Does Disabling Cloud Radiative Feedbacks Change Spatial Patterns of Surface Greenhouse Warming and Cooling?

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SIGNIFICANCE STATEMENT: We analyze the processing controlling idealized warming and cooling under abrupt CO2 forcing using a modern and highly vetted fully coupled climate model (CESM1-CAM5). We compare simulations with and without cloud radiative feedbacks. Notably, 20% more global warming than global cooling occurred regardless of whether cloud feedbacks were enabled or disabled (Figure 1). This surprising consistency resulted from the cloud influence on forcing, non-cloud feedbacks, and circulation (Table 1). Excluding the tropical Pacific, disabling cloud feedbacks did little to change surface temperature response patterns including the large high-latitude responses driven by non-cloud feedbacks (Figure 2). Tropical Pacific cloud feedbacks amplified: 1) more fast warming than fast cooling in the west, and 2) slow pattern differences between 2xCO2 warming and 0.5xCO2 cooling in the east (Figure 3). The findings provide new insights into the regional processes controlling the response to greenhouse gas forcing, especially for clouds. When combined with estimates of cooling at the Last Glacial Maximum, the findings also help rule out large (4+ K) values of equilibrium climate sensitivity.

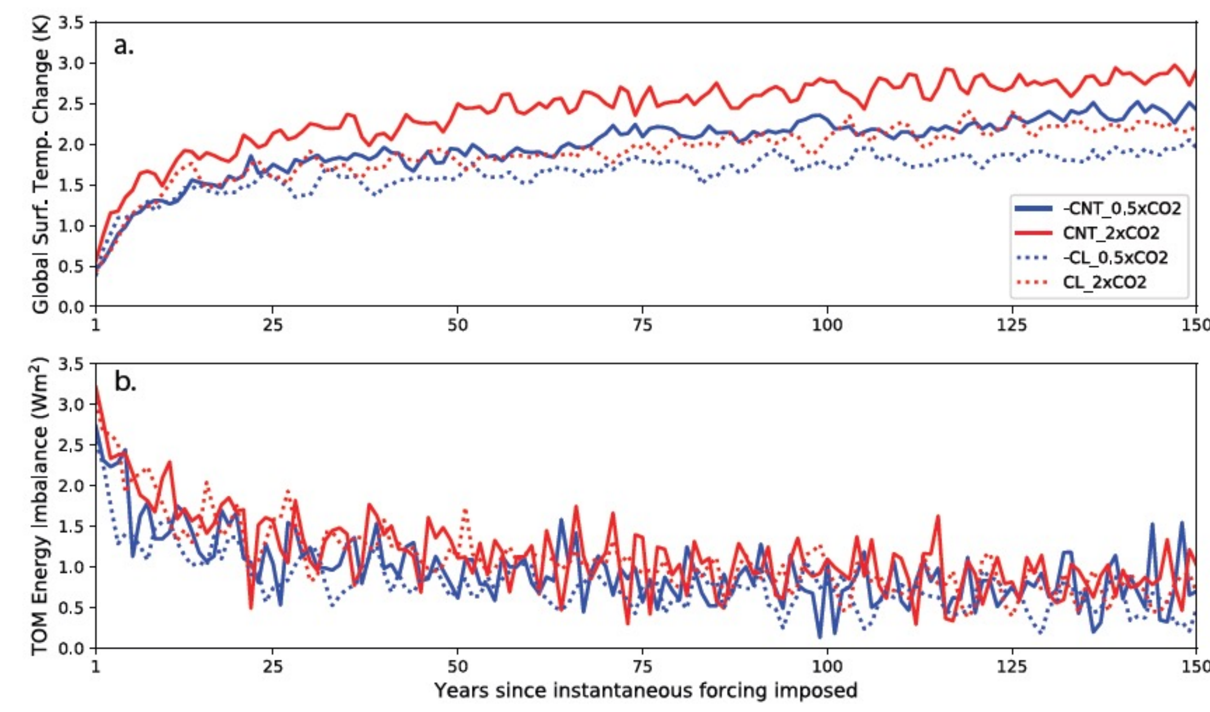

FIG 1. Global surface temperature and top of model energy imbalance time evolution for simulations with (CNT_2xCO2, CNT_0.5xCO2) and without cloud radiative feedbacks (CL_2xCO2, CL_0.5xCO2).

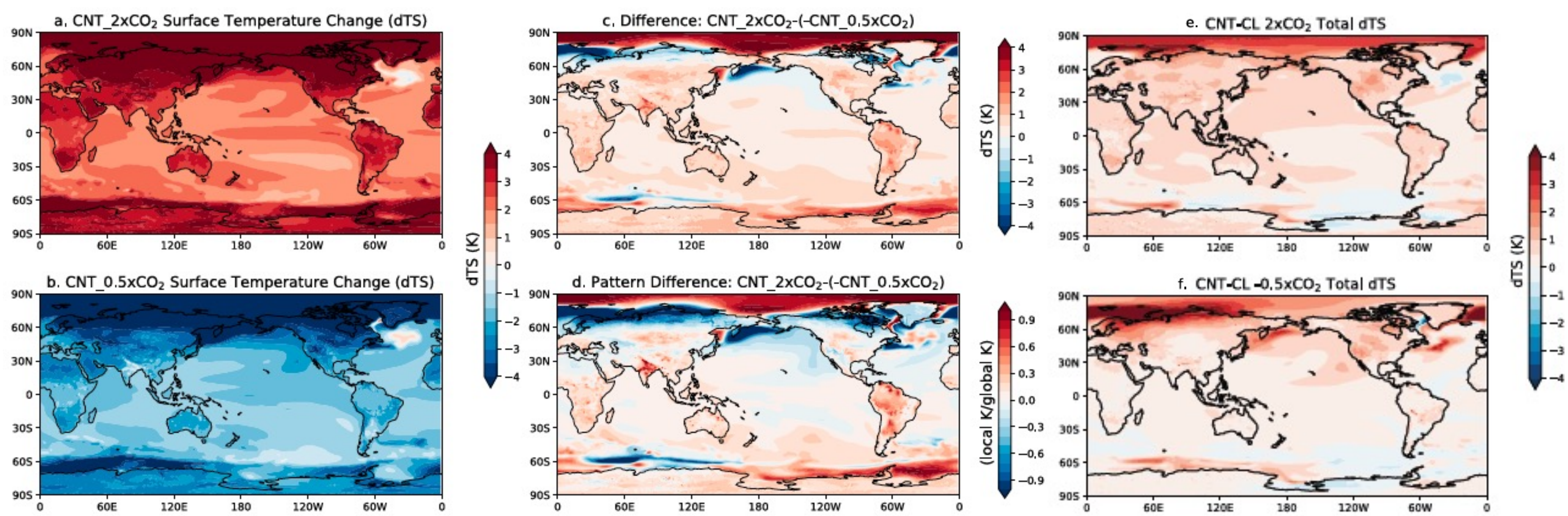

FIG. 2. Global maps of total surface temperature change from CNT for the last 50 years of simulations (years 100–150): (a) CNT_2xCO2, (b) CNT_0.5xCO2, (c) difference [CNT_2xCO2 - (-CNT_0.5xCO2)], and (d) pattern difference [CNT_2xCO2 - (-CNT_0.5xCO2)]. Pattern found by dividing local surface temperature change by the global mean surface temperature change. (e) Global maps of cloud influence on the total surface temperature change (dTS) for 2xCO2, (f) as in (e) but for 0.5*xCO2.* Cloud influence is calculated by differencing simulations with and without cloud radiative feedbacks (CNT-CL).

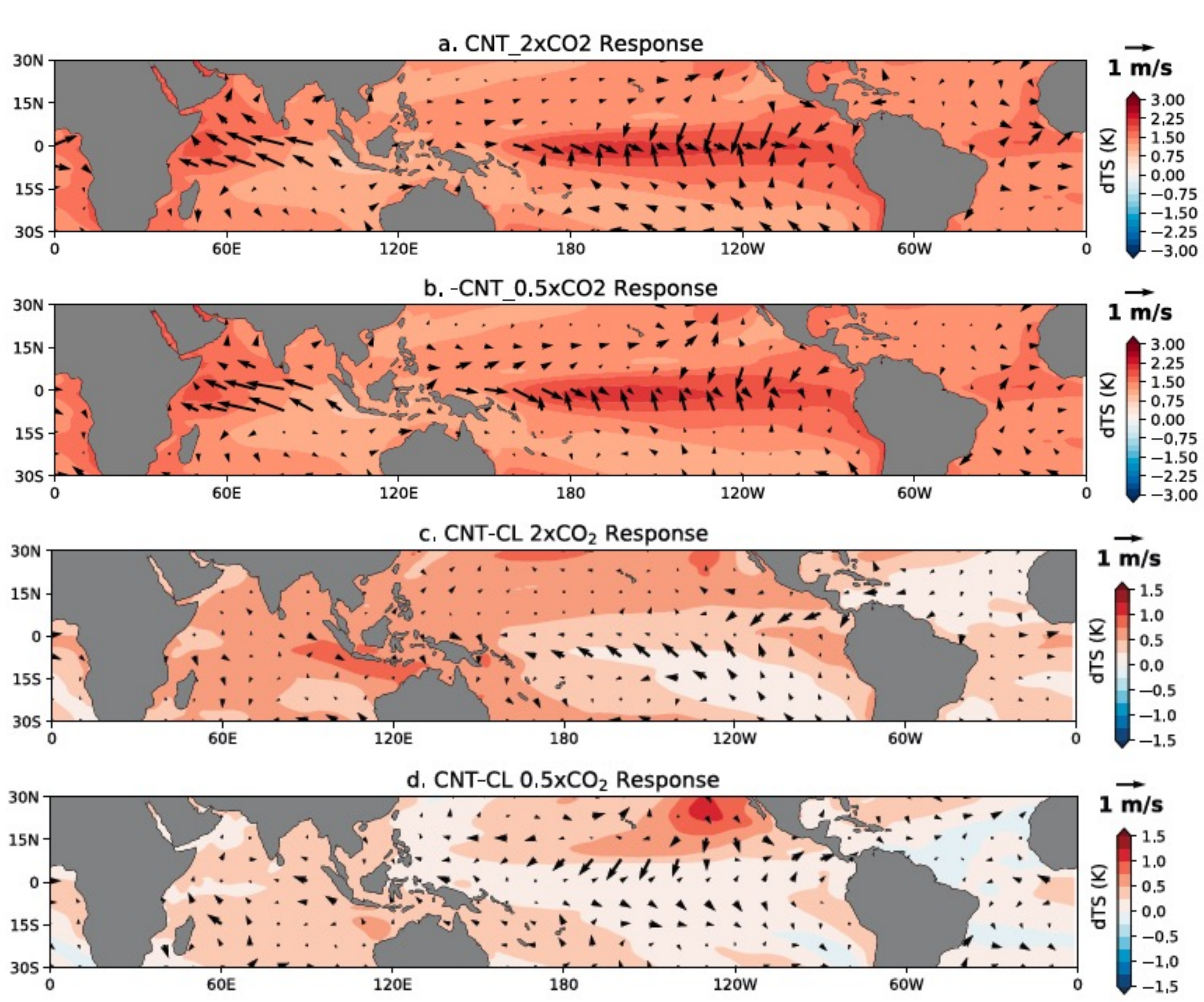

FIG. 3. Tropical ocean response over the last 50 years of the simulations (years 100–150): (a) CNT_2xCO2 sea surface temperature (contours) and surface wind (arrows); (b) as in (a), but for CNT_0.5xCO2. (c) 2xCO2 cloud influence; and (d) 0.5x CO2 cloud influence. Cloud influence is calculated by differencing simulations with and without cloud radiative feedbacks (CNT-CL). Note that in (c) and (d) dTS color contours are scaled at half of (a) and (b).

TABLE 1. Global surface temperature change, effective radiative forcing, and global radiative feedbacks. Radiative feedbacks are estimated using radiative kernels over the last 50 year of the simulations. Uncertainties in the global mean surface temperature response and ERF are based on 95% confidence intervals following Forster et al. (2016). Maximum uncertainties in global feedbacks due to sampling are 0.03 W m2 K-1 [see supporting information of Middlemas et al. (2020)].

Description	$CNT\_2\times CO_2$	$CNT\_0.5\times CO_2$	$CL\_2\times CO_2$	$CL\_0.5\times CO_2$
Global mean surface temperature response (K)	2.75 ± 0.03	−2.28 ± 0.03	2.19 ± 0.03	−1.85 ± 0.02
ERF_fSST ($W\ m^{-2}$)	3.82 ± 0.05	−3.44 ± 0.06	3.39 ± 0.03	−3.13 ± 0.04
ERF_reg ($W\ m^{-2}$)	3.84 ± 0.69	−3.26 ± 0.58	3.51 ± 0.17	−3.24 ± 0.36
Total feedback parameter ($W\ m^{-2}\ K^{-1}$)	−1.10	−1.19	−1.55	−1.66
Non-cloud feedbacks ($W\ m^{-2}\ K^{-1}$)	−1.55	−1.43	−1.55	−1.66
Planck feedback ($W\ m^{-2}\ K^{-1}$)	−3.19	−3.18	−3.18	−3.21
Surface albedo feedback ($W\ m^{-2}\ K^{-1}$)	0.54	0.56	0.59	0.53
Lapse rate feedback ($W\ m^{-2}\ K^{-1}$)	−0.42	−0.28	−0.28	−0.45
Water vapor feedback ($W\ m^{-2}\ K^{-1}$)	1.52	1.47	1.32	1.47
Cloud feedback ($W\ m^{-2}\ K^{-1}$)	0.45	0.24	0.00	0.00
Shortwave cloud feedback ($W\ m^{-2}\ K^{-1}$)	0.34	0.11	—	—
Longwave cloud feedback ($W\ m^{-2}\ K^{-1}$)	0.11	0.13	—	—

More details in our recently published paper: *Chalmers, J.,* Kay, J. E., *Middlemas, E. A.*, Maroon, E. A., and P. DiNezio (2022), Does disabling cloud radiative feedbacks change spatial patterns of surface greenhouse warming and cooling?, *Journal of Climate, 35:6, 1787-1807* DOI: 10.1175/JCLI-D-21-0391.1

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