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Supplement of

How reliable are CMIP5 models in simulating dust optical depth?

Bing Pu and Paul Ginoux

Correspondence to: Bing Pu (bpu@princeton.edu)

Supplement

1. Validation of MODIS DOD against observation

Figures S1-2 compare aerosol optical depth (AOD) between MODIS and AErosol RObotic NETwork (AERONET) sites data (top), and between MODIS DOD and AERONET coarse mode aerosol optical depth (COD; bottom). AERONET COD is processed by the Spectral Deconvolution Algorithm (O'Neill et al., 2003). We used an evaluation method following Levy et al. (2003; their Fig. 11) for AOD and COD errors. The AERONET Level 2 (quality assured) 10 minutes AOD and COD (500 nm) are extracted for Aqua equatorial crossing time (1:30 PM) and Terra equatorial crossing time (10:30 AM) plus or minus 30 minutes, and are considered if there is at least 2 measurements per day and there should be at least 100 days with data. We select AERONET sites within a spatial radius of 15 km of MODIS measurement. 883 AERONET sites are used. Total number of valid data is about 35,747. In box-whisker plots (e.g., Fig. S1), all collocated MODIS and AERONET data are grouped into bins of 500 measurements. The last bin will contain a larger number of values corresponding to the remaining of the division.

As shown in Fig. S1, MODIS slightly underestimated Aqua AOD and DOD for most of the AOD and DOD ranges. Compared to AERONET station data, Aqua AOD is underestimated, and DOD largely inherits this error. For Aqua DOD around 0.50, the median error is around 0.08, with estimated errors ranging from -0.29 to 0.16. Terra DOD is better than Aqua DOD in terms of the median of errors (Fig. S2 bottom vs. Fig S1 bottom). The median error for Terra DOD around 0.50 is very close to zero, with estimated errors ranging from -0.23 to 0.25.

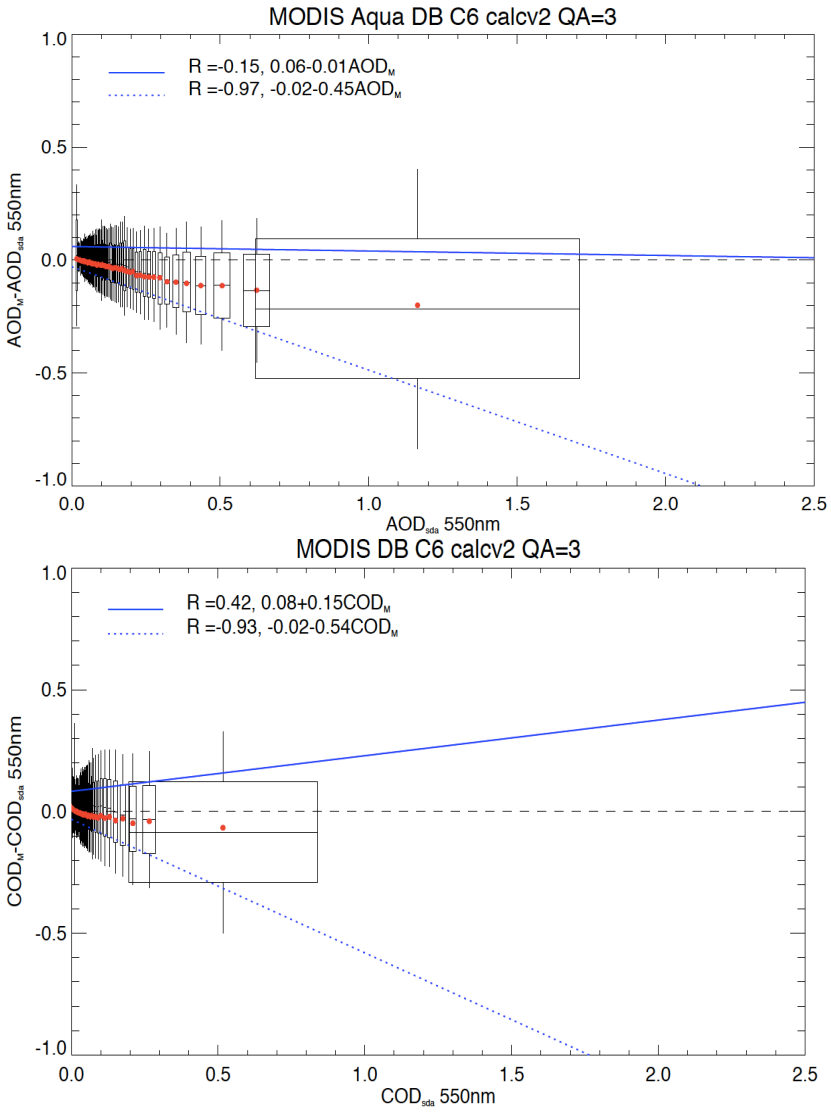


Figure S1. Comparison between grouped Aqua AOD error (i.e., the differences between MODIS AOD and AERONET AOD versus AERONET AOD, top), and grouped coarse mode aerosol optical depth (COD) error (i.e., the differences between MODIS DOD and AERONET COD versus AERONET COD, bottom). For each box-whisker, its width is 1σ of the AOD (COD) bin, while its height, whiskers, middle line and red dots are the 1σ, 2σ, mean, and median of AOD (COD) error, respectively. The envelope of estimated errors are blue and the one-one line (zero error) is dashed black.

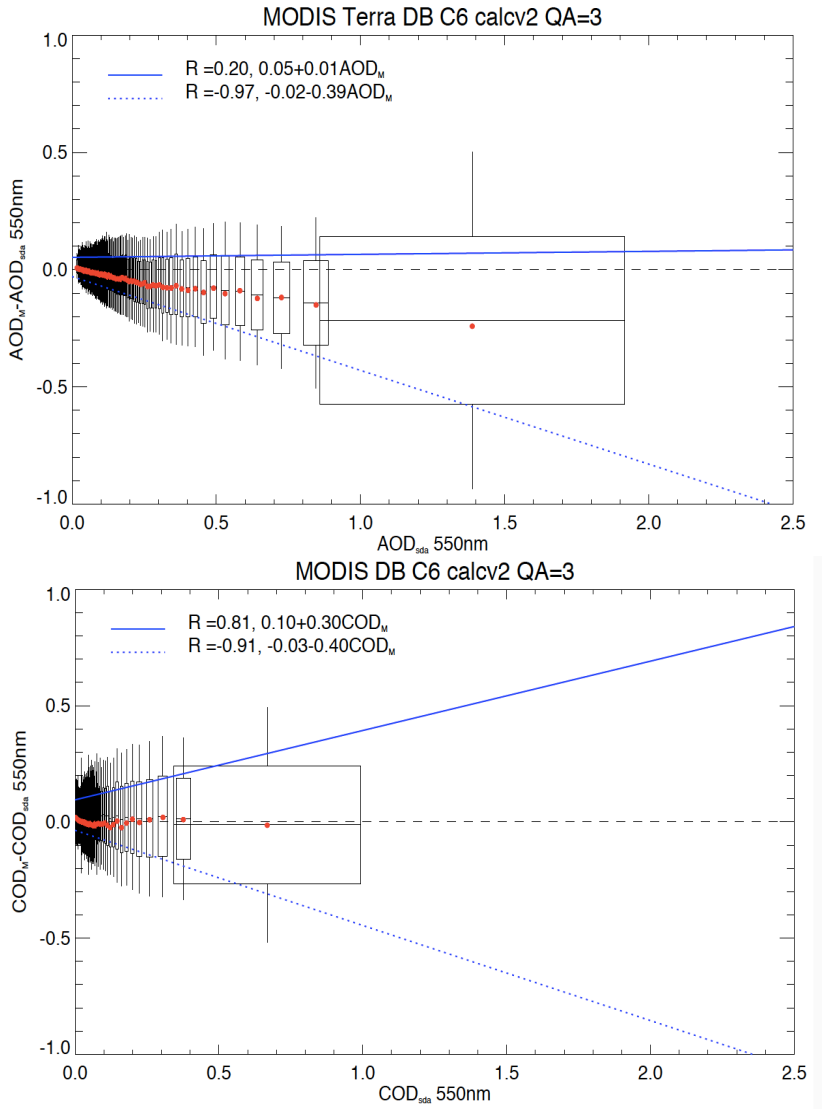
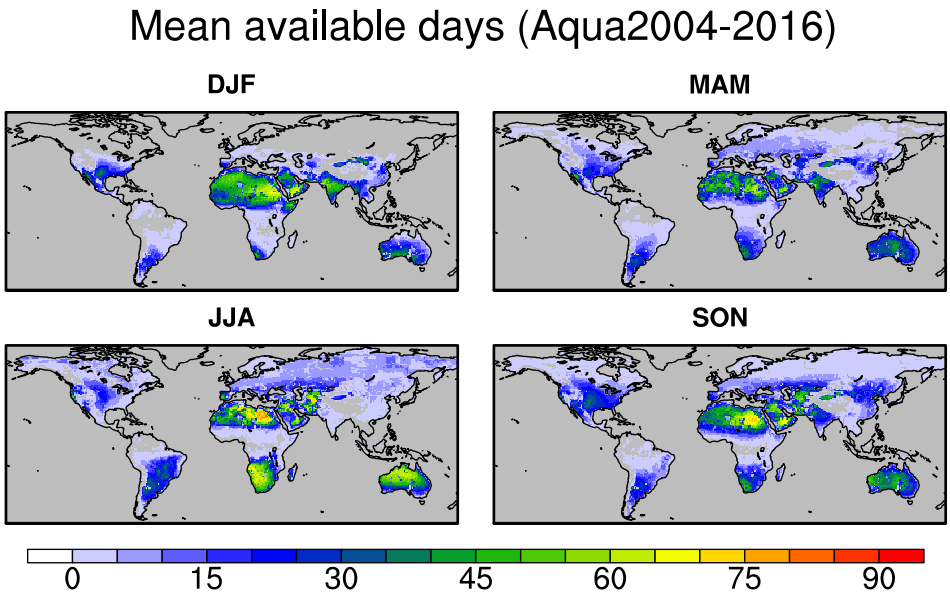


Figure S2. Same as Fig. S1 but for Terra DOD.

2. Supplementary tables and figures for the analysis on DOD from CMIP5 models and future projections

Table S1 Correlation between reconstructed DOD (using three controlling factors) and MODIS DOD for nine regions in four seasons from 2004 to 2016. All coefficients are significant at the 95% confidence level except those in Italic.

	N. Africa	Middle East	N. China	N. America	India	SE. Asia	S. Africa	S. America	Australia
DJF	0.94	0.91	0.79	0.84	0.89	0.86	*0.35*	0.70	0.97
MAM	0.90	0.95	0.92	0.91	0.92	0.72	0.79	*0.54*	0.95
SON	0.68	0.95	0.79	0.90	0.87	0.77	0.92	0.68	0.77
JJA	0.89	0.96	0.88	0.93	0.74	0.86	0.88	0.58	0.89



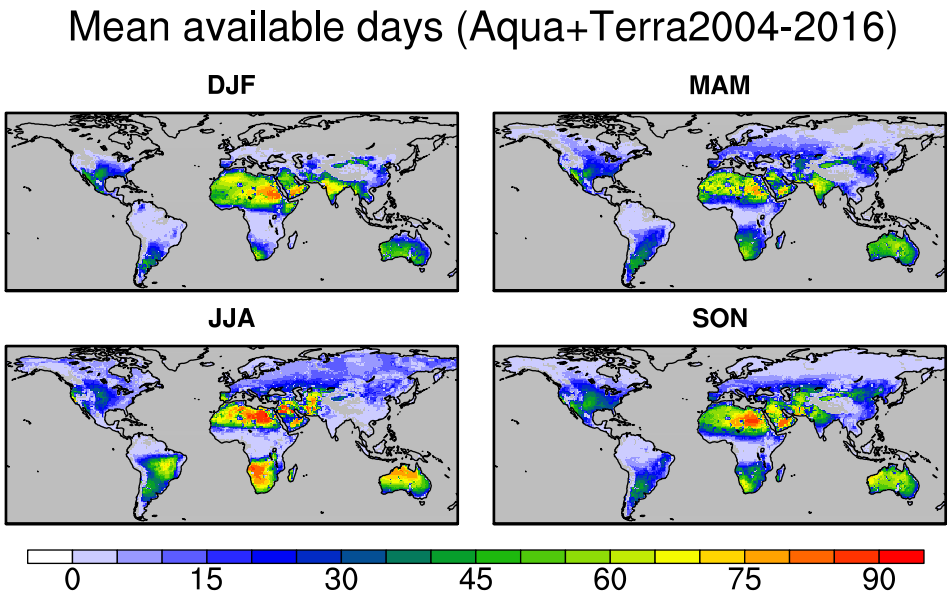


Figure S3. Number of days with available DOD record in each season from Aqua (top) and from Aqua-Terra combined DOD (i.e., MODIS DOD as referred in text; bottom) averaged over 2004-2016.

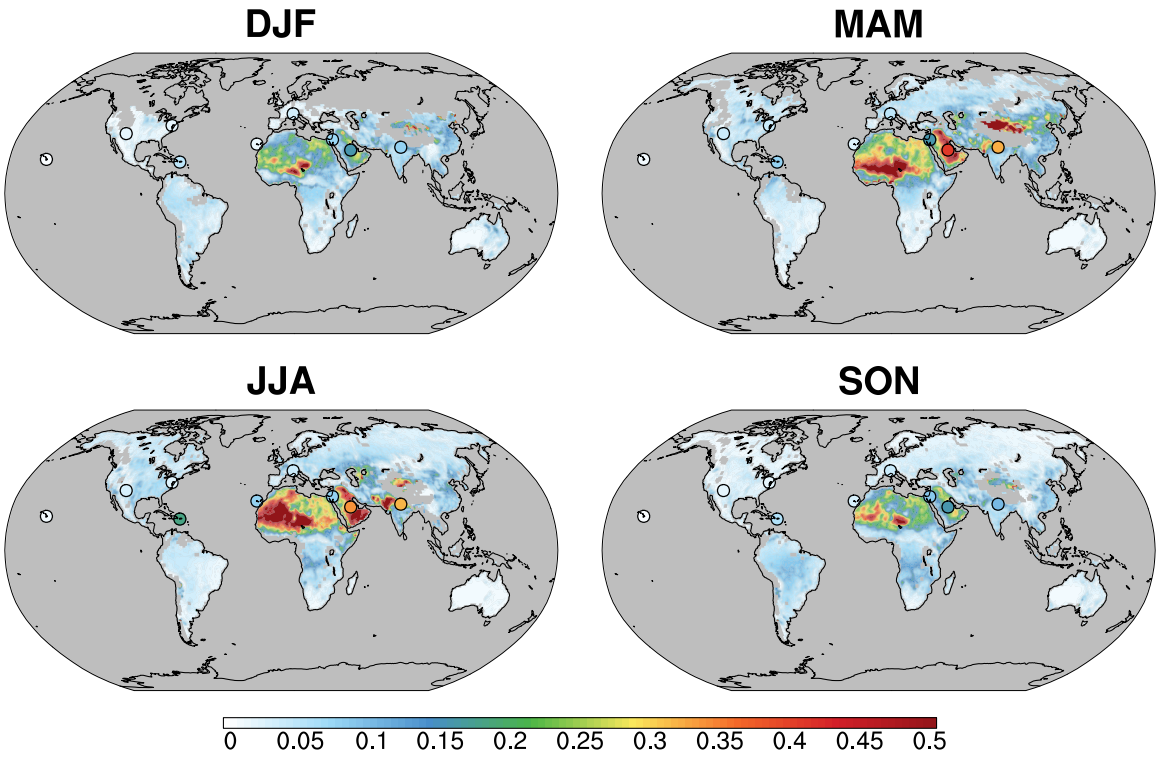


Figure S4. Climatology (2004-2016) of MODIS DOD (shading) and coarse mode aerosol optical depth (COD) at 500 nm from AERONET long-term stations (filled colorful circles).

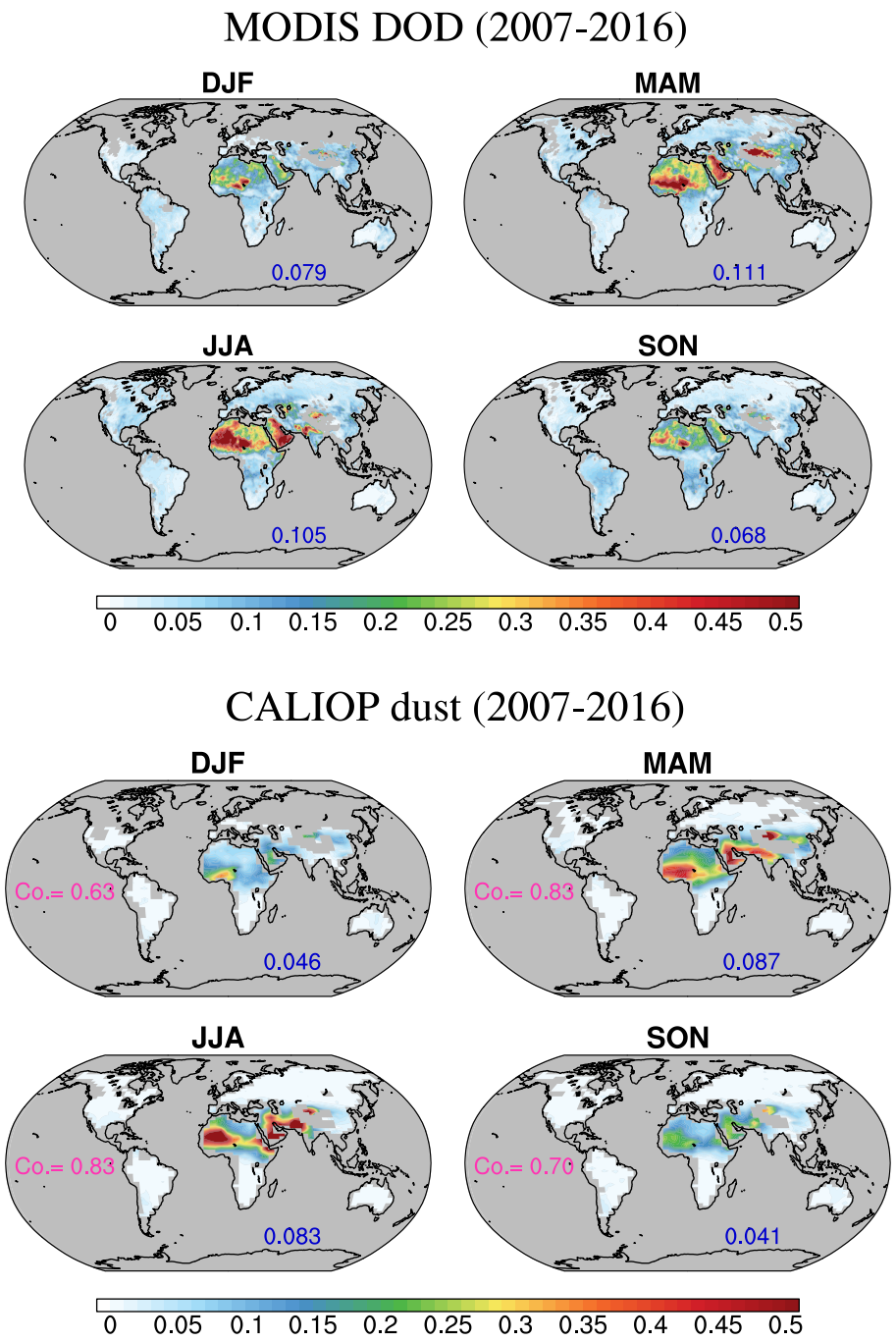


Figure S5. Climatology of MODIS DOD (2004-2016) versus CALIOP DOD (2007-2016). The global mean over land are listed at bottom right of each plot in blue, the pattern correlations (calculated after interpolating MODIS DOD to CALIOP grids) between MODIS and CALIOP DOD are also shown in the bottom panel in pink.

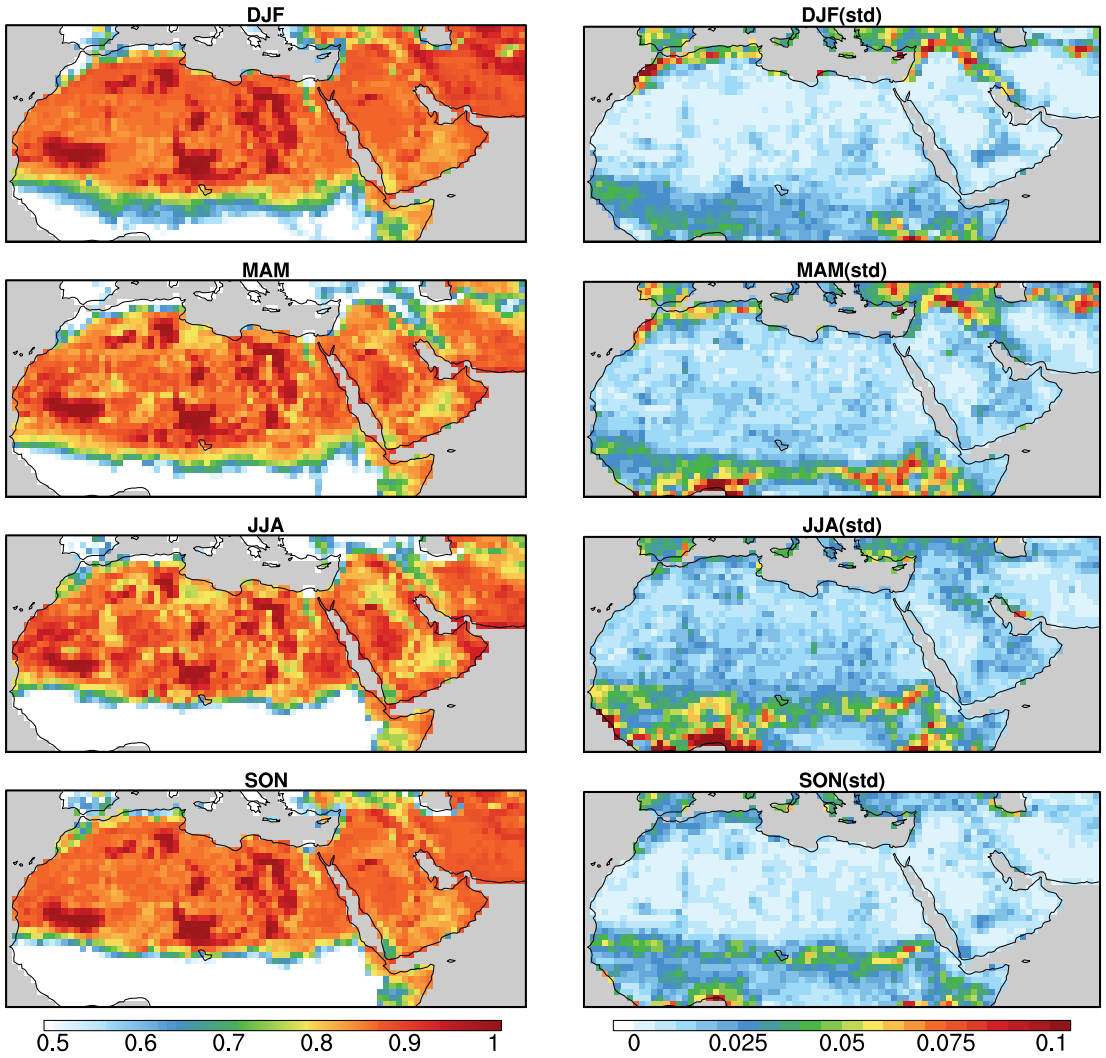


Figure S6. Seasonal mean (left) and standard deviation (right) of bareness over North Africa and the Arabian Peninsula from AVHRR during 2004-2016.

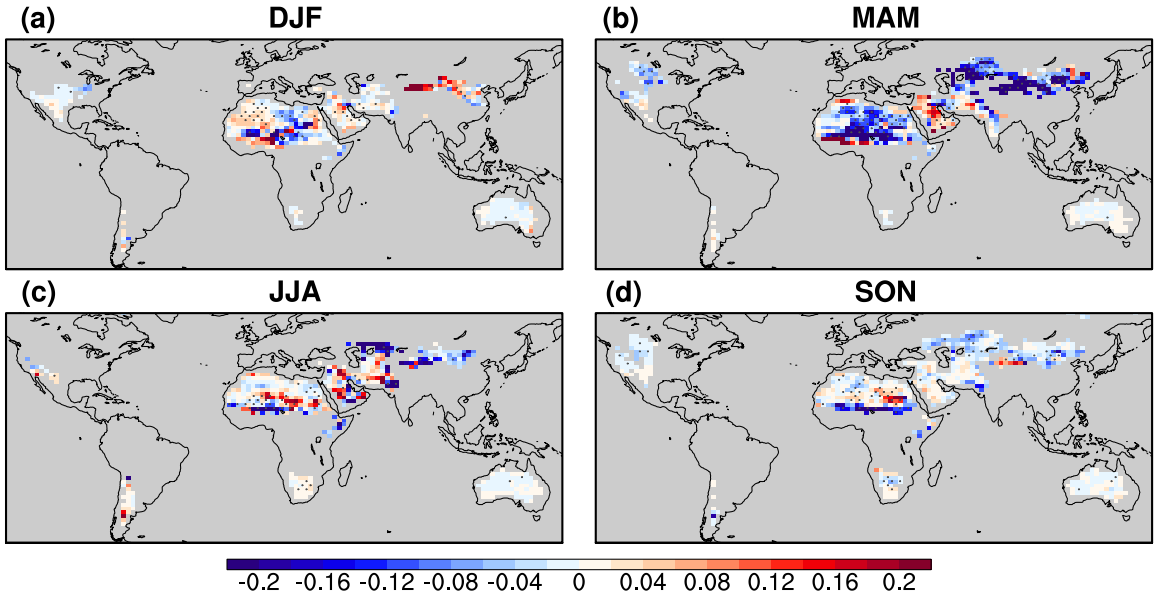


Figure S7. Same as Fig. 9, but used the output of 16 models (Supplementary Table S1 of Pu and Ginoux, 2017). Dotted areas are regions with sign agreement among the regression projections above 62.5% (i.e., at least ten out of 16 projections have the same sign as the multi-model mean projection).

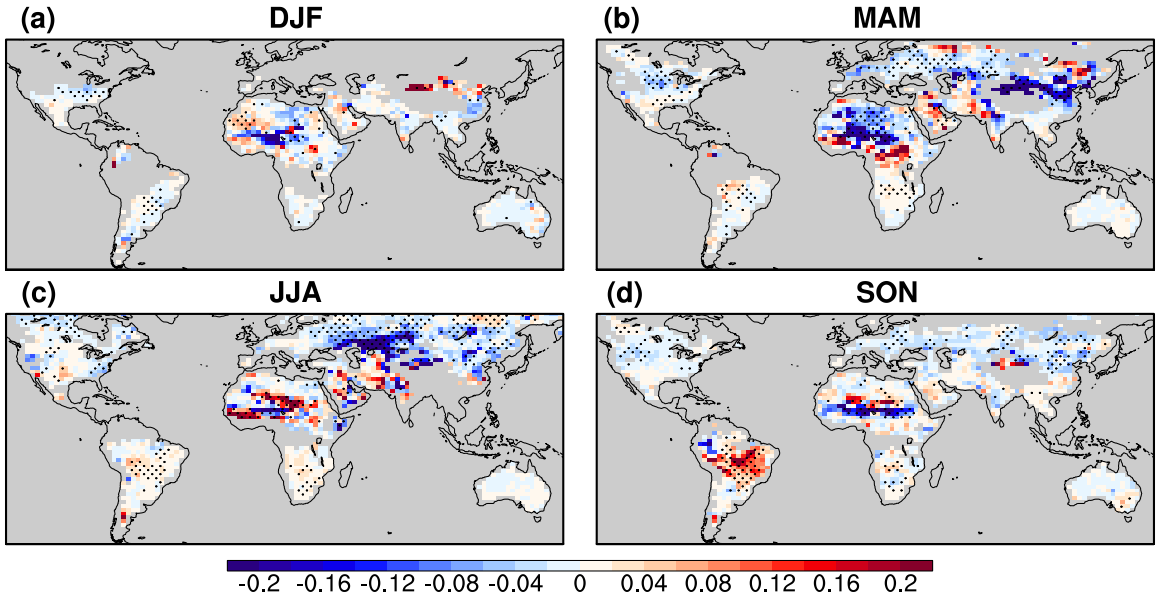


Figure S8. Same as Fig. 9 but without applying the LAI mask.

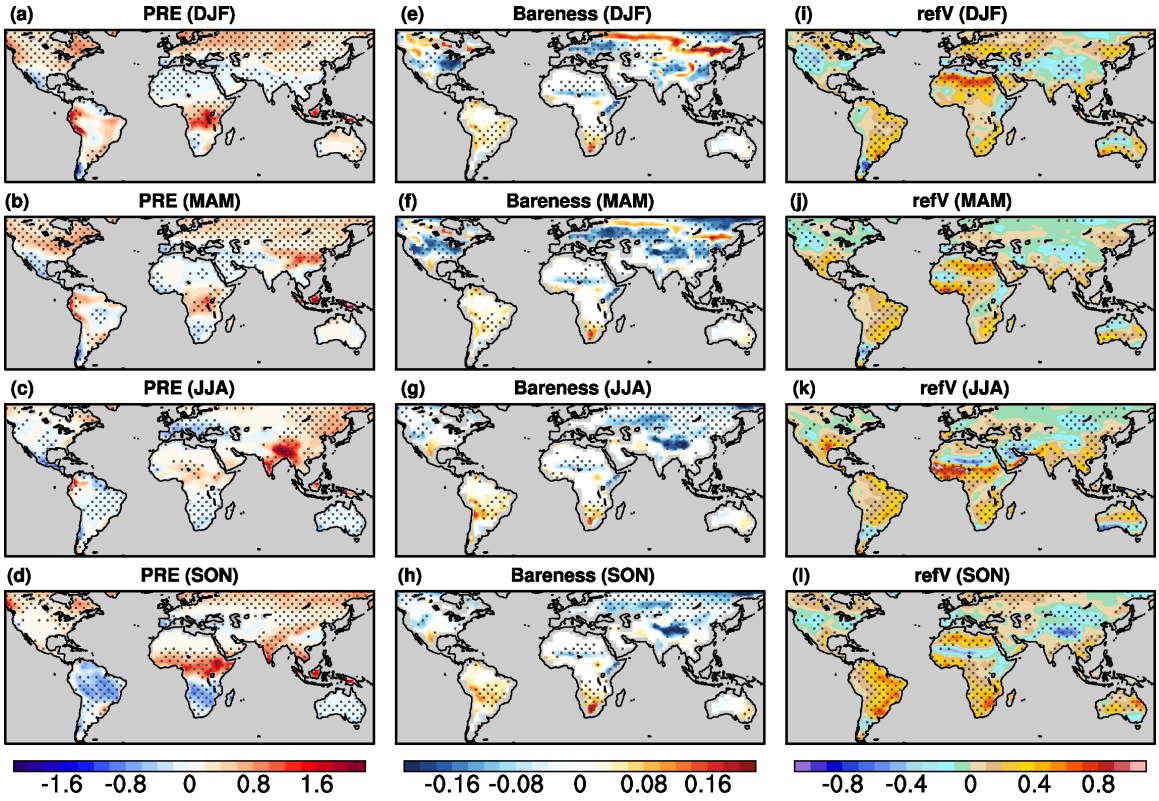


Figure S9. Projected difference of (a)-(d) precipitation (mm day^{-1}), (e)-(h) bareness, and (i)-(l) 10 m wind (m s^{-1}) between the late half of the 21st century (2051-2100; RCP 8.5 scenario) and historical level (1861-2005) from multi-model mean of 16 CMIP5 models. Areas with sign agreement among the models reaches 62.5% (i.e., at least ten out of 16 models have the same sign as the multi-model mean) are dotted.