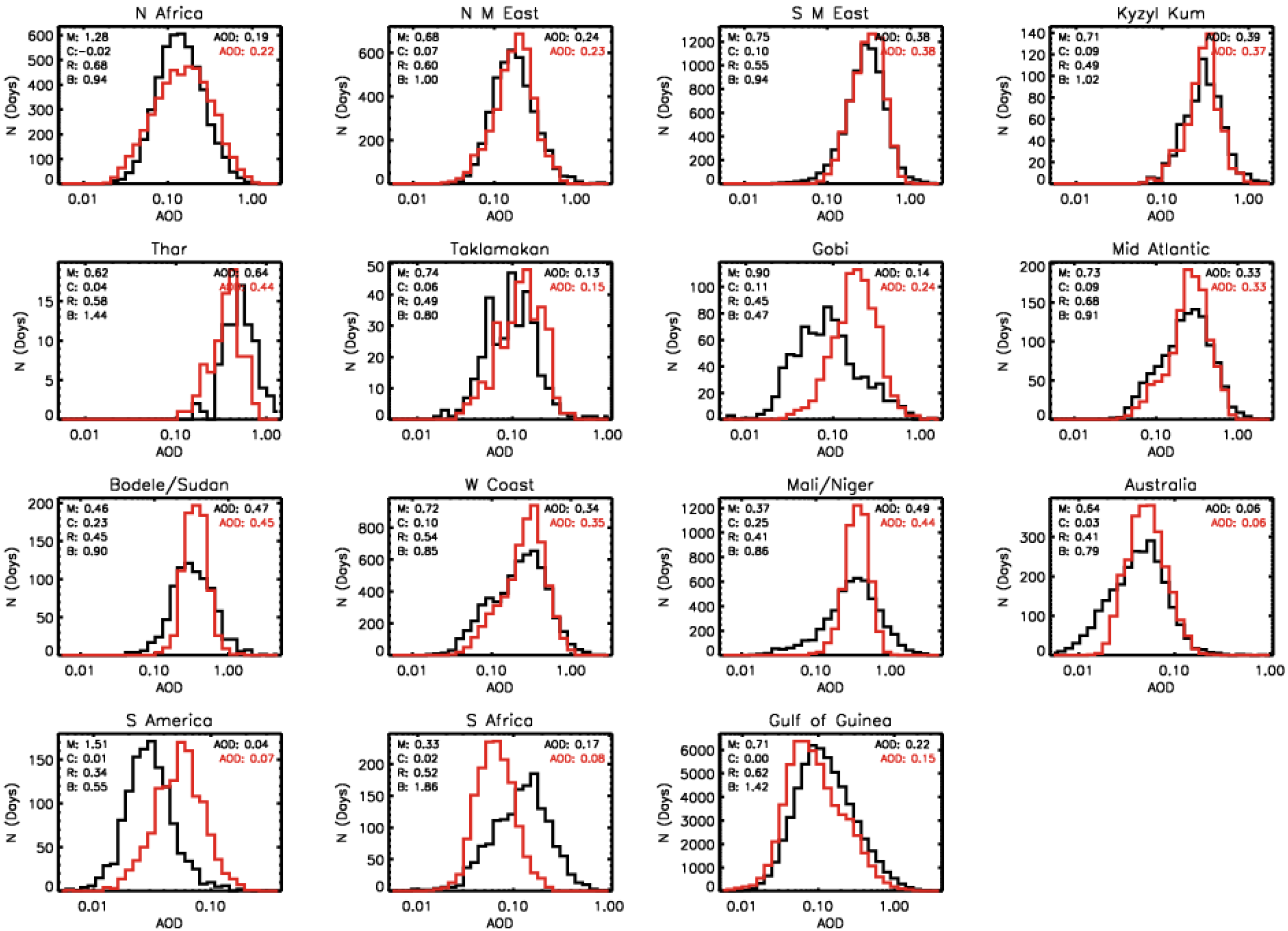

Figure S8 – Same as S6 but for WRF-Chem modeled AOD.

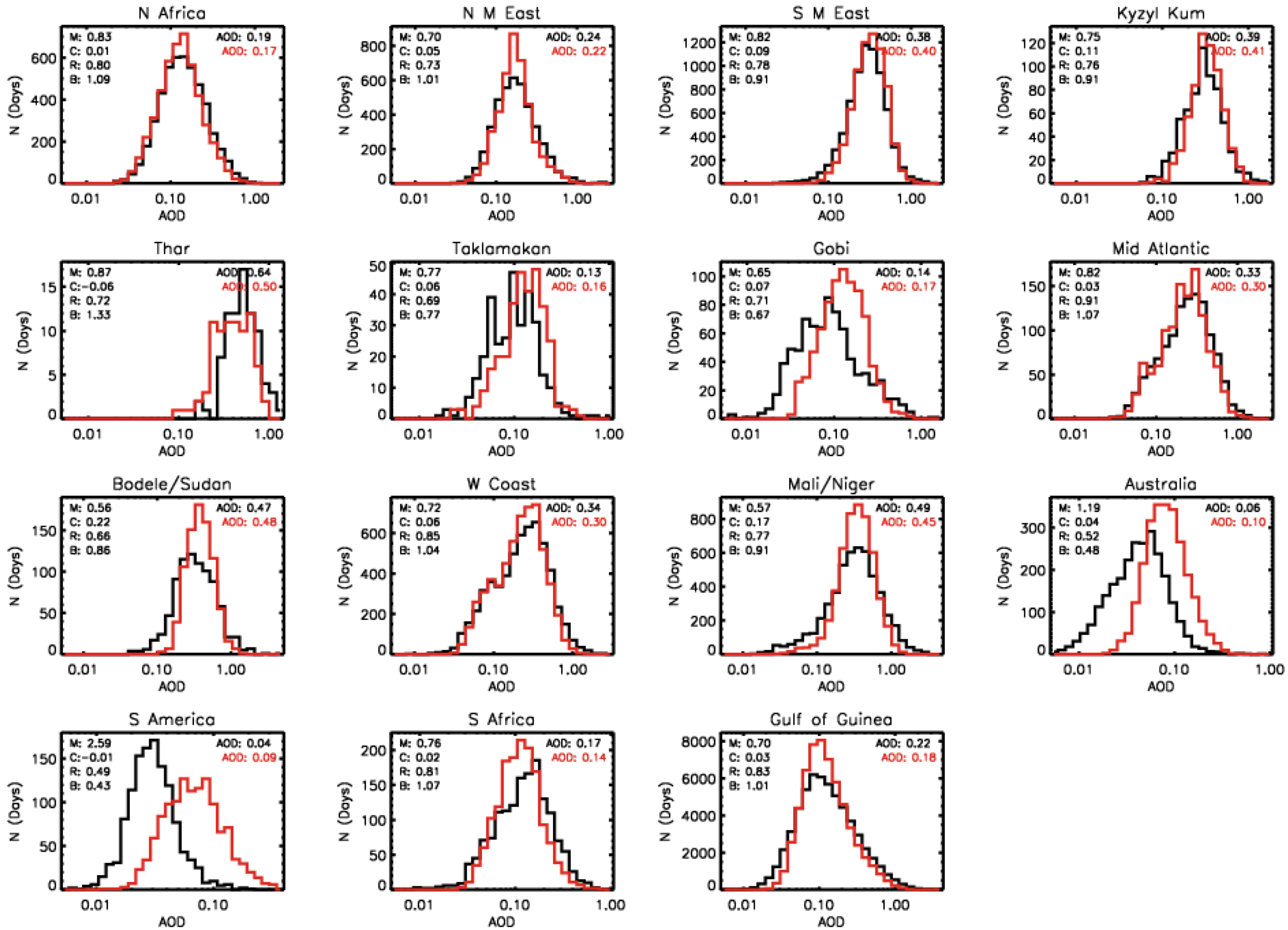

Figure S9 – Same as S6 but for MERRAero modeled AOD.

Dust Deposition Estimate

We provide a comparison with the DIRTMAP deposition measurement network, using the data presented in Albani et al. (2014). To estimate the observational dust deposition estimate, we use the ratio between the observational estimate of dust AOD and the GEOS-Chem dust AOD to scale the GEOS-Chem dust deposition. Because we only assess the dust AOD over key regions, the scaling factors can only be applied for those regions. Therefore, the dust deposition estimate relies heavily on the dust deposition in the GEOS-Chem model and the dust AOD – deposition relationship from the model. For this reason, we find an insignificant improvement in the correlation and RMS error between the derived dust deposition compared to the DIRTMAP network measurements.

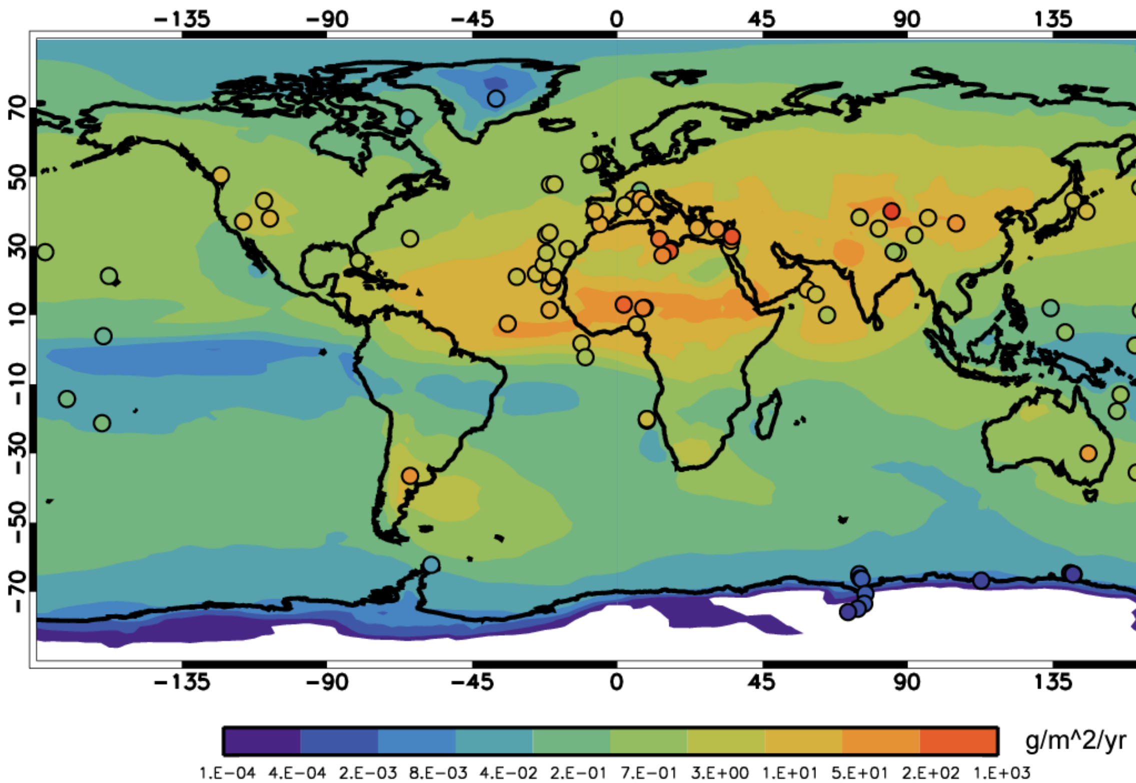

Figure S10 – Spatial map of dust deposition (averaged over 2004 – 2008) based on the GEOS-Chem model, with scaling applied based on the observational estimate of dust AOD. DIRTMAP deposition measurements are indicated with circles, using the same color scale (log).

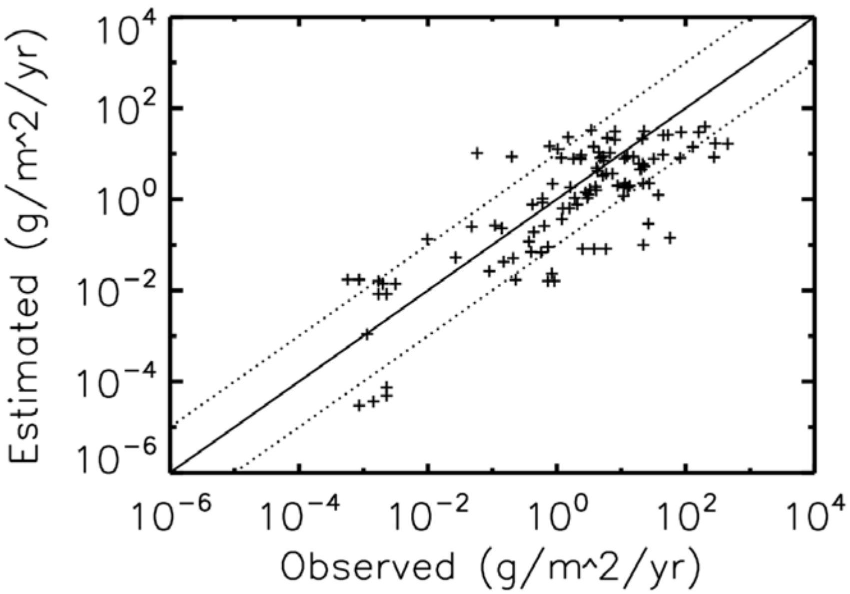

Figure S11 – Dust deposition rate, derived by using the observationally-estimated dust AOD to scale GEOS-Chem deposition, compared with the observed deposition from the DIRTMAP measurement network.