SUPPLEMENTARY INFORMATION
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Recent Walker circulation strengthening and Pacific cooling amplified by Atlantic warming

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1. Partially coupled experiments

Seven main CAM4 experiments make up the suite of partially coupled experiments for this study. In these experiments, we prescribe the 1992-2011 SST trend in some basins while allowing the ocean in the other basin/basins to integrate the atmospheric heat fluxes using a slab ocean thermodynamic mixed layer (ML) model. Summary details of these simulations can be found in Table S2.

In the partially coupled experiments we always use the thermodynamic ML and thermodynamic sea-ice model polewards of 55^o latitude. To avoid sharp SST gradients we utilize a buffer zone between 50^o and 55^o latitude, in which the prescribed SST boundary forcing is gradually merged with the SST obtained from the ML temperature tendency equation. Depending on the experiment, climatological SST boundary forcing is either prescribed or calculated using the ML model in the respective ocean basins (Table S2).

The SST (T) tendency equation for the ML model (Kiehl et al. 2006) reads:

$$dT/dt = (F_{net} - Q_{flx}^{clim})/(\rho\ C_p\ H_{mix}),$$

where F_{net} is the surface net energy balance at each time step, ρ is the sea water density, C_p the specific heat of sea water and H_{mix} the observed annual mean ocean mixed layer depth (Monterey and Levitus 1997). The climatological heat flux, Q_{flx}^{clim}, is calculated from:

$$Q_{flx}^{clim} = F_{net} - (\rho\ C_p\ H_{mix})\ dT^{clim}/dt,$$

where F_{net} and dT^{clim}/dt are calculated from a 30 year CAM4 T42 resolution AGCM control simulation forced with the prescribed modern SST climatology (Hurrell et al. 2008).

All AGCM and partially coupled experiments are integrated for a one-year spin up before starting the respective 1992-2011 experiments.

Exp name	1992-2011 SST trend applied	Climatological SST applied	Mixed Layer (ML) active
Full SST trend	Globally	None	None
AO SST trend only	Atlantic	Indian & Pacific	None
AO SST trend/PO ML	Atlantic	Indian	Pacific
AO SST trend mean/PO ML	Spatial Atl. Mean	Indian	Pacific
AO SST trend grad/PO ML	Atl. mean removed	Indian	Pacific
IO SST trend/PO ML	Indian	Atlantic	Pacific
PO SST trend/IO & AO ML	Pacific	none	Indian & Atlantic

Table S1: CAM4 Experiments: Description of basin regions where observed SST trends, climatological SSTs are prescribed and where the ML model is active in the suite of CAM4 AGCM experiments utilized here. The ML model is always used poleward of 55^{o}.

Exp name	Ens 1	Ens 2	Ens 3	Ens 4	Ens 5	Ens mean
Full trend	-0.56	-0.54	-0.64	-0.67	-0.68	**-0.6**
AO trend/PO ML	-0.78	-0.67	-0.45	-0.51	-0.29	**-0.54**
IO trend/PO ML	0.19	-0.4	-0.36	-0.07	0.08	**-0.11**

Table S2: Equatorial region (5^{o}S-5^{o}N and 160^{o}E-180^{o}E) wind stress trends (x10^{-3} Nm^{-2}/year) calculated over the period 1992-2011 from each of the five experiment ensemble members and their mean. It is notable that all trends are smaller than the observed (ERA-interim) zonal wind stress trend, which has a trend of -1.8 x10^{-3} Nm^{-2}/year over the same period.

Exp name	Ens 1	Ens 2	Ens 3	Ens 4	Ens 5	Ens mean
Full trend	-0.99	-0.90	-0.89	-1.07	-1.07	**-0.98**
AO trend/PO ML	-2.02	-1.75	-1.36	-1.20	-0.88	**-1.44**
IO trend/PO ML	0.05	-1.10	-0.48	0.04	0.14	**-0.29**

Table S3: Equatorial region (5^{o}S-5^{o}N and 160^{o}E-180^{o}E) 850 hPa zonal wind trends (x10^{-1} m s^{-1}/year) calculated over the period 1992-2011 from each of the five experiment ensemble members and their mean. It is notable that all trends are smaller than the observed (ERA-interim) 850 hPa zonal wind trend, which has a trend of -1.9 x10^{-1} m s^{-1}/year over the same period.

	Atlantic – LF GM	Pacific – LF GM	Global mean – LF GM	TBV
Atlantic – LF GM	1	0.46	0.69	0.66
Pacific – LF GM	0.46	1	0.84	-0.37
Global mean – LF GM	0.69	0.84	1	0
TBV	0.66	-0.37	0	1

Table S4: Correlation Coefficients between 11-month running mean Atlantic, Pacific, global mean SST indices after removing a 301-month running mean (low frequency, LF) global mean SST (LF GM). Correlation between 11-month running TBV SST index (defined as spatially averaged SST difference over 30^{o}S-60^{o}N, 70^{o}W-20^{o}E and 30^{o}S-60^{o}N, 120^{o}E-90^{o}W) and other indices. All correlations marked in red are statistically significant above the 95% level.

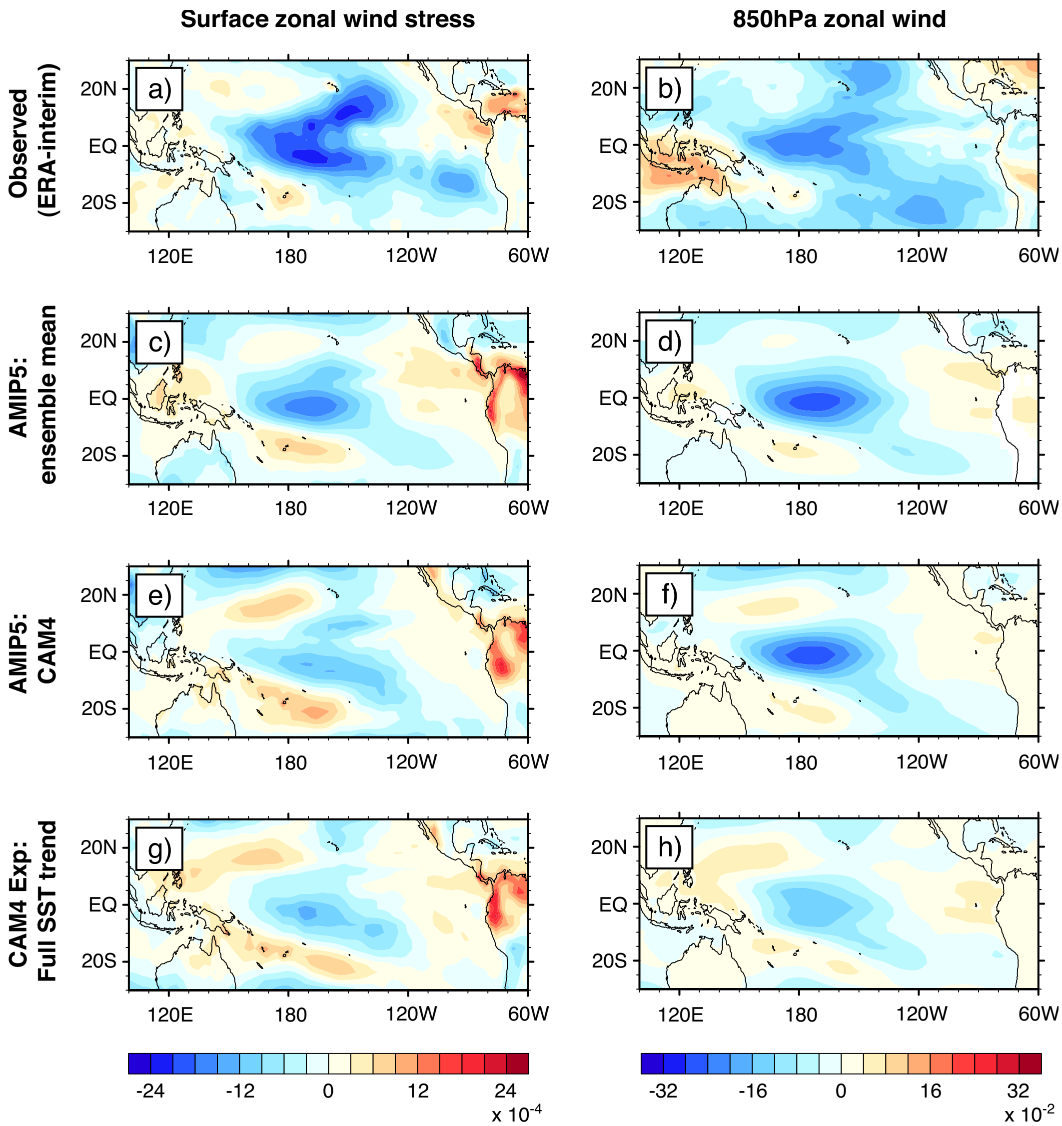

Figure S1: **Left panels**: Zonal surface wind stress trends [Nm^{-2}/year] calculated over the 1992-2011 period from a) ERA-interim reanalysis data, (Dee et al. 2009), and g) CAM4 forced with only the observed SST trend over the 1992-2011 period, while panels c) and e) display the AMIP5 ensemble mean, and the CAM4 AMIP5 simulation wind stress trends calculated from 1992 to 2008 (when the majority of the AMIP5 runs end), respectively. **Right panels:** Same as left, but for the simulated 850 hPa zonal wind trends [m/s/year]. The AMIP5 models utilized to generate panel c) and d) of this this figure are: ACCESS1.0, BNU-ESM, CCSM4, CMCC-CM, CNRM-CM5, CSIRO-mk6, CanAM4, FGOALS, GFDL-HIRAM-C180, GFDL-HIRAM-360, GISS-E2-R, HadGEM2-A, IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR, MIROC5, MPI-ESM-LR, MPI-ESM-MR, MRI-AGCM3-2H, MRI-AGCM3-2S, MRI-CGCM3, NorESM1-M, bcc-csm1-1-m, bcc-csm1-1 and inmcm4.

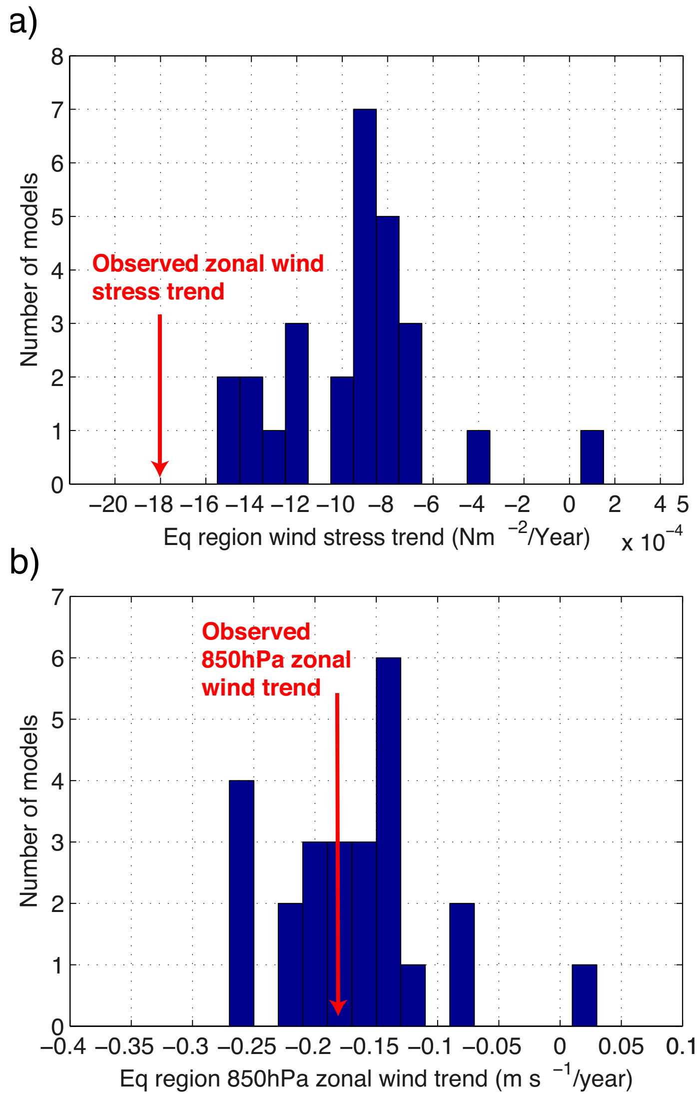

Figure S2: a) Histogram of the 25 AMIP5 model equatorial region (5°S-5°N and 160°E-180°E) zonal wind stress trends over the period 1992-2008 (when the majority of the AMIP5 runs end). The mean value is -0.94 x10^{-3} Nm^{-2}/year, which is roughly a factor of 2 smaller than the observed trend (-1.8 x10^{-3} Nm^{-2}/year) calculated using ERA-interim data over the same period. b) same as a), but using 850 hPa zonal velocities. To generate this figure the following AMIP model experiments were analyzed: ACCESS1.0, BNU-ESM, CCSM4, CMCC-CM, CNRM-CM5, CSIRO-mk6, CanAM4, FGOALS, GFDL-HIRAM-C180, GFDL-HIRAM-360, GISS-E2-R, HadGEM2-A, IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR, MIROC5, MPI-ESM-LR, MPI-ESM-MR, MRI-AGCM3-2H, MRI-AGCM3-2S, MRI-CGCM3, NorESM1-M, bcc-csm1-1-m, bcc-csm1-1 and inmcm4.

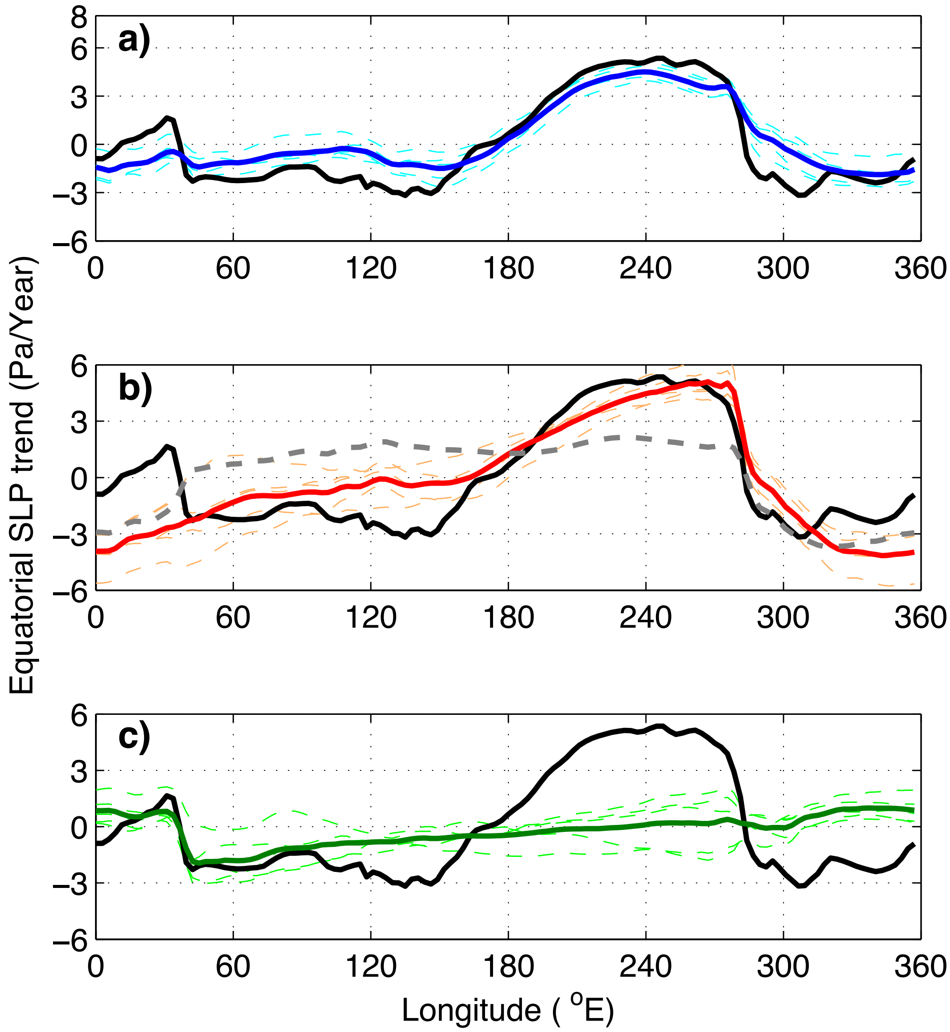

Figure S3: The simulated equatorial average (5°S-5°N) 1992-2011 SLP trends (Pa/year) from the a) Full SST trend (blue), b) AO Trend/PO ML (red), and c) IO Trend/PO ML (green) experiments. The black line in each panel is the observed (ERA-interim) SLP trend (Pa/year) and each of the individual ensemble members from panels a)-c) are plotted in thin dashed cyan, orange and bright green respectively. The gray dashed line in b) is the equatorial average (5°S-5°N) SLP trend (Pa/year) from the AO Trend only simulation.

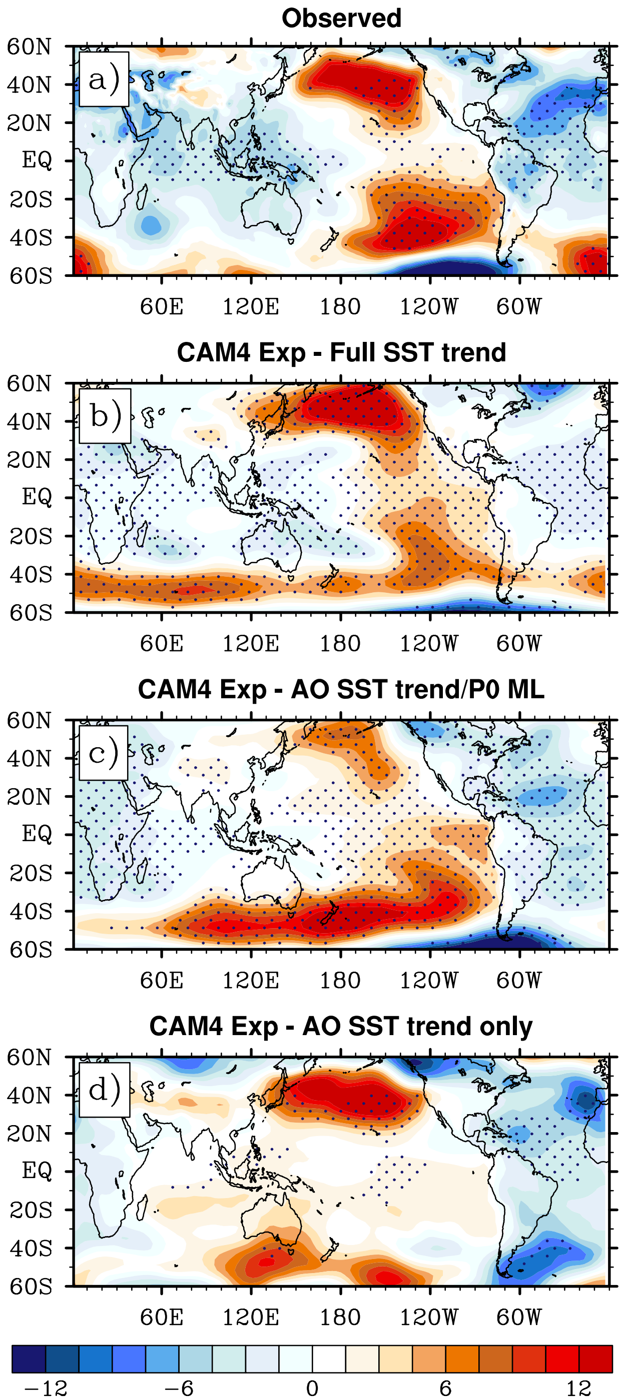

Figure S4: 1992-2011SLP trend [Pa/year] from a) the Observations, and for the b) ensemble mean Full SST trend, c) ensemble mean AO SST trend/PO ML, and d) AO SST trend only (i.e., no Pacific ocean mixed layer) CAM4 experiments (Table S2). SLP trends significant above the 95% level are stippled.

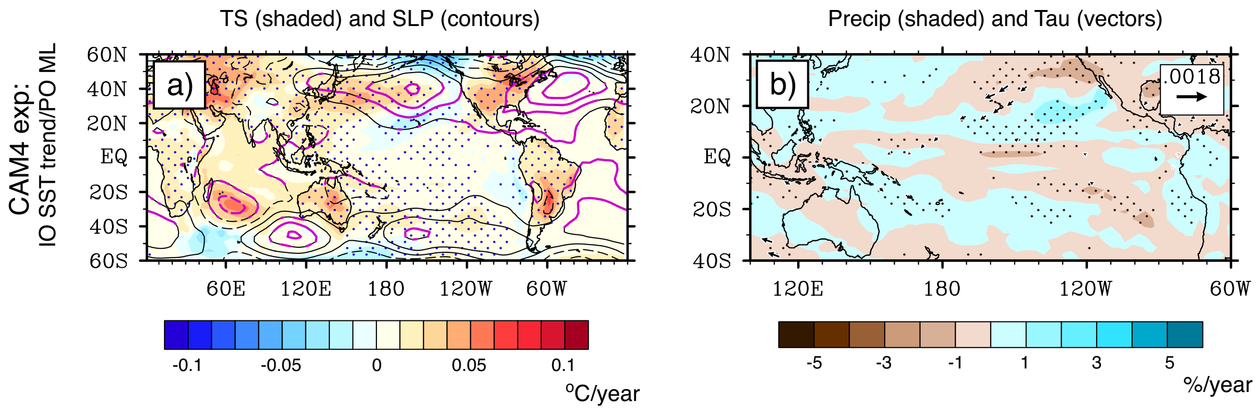

Figure S5: a) 1992-2011 SST [C/year] (shading) and SLP [Pa/year] (contour) trend for experiment prescribing the Indian Ocean SST trend and Pacific ocean mixed layer; contour levels range from -15 Pa to 15 Pa with contour interval of 2 Pa, negative contours are dashed and significant (above the 95% level) contours are magenta. b) Corresponding simulated precipitation change (shading) and significant wind trends (vector). In both panels stippling indicates that the changes in the underlying shaded plots are significant above the 95% level.

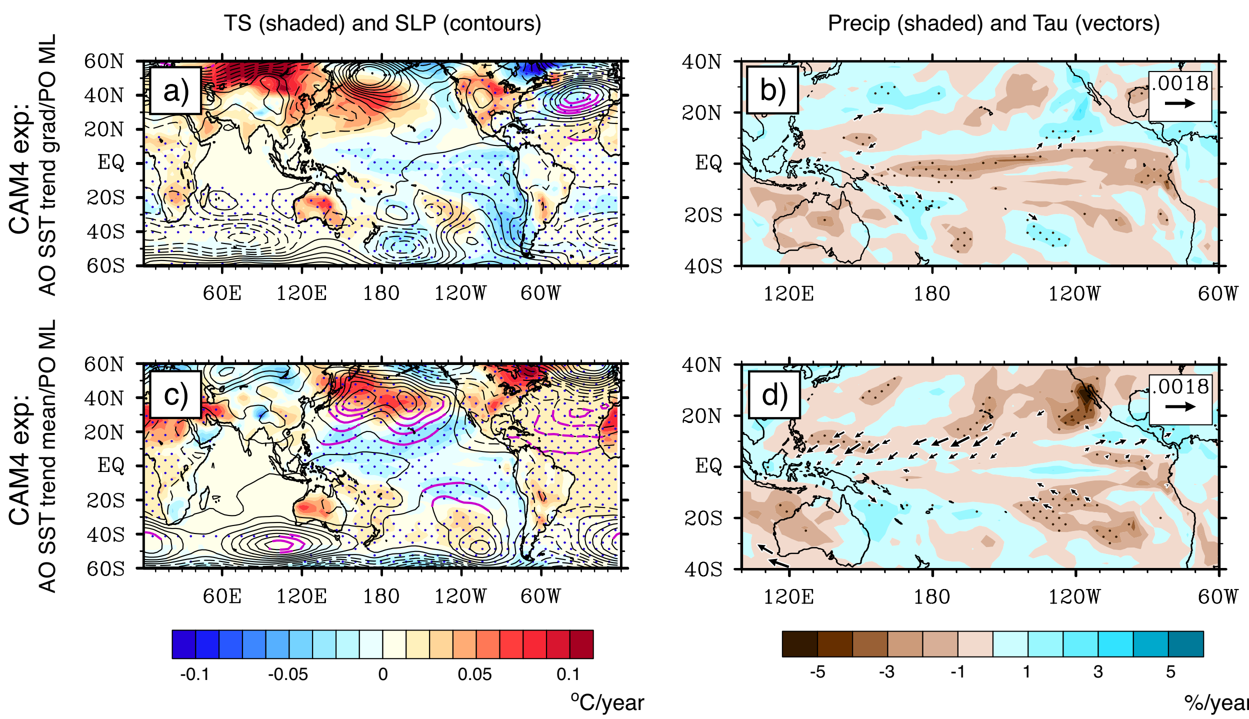

Figure S6: a) 1992-2011 SST [C/year] (shading) and SLP [Pa/year] (contour) trend for experiment prescribing the gradient component (with the spatial averaged Atlantic SST trend removed) of the Atlantic SST trend and Pacific ocean mixed layer; contour levels range from from -15 Pa to 15 Pa with contour intervals of 2 Pa; negative contours are dashed and significant (above the 95% level) contours are magenta. b) Corresponding simulated precipitation change (shading) and significant wind trends (vector). In both panels stippling indicates that the changes in the underlying shaded plots are significant above the 95% level. c) as in a) and d) as in b) except for the experiment prescribing the spatially

averaged Atlantic SST trend (a single value over the Atlantic).

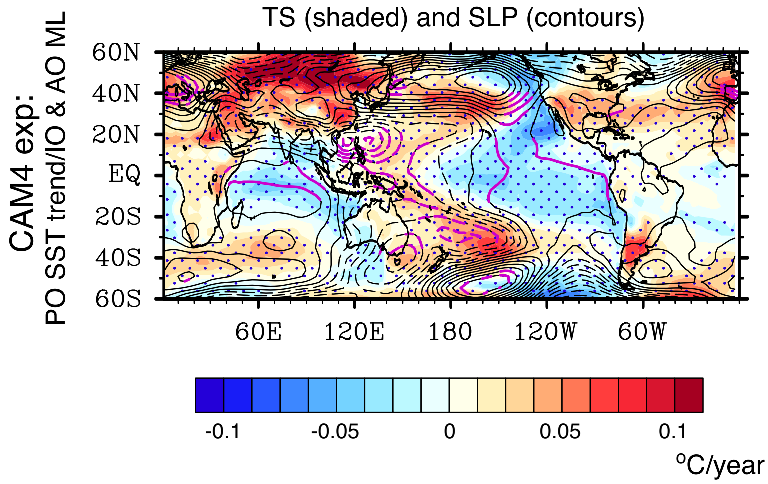

Figure S7: 1992-2011 SST [C/year] (shading) and SLP [Pa/year] (contour) trends for CAM4 experiment with prescribed Pacific SST trend pattern and Atlantic and Indian ocean mixed layer; contour levels range from -15Pa to 15Pa with contour intervals of 2Pa, negative contours are dashed and significant (above the 95% level) contours are magenta. In both panels stippling indicates that the changes in the underlying shaded plots are significant above the 95% level.

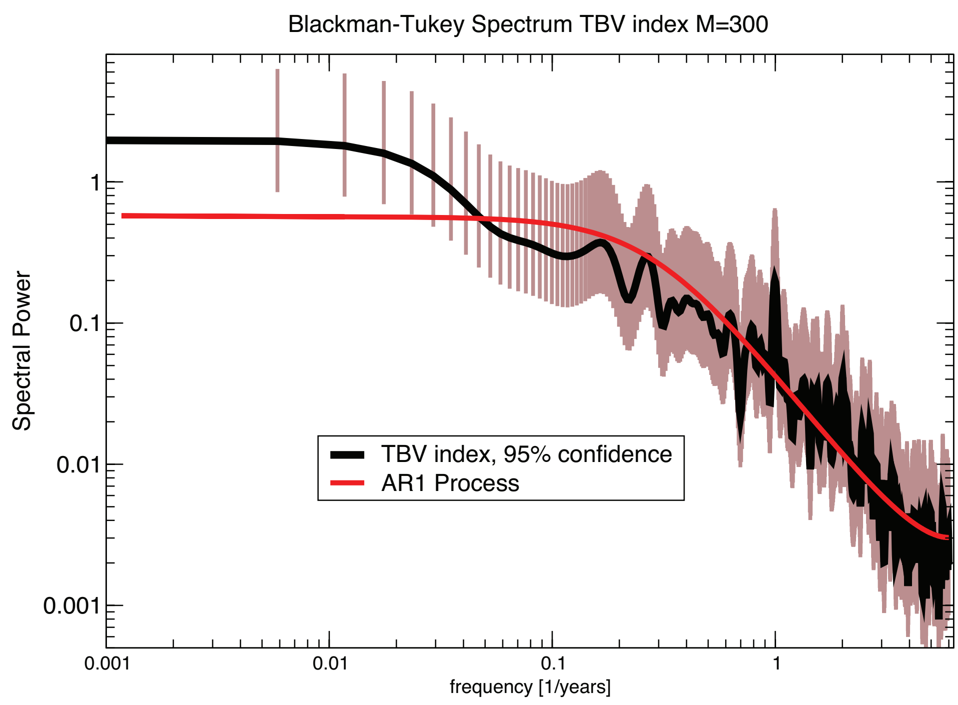

Figure S8: Blackman Tukey spectrum (black) of observed Trans-Basin-Variability (TBV) SST index (defined as the monthly mean SST area averaged difference between 30°S-60°N, 70°W-20°E and 30°S-60°N, 120°E-90°W) with 95% confidence range (brown) and red-noise null hypothesis (red), obtained from a maximum entropy spectrum of 1st order.

2. References:

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