Supplemental Material

Journal of Climate

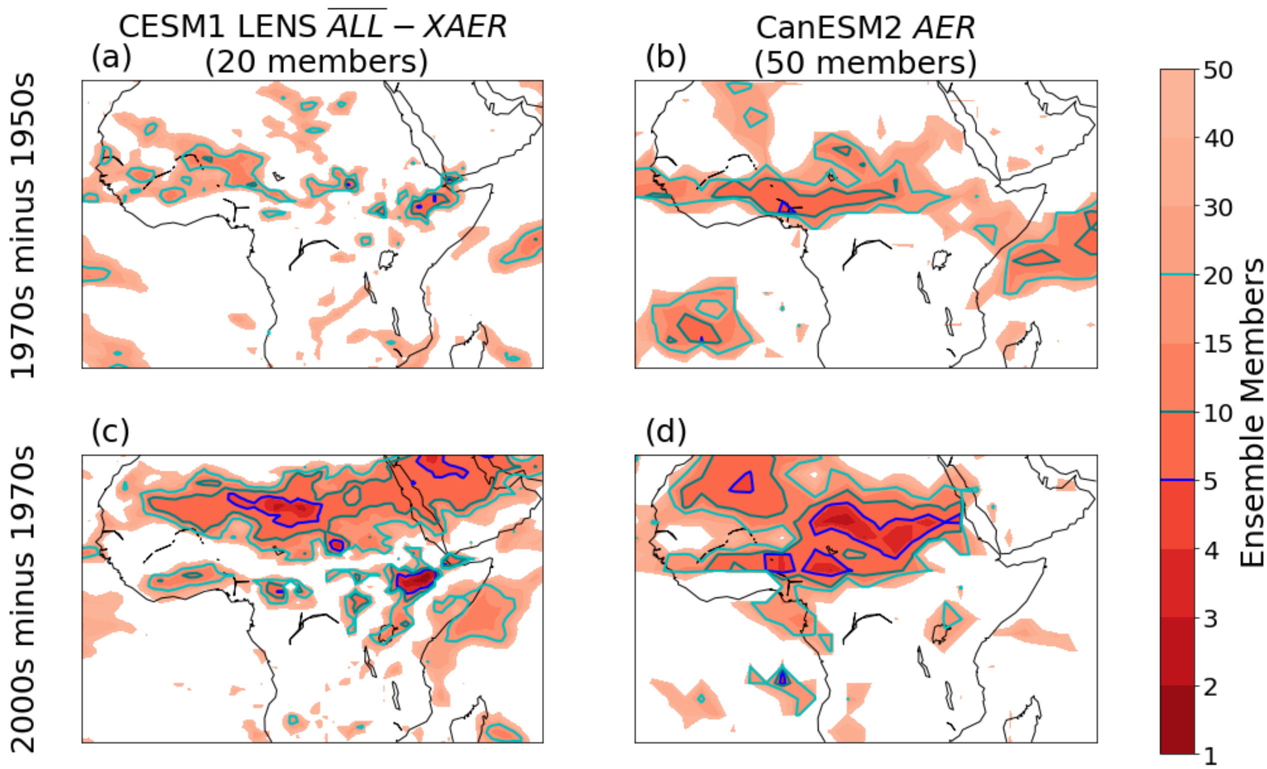
Anthropogenic Aerosols Dominate Forced Multidecadal Sahel Precipitation Change through Distinct Atmospheric and Oceanic Drivers

https://doi.org/10.1175/JCLI-D-19-0829.1

Supplementary Material for: Anthropogenic aerosols dominate forced multidecadal Sahel precipitation change through distinct atmospheric and oceanic drivers.

Effect	Background State	CAM5 and CanAM4
2000s-1970s Direct Atmospheric Response	CLIM SST	Exp 1 - Exp 2
	PERT SST	Exp 3 - Exp 4
2000s-1970s Ocean Mediated Response	CLIM EMIS	Exp 1 - Exp 3
	PERT EMIS	Exp 2 - Exp 4
2000s-1970s Total Direct Atmospheric plus Ocean Mediated Response	AVERAGE	Exp 1 - Exp 4
	CTRL SUM	Exp 1 - Exp 2 + Exp 1 - Exp 3
	PERT SUM	Exp 3 - Exp 4 + Exp 2 - Exp 4
1970s – 1950s Direct Atmospheric Response	CLIM SST	Exp 2 - Exp 5
	PERT SST	(Exp 6 - Exp 7) - (Exp 3 - Exp 4)
1970s – 1950s Ocean Mediated Response	CLIM EMIS	Exp 3 - Exp 6
	PERT. EMIS.	(Exp 5 - Exp 7) - (Exp 2 - Exp 4)
1970s-1950s Total Direct Atmospheric plus Ocean Mediated Response	AVERAGE	Exp 4 - Exp 7
	CTRL SUM	Exp 2 - Exp 5 + Exp 3 - Exp 6
	PERT SUM	(Exp 6 - Exp 7) - (Exp 3 - Exp 4) + (Exp 5 - Exp 7) - (Exp 2 - Exp 4)
Linearity Check, 1970s-1950s		Exp 4 - Exp 7 vs. (Exp 3 - Exp 6) + (Exp 2 - Exp 5)
Linearity Check, 2000s-1970s		Exp 1 - Exp 4 vs. (Exp 1 - Exp 2) + (Exp 1 - Exp 3)

Supplementary Table S1. Description of how the CAM5 AGCM simulations are differenced in order to obtain the direct atmospheric and ocean mediated responses for the 2000s minus 1970s and the 1970s minus 1950s. Refer to Table 2 for the AGCM experiment list.



Supplementary Figure S1: Estimate of the minimum ensemble size required to find a statistically significant JAS precipitation response to anthropogenic aerosol forcing with a student's t-test in CESM1 (left column) and CanESM2 (right column) for the 1970s minus 1950s (top row) and the 2000s minus 1970s (bottom row).

The minimum ensemble size required to find a statistically significant difference between two populations N is estimated as

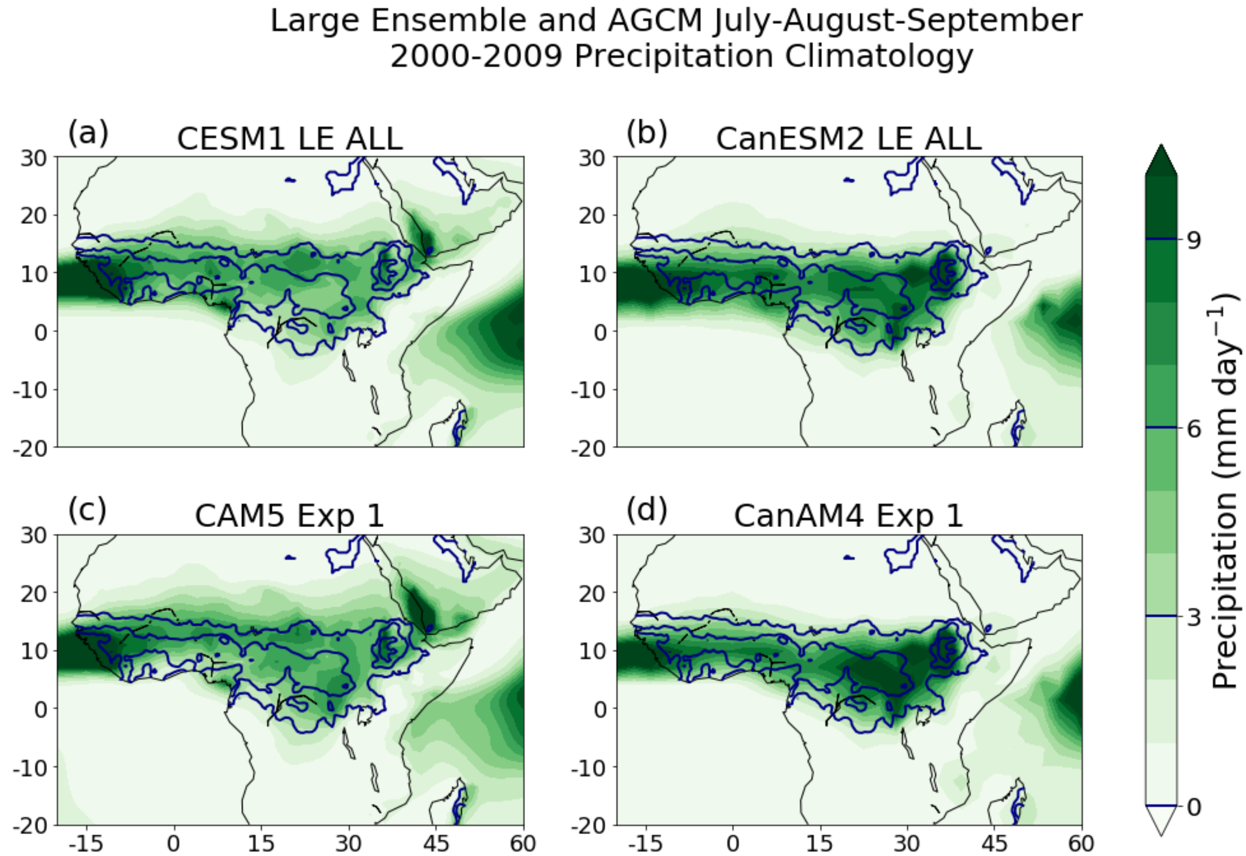
$$N = 2\left(\frac{t_0 s_p}{\Delta x}\right)^2$$

where t_0 is the threshold for statistical significance of the student's t-test, s_p is the pooled standard deviation of the populations, and Δx is the difference of the means of the populations. This formula is obtained by inverting the Student's t-test for two populations with equal size and is the version of the metric described by Wehner (2000). Following Deser et al. (2012), we approximate t_0 as 2 and calculate

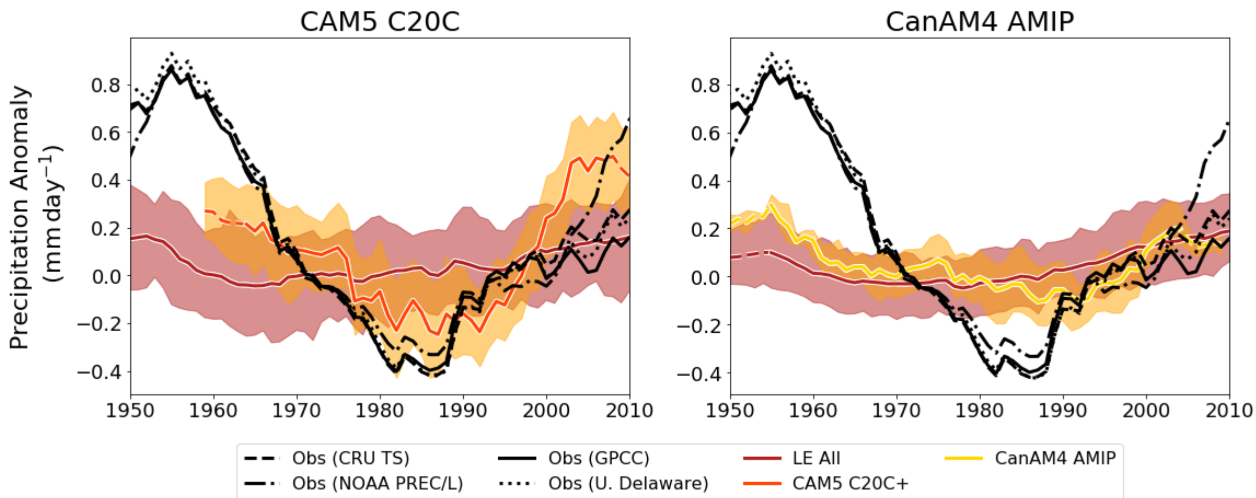
$$N \approx 8\left(\frac{s_p}{\Delta x}\right)^2$$

Wehner, M. F. (2000). A method to aid in the determination of the sampling size of AGCM ensemble simulations. Climate Dynamics, 16(5), 321–331. https://doi.org/10.1007/s003820050331

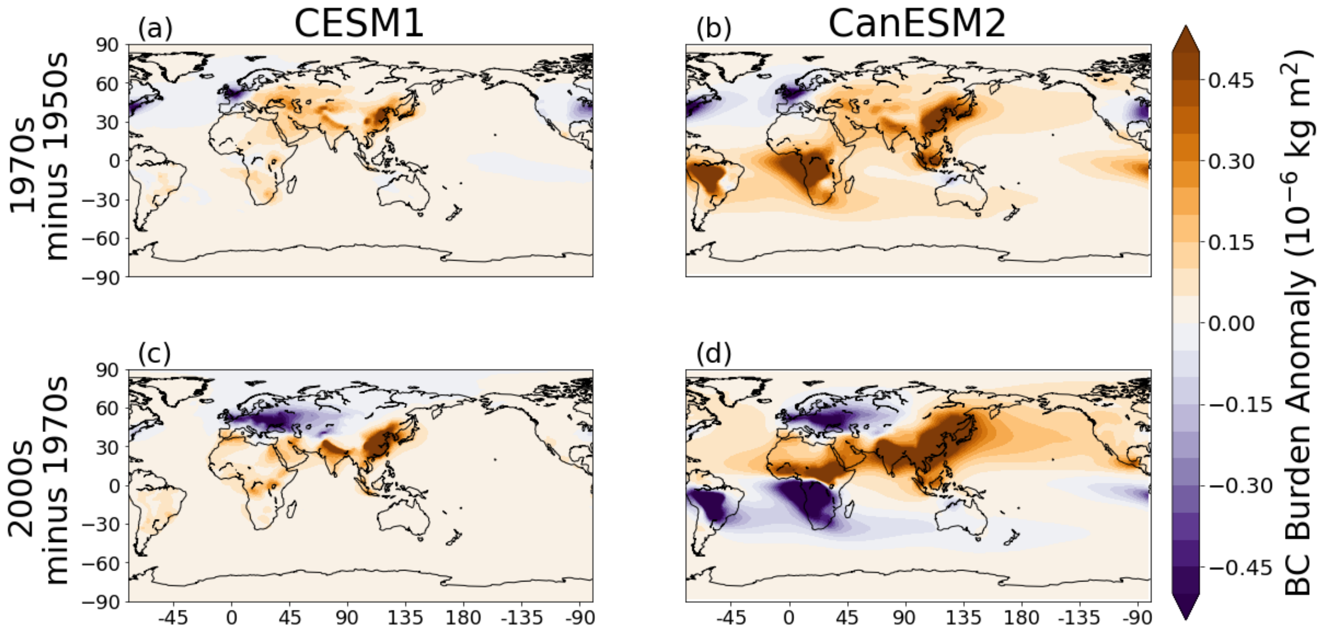
Deser, C., Phillips, A., Bourdette, V. et al. Clim Dyn (2012) 38: 527. https://doi.org/10.1007/s00382-010-0977-x



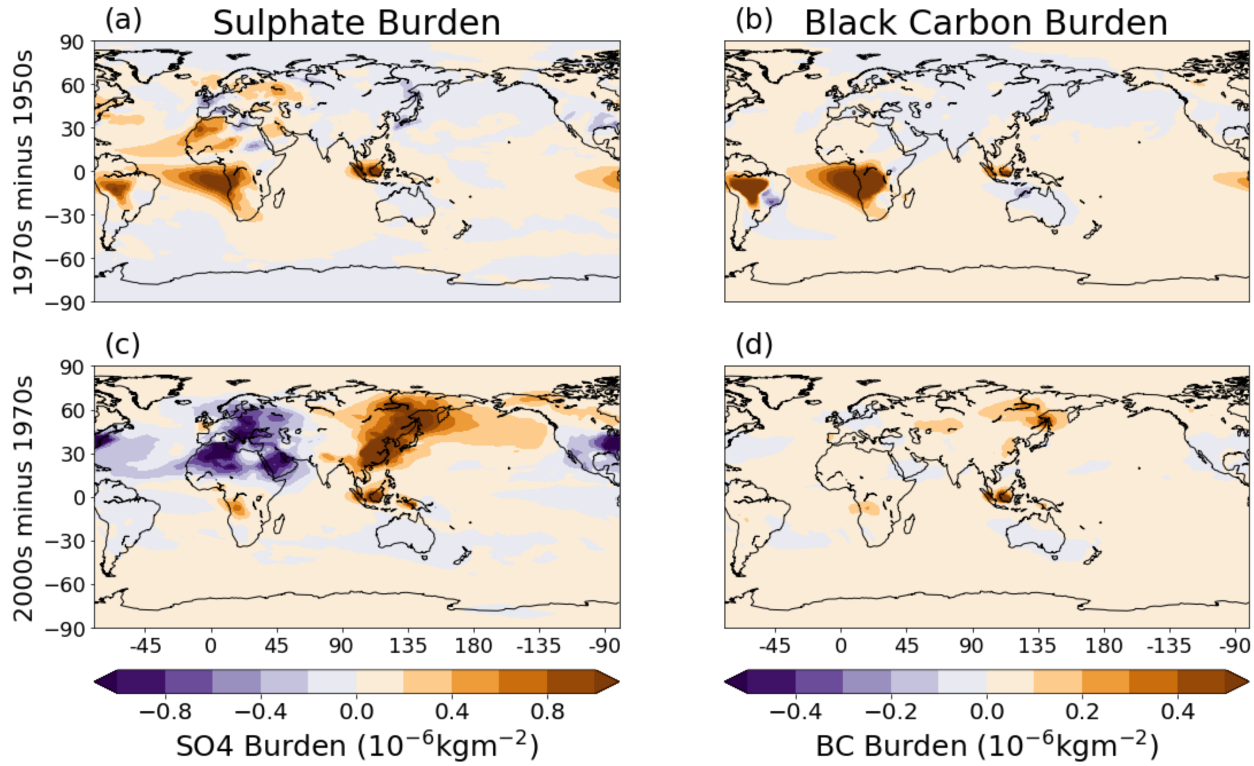
Supplementary Figure S2: Climatological JAS precipitation for 2000-2009 in a) the CESM1 LE All forcing simulation, b) the CanESM2 LE All forcing simulation, c) the CAM5 EXP1 simulation, and d) the CanAM4 EXP1 simulation. The observed climatology of GPCC for 2000-2009 is plotted in blue contours on 3mm/day intervals.



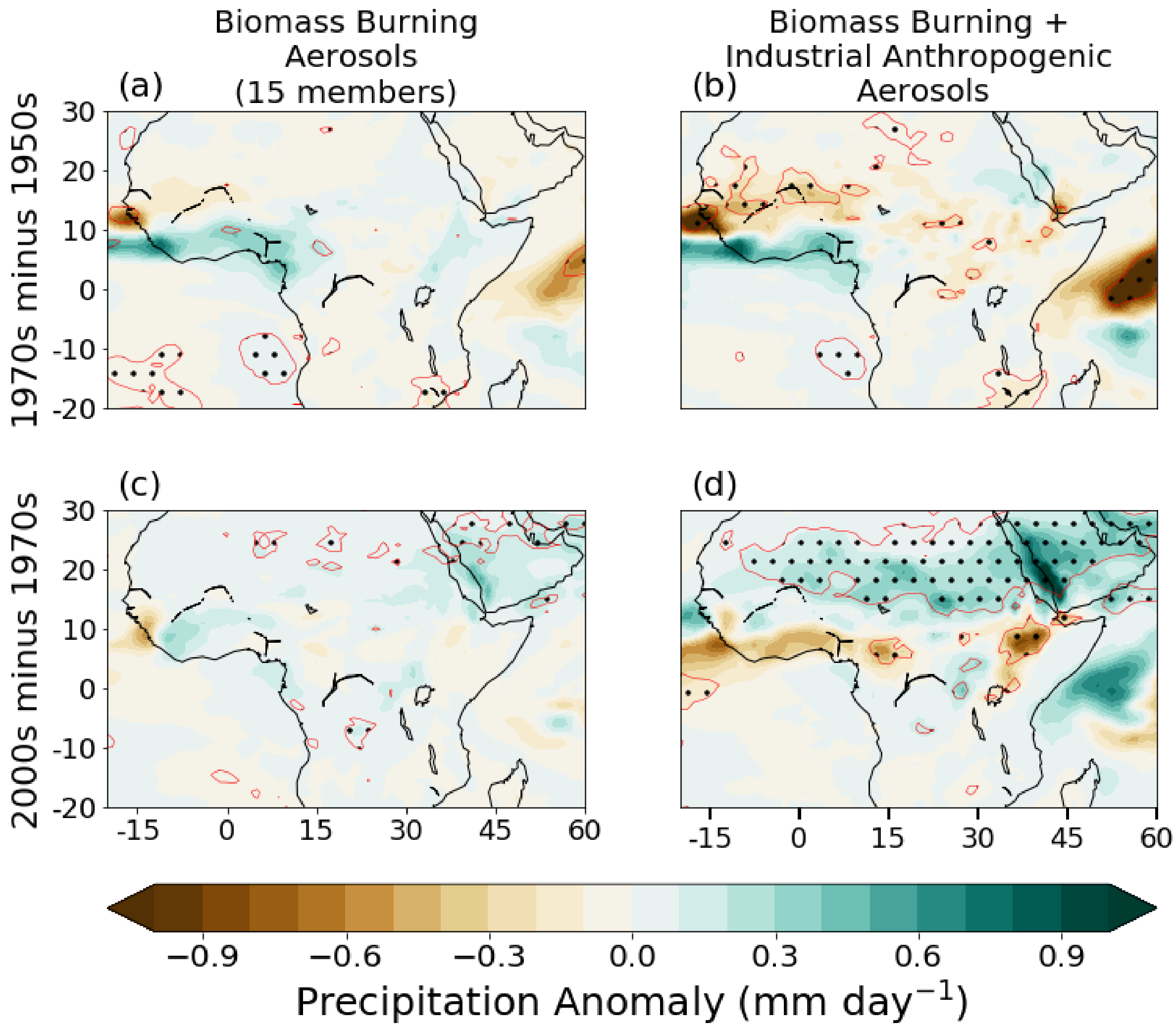
Supplementary Figure S3: As in Figure 5, but with a) CAM5 C20C+ and b) CanAM4 AMIP Sahel precipitation anomalies rather than the CESM1 and CanESM2 LE AER time series.



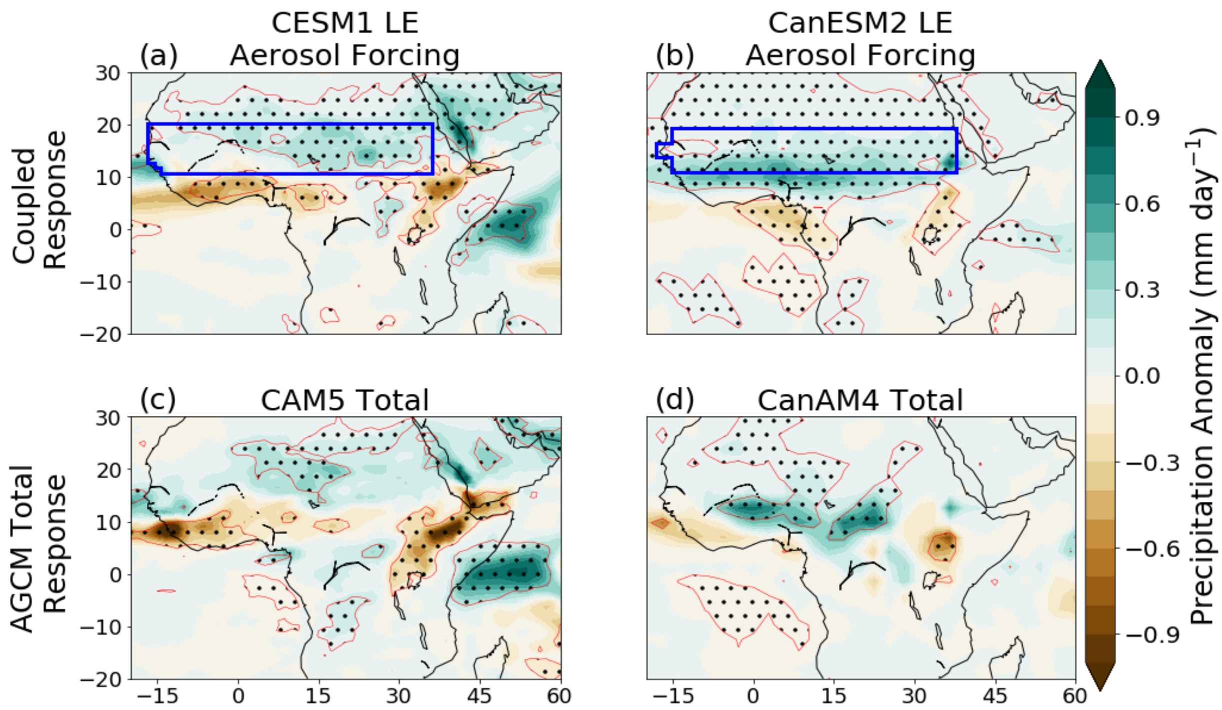
Supplementary Figure S4: As in Fig. 4 for Black Carbon (BC) burden.



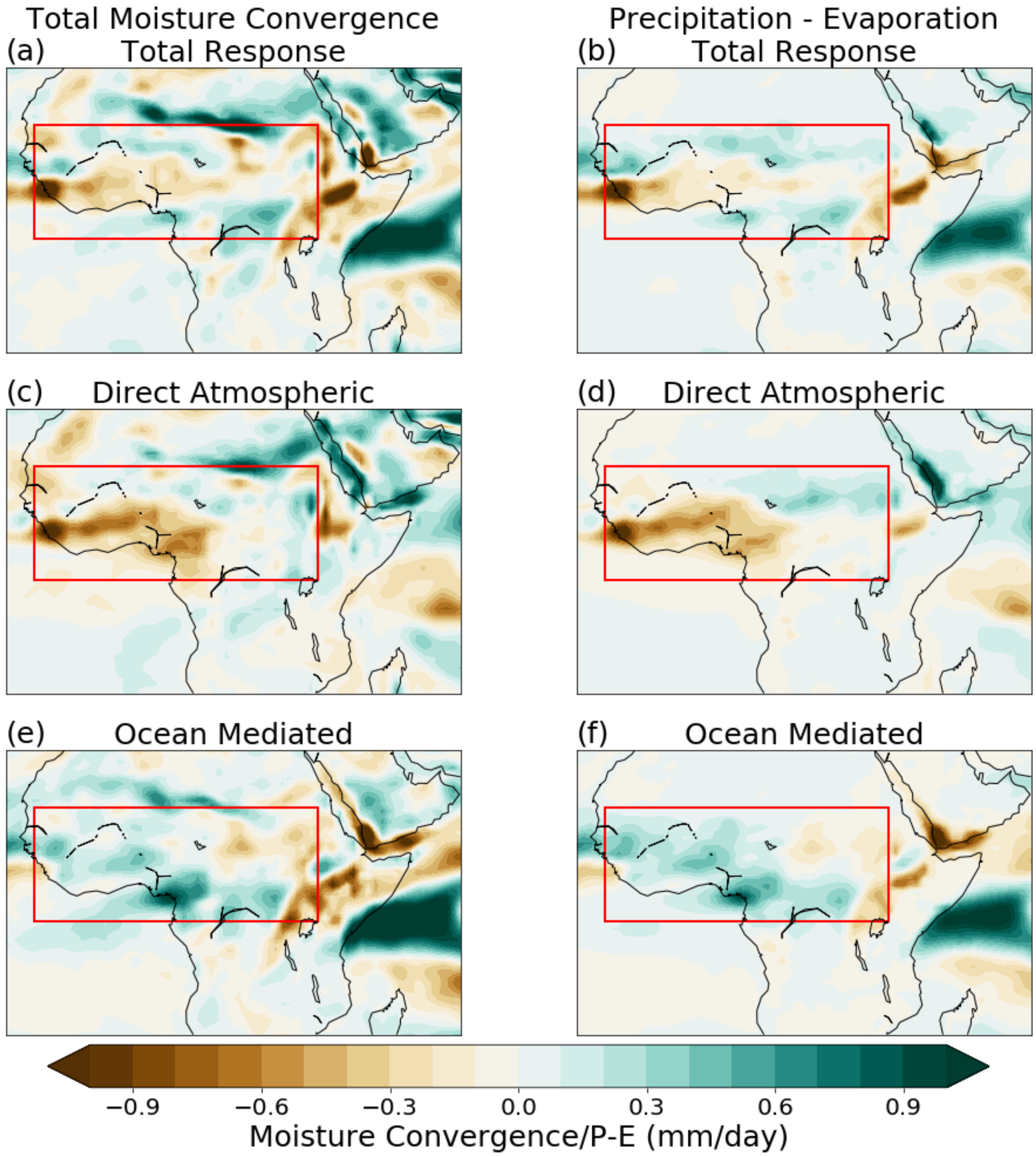
Supplementary Figure S5: CESM1-LE All forcing minus All-but-Biomass Burning ensemble average JAS mean Sulphate burden (left column) and Black Carbon burden (right column) anomalies for the 1970s minus 1950s (top row) and 2000s minus 1970s (bottom row).



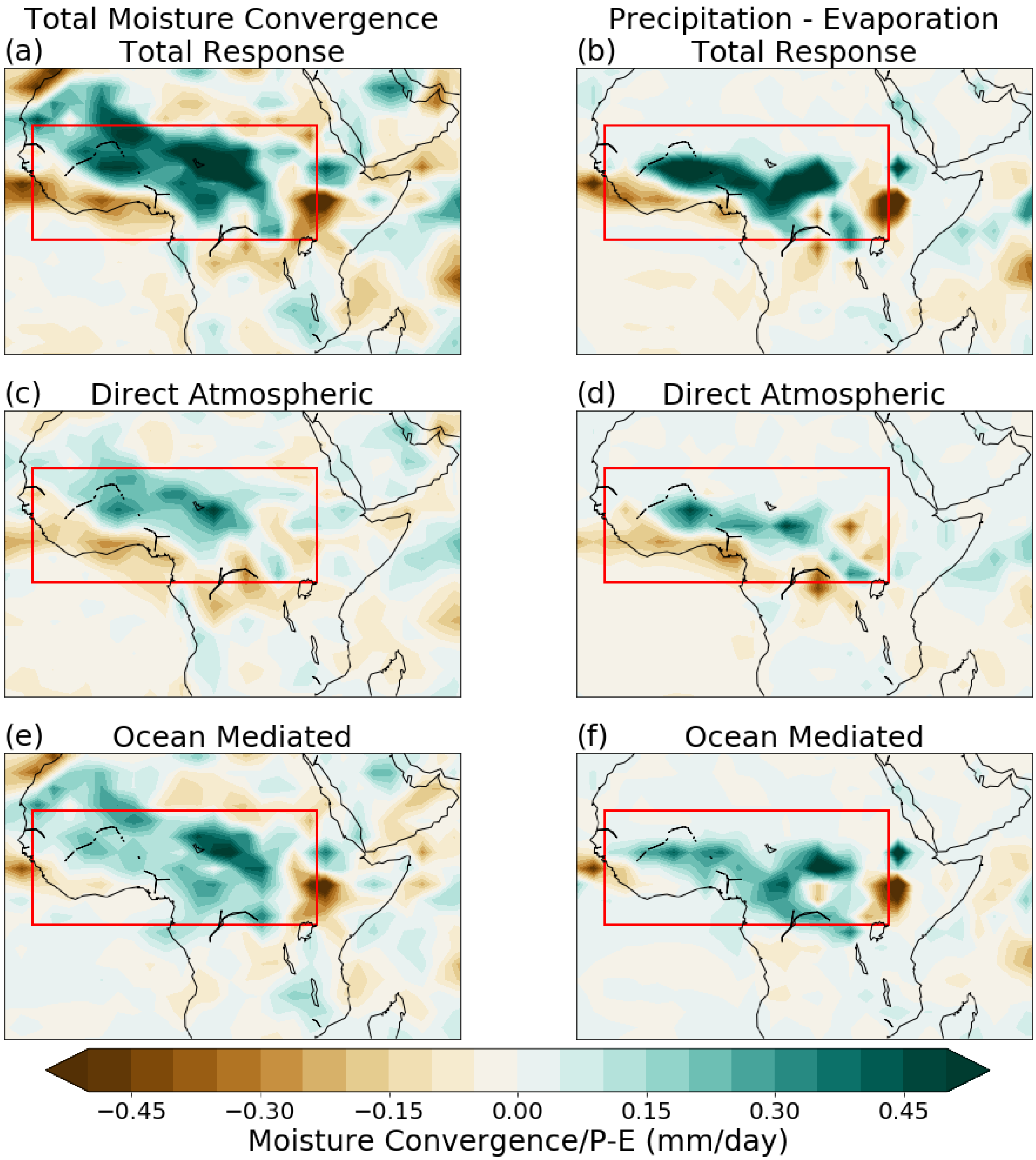
Supplementary Figure S6: CESM1 LE JAS precipitation response to biomass burning aerosols (left column) and combined biomass burning and other anthropogenic (primarily energy-sector) aerosols (right column) for the 1970s minus 1950s (top row) and the 2000s minus 1970s (bottom row). Stippling surrounded by a thin red contour indicates grid points whose responses are statistically significant at the 95% level.



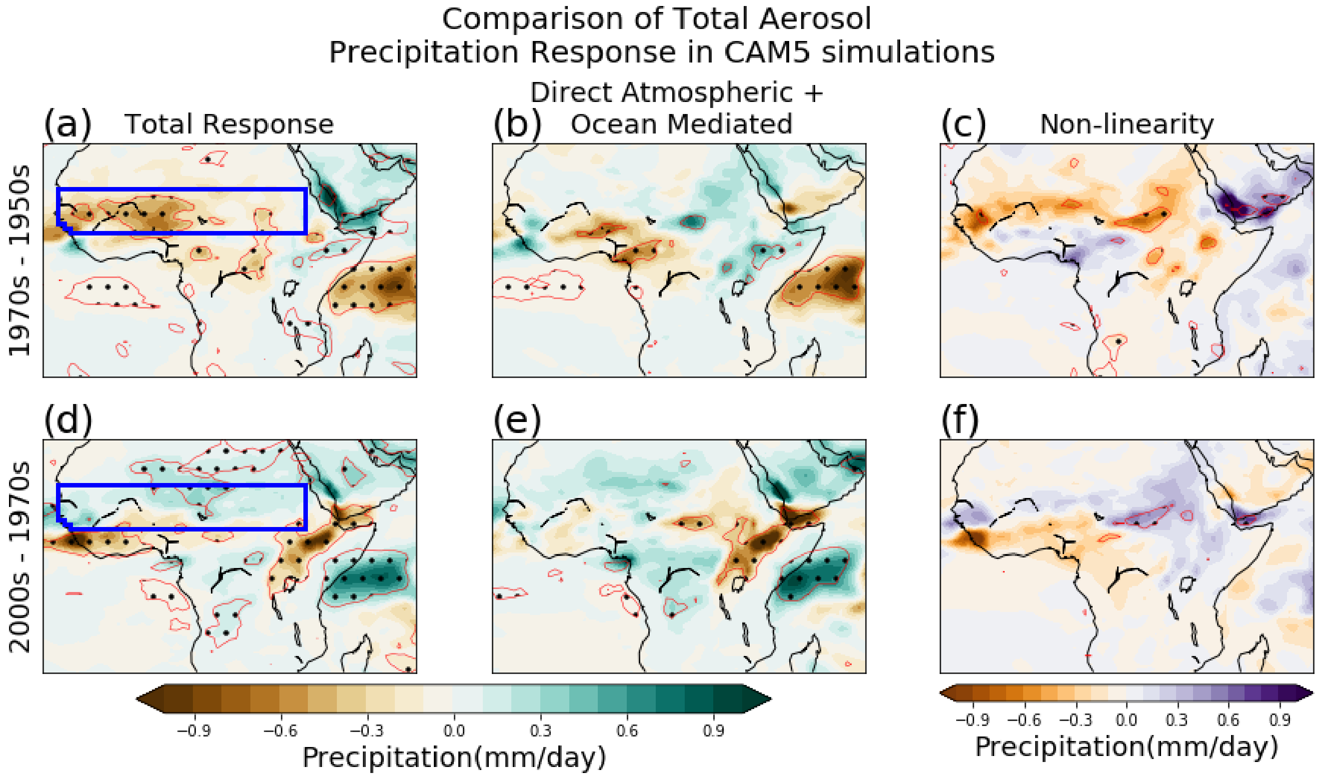
Supplementary Figure S7: As in Fig. 6, but for the 2000s minus 1970s. Note that (a) and (b) are the same as Fig. 1d and Fig. 2d respectively.



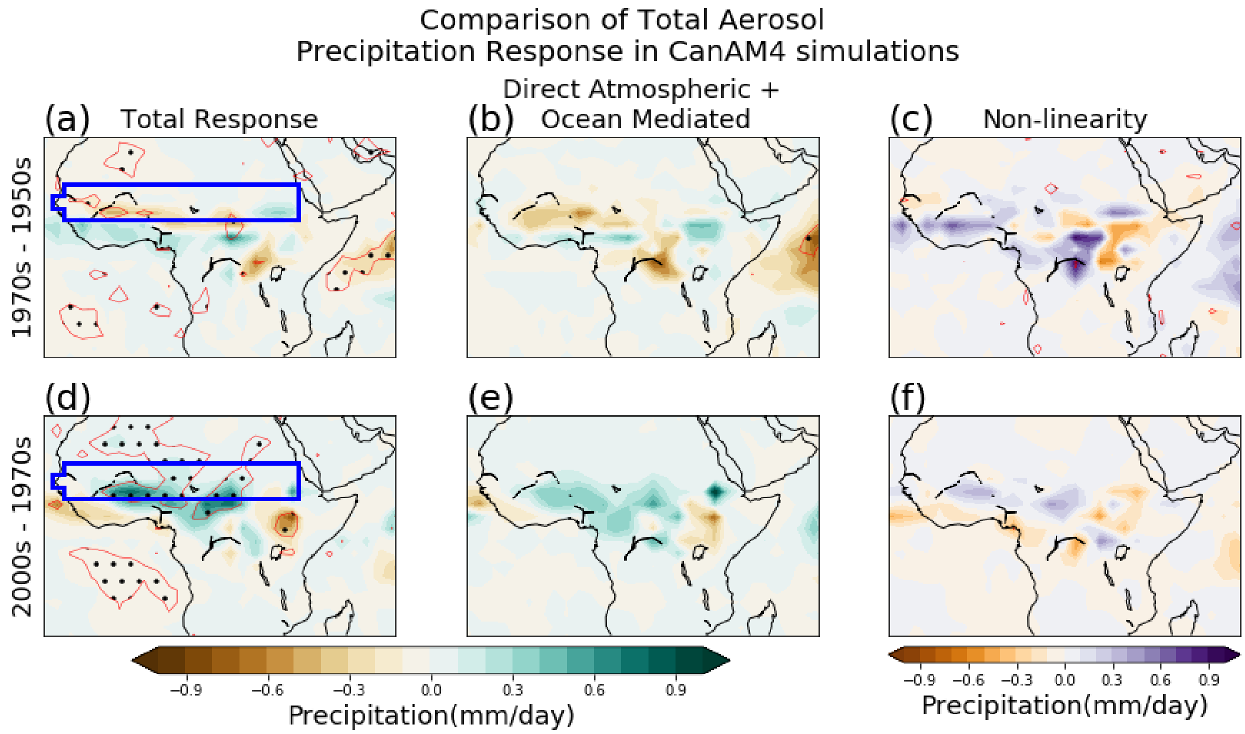
Supplementary Figure S8: Moisture Convergence (δMC) (Left column) and P-E (right column) over Africa for the 2000s minus the 1970s for the Total (Top row), direct atmospheric (Middle), and ocean mediated (Bottom) responses in the CAM5 simulations. Red boxes indicate the region for which the covariance fractions are computed.



Supplementary Figure S9: As in Supplementary Figure 7, but for CanAM4.



Supplementary Figure S10: The combined CAM5 total response to the direct atmospheric and ocean mediated responses (left column), the sum of the individual components (middle column), and the difference between the two (right column) in the1970s-1950s (top row) and 2000s-1970s (bottom row) AGCM experiments for the 1970s minus 1950s. Note due to the configuration of the AGCM experiments the difference here is the same difference as for the two different methods for calculating either the direct atmospheric or the ocean mediated responses through algebraic rearrangement of the simulations. Stippling surrounded by a thin red contour indicates grid points whose responses are statistically significant at the 95% level. The blue boxes indicate the averaging region used in Fig. 12.



Supplementary Figure S11: As in Fig. S10, but for CanAM4.