Supporting Information for "Circus tents, convective thresholds and the non-linear climate response to tropical SSTs"

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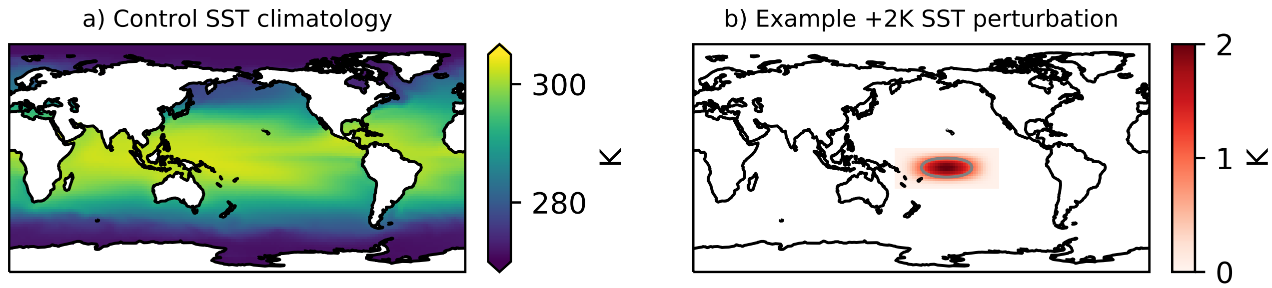

Figure S1. a) Annual-mean climatological SST in the control run. b) Representative example of a +2K ΔSST perturbation in the Central Pacific, with the half-amplitude (+1K) contour shown in grey.

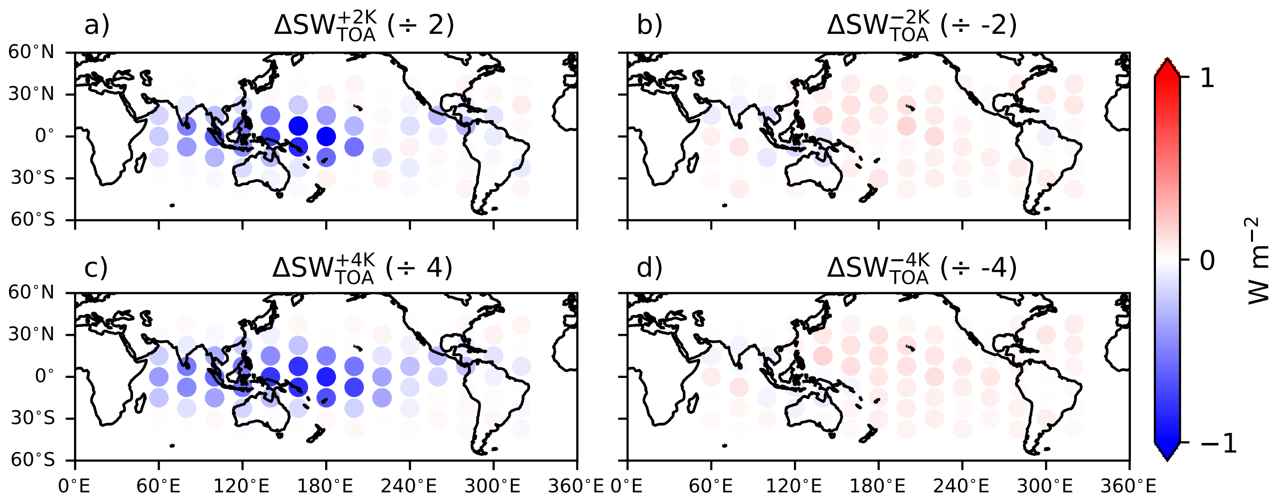

Figure S2. As in Figure 1 of the main text, but for SW TOA changes.

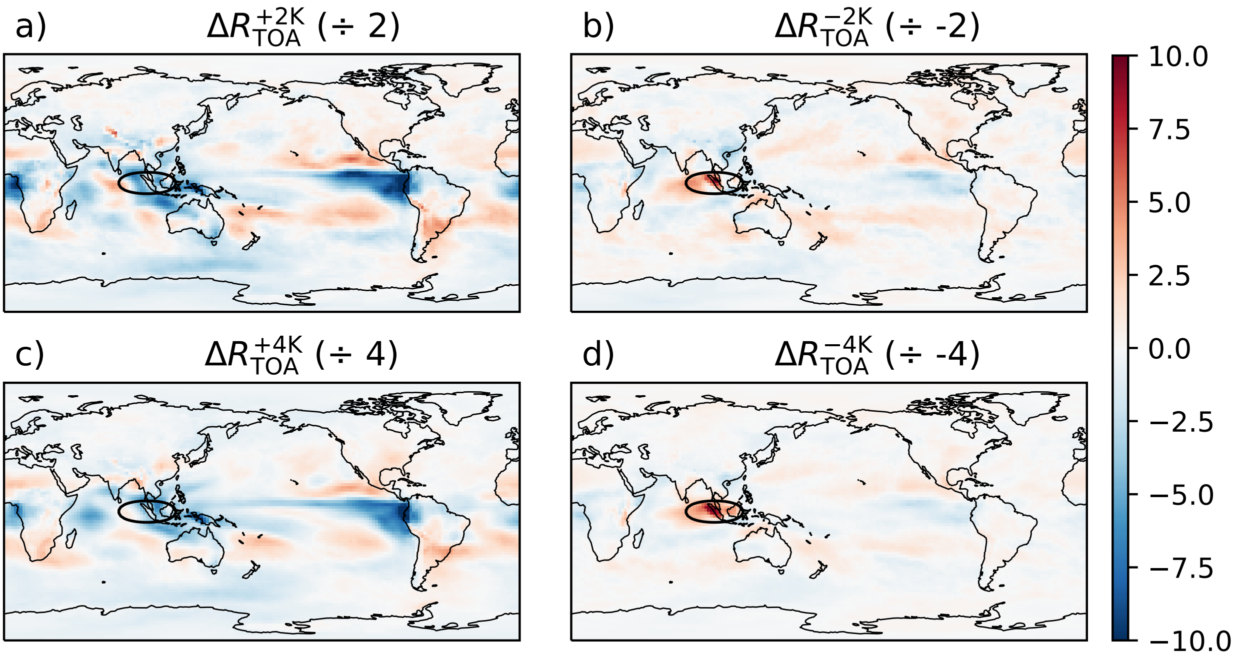

Figure S3. Spatial maps of the time-averaged ΔR_{TOA} for a patch in the Western Pacific warm pool (140E, 0N) for ΔSST = $\pm$2K divided by $\pm$2 (a,b) and ΔSST = $\pm$4K divided by $\pm$4 (c,d).

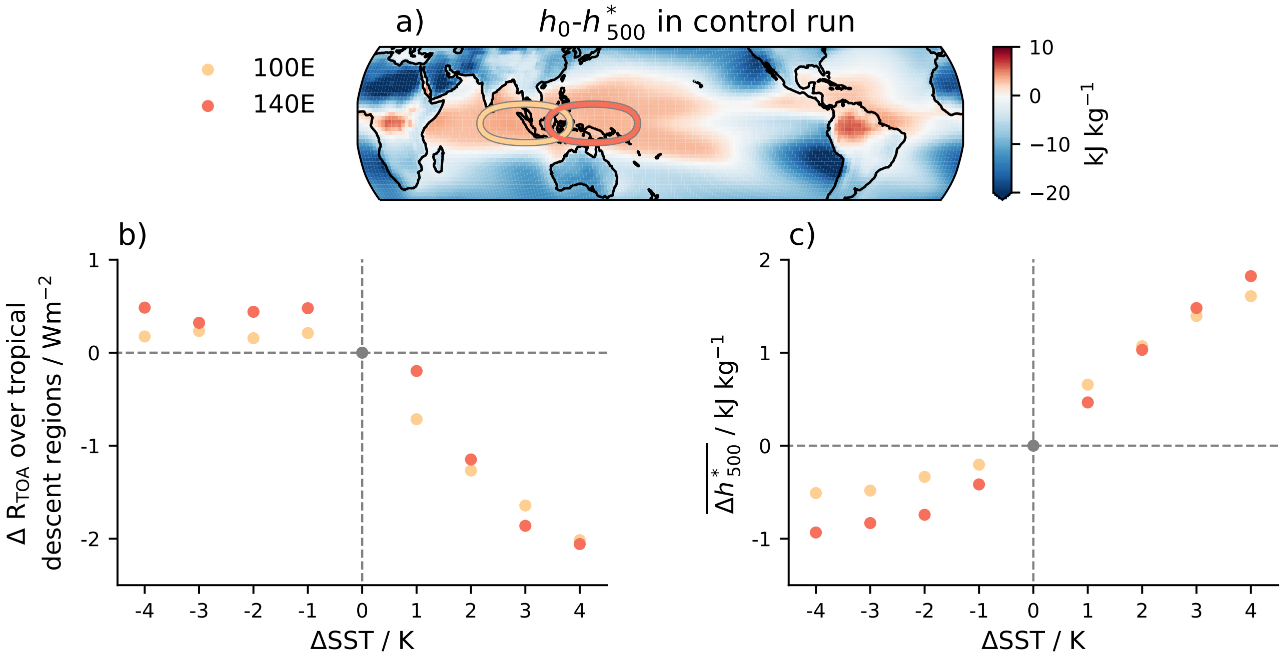

Figure S4. As in Figure 2 of the main text, but in panel b we plot the change in R_{TOA} averaged over tropical regions where $\omega_{500} > 0$ in the control run (to pick out low cloud subsidence regions). We also plot the two patches in deeply convective regions. This figure illustrates how the ΔR_{TOA} response to negative ΔSST anomalies in convective regions is linear over a very small region, but quickly saturates.

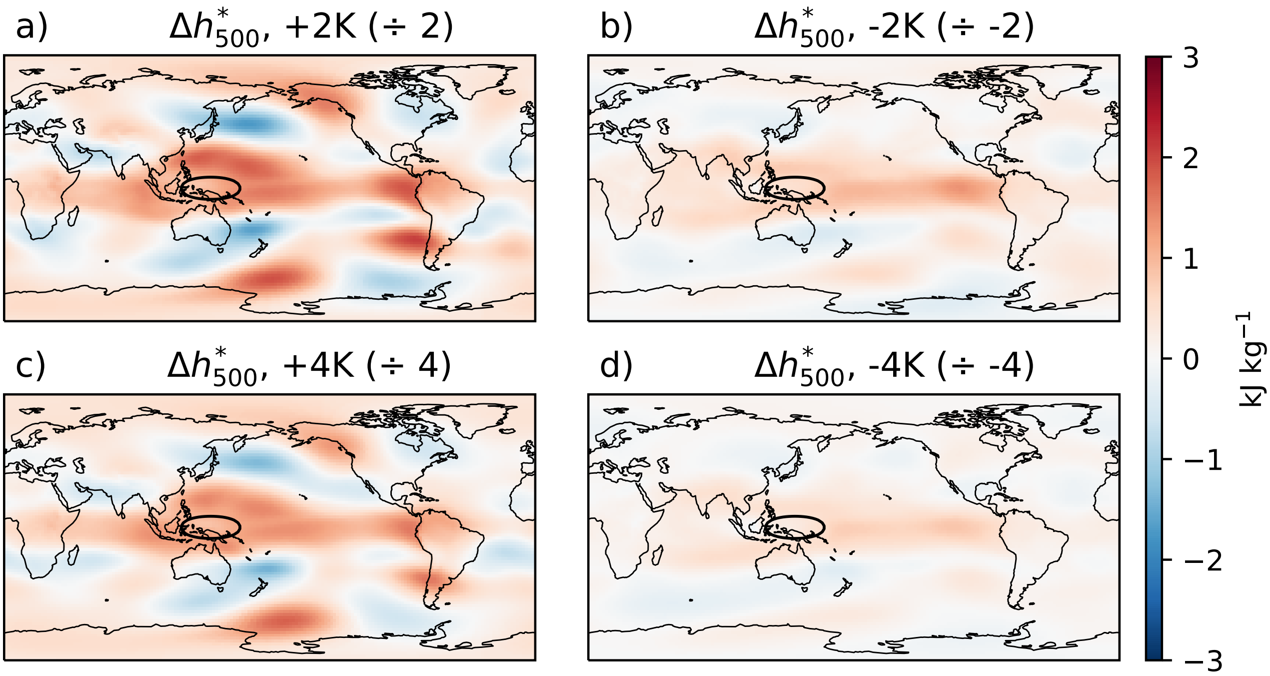

Figure S5. Spatial maps of the time-averaged Δh^*_{500} for a patch in the Western Pacific warm pool (140E, 0N) for ΔSST $= \pm$2K, divided by $\pm$2 (a,b) and ΔSST $= \pm$4K (c,d) divided by $\pm$4.

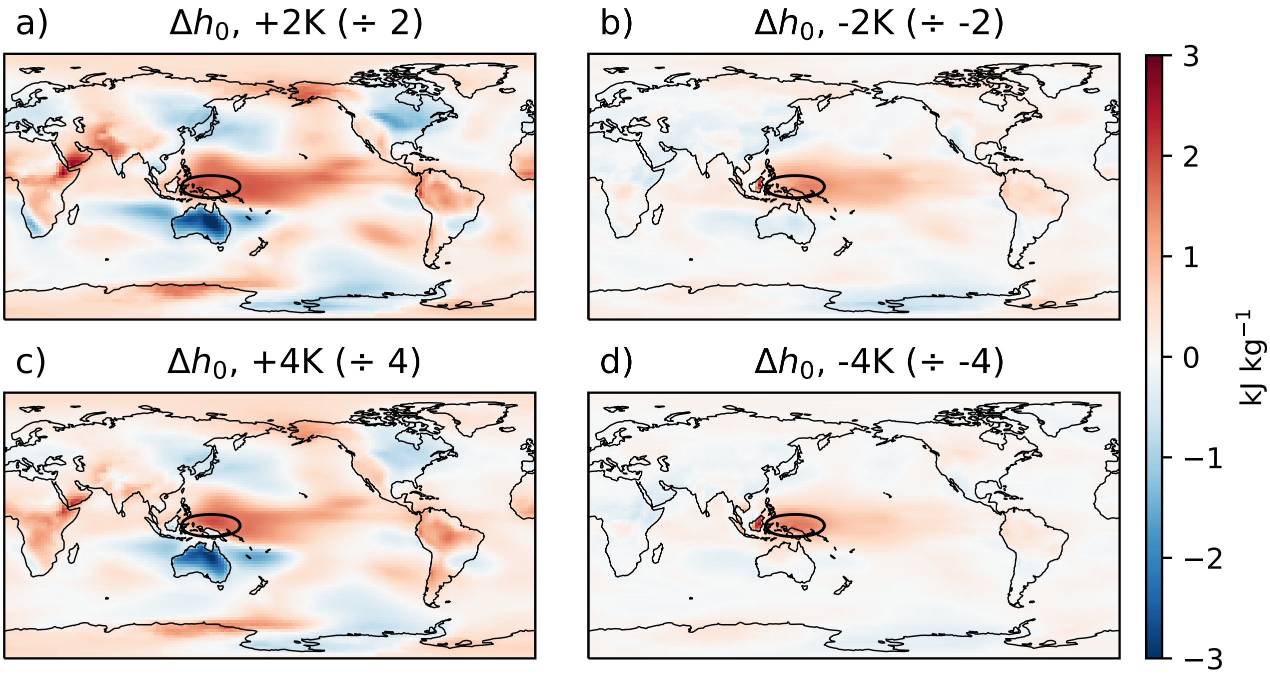

Figure S6. Spatial maps of the time-averaged Δh_0 for a patch in the Western Pacific warm pool (140E, 0N) for ΔSST $= \pm 2$K divided by ± 2 (a,b) and ΔSST $= \pm 4$K (c,d) divided by ± 4.

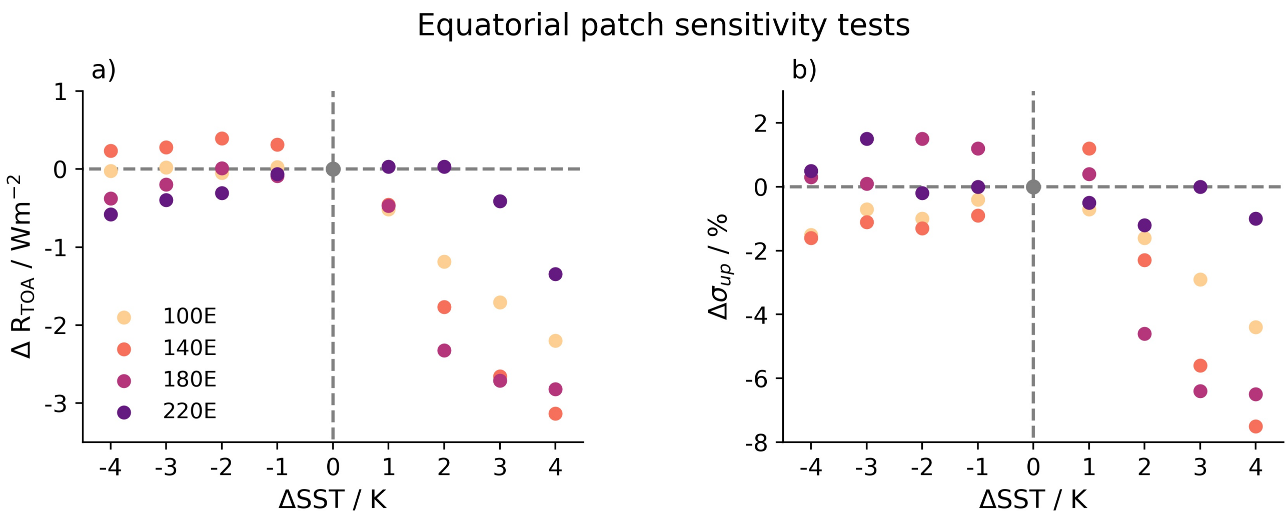

Figure S7. Panel (a) is identical to Fig. 2b of the main text. Panel (b) shows the corresponding changes in the fraction of gridpoints in the tropics (±30° latitude) which are characterized by time-mean ascent at 500hPa (i.e., with $\omega_{500} < 0$) for each of the experiments, denoted by $\Delta\sigma_{up}$. This plot shows that while we do see changes in the ascent fraction in response to warming, the changes in ascent fraction do not track the ΔR_{TOA} changes in a simple way. For example, the 220E patch results demonstrate an asymmetry and magnitude-dependence in the TOA response, but this does not translate into an asymmetry or magnitude-dependence in the ascent fraction, whose changes are small and near zero. Additionally, for the 140E patch, while the sign of the TOA change differs between warming/cooling (panel a), the ascent fraction decreases in almost all cases (panel b).

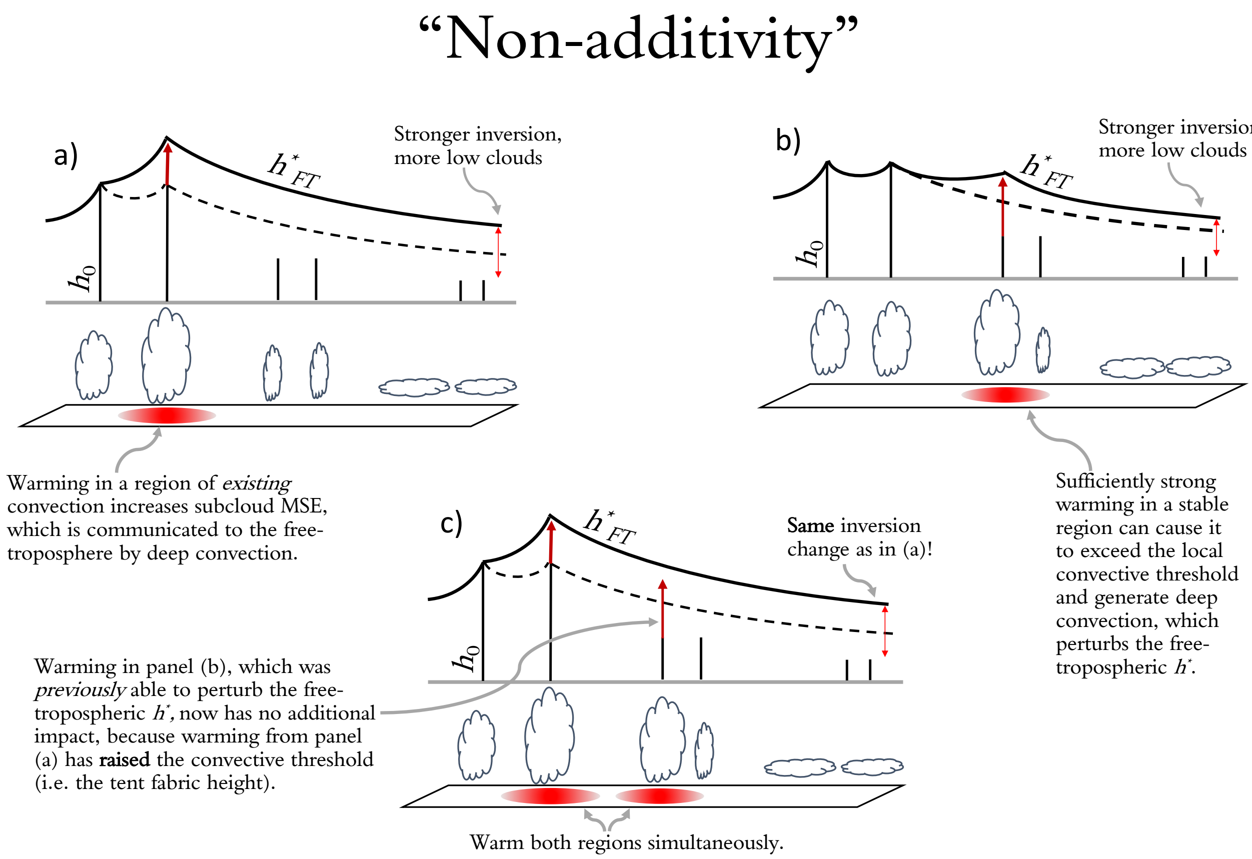

Figure S8. Schematic representation of how the ‘circus tent’ framework predicts the climate impact of isolated SST perturbations may not combine linearly. In panel (a) we show a similar sketch to Fig. 3b of the main text, with warming in a convective region being communicated across the free-troposphere and strengthening the inversion. In panel (b) we show a similar sketch to Fig. 3e of the main text, which depicts how warming can cause a region which was previously not deeply convecting to exceed the convective threshold and influence the free-tropospheric saturation MSE (h^*_{FT}). In panel (c) we show what would happen if we applied the warming perturbations from panels (a) and (b) simultaneously. In this framework, while the warming in panel (b) was originally sufficient to exceed the convective threshold and perturb the free-tropospheric h^*, is now insufficient because warming in a different region has raised the threshold subcloud MSE required for deep convection.

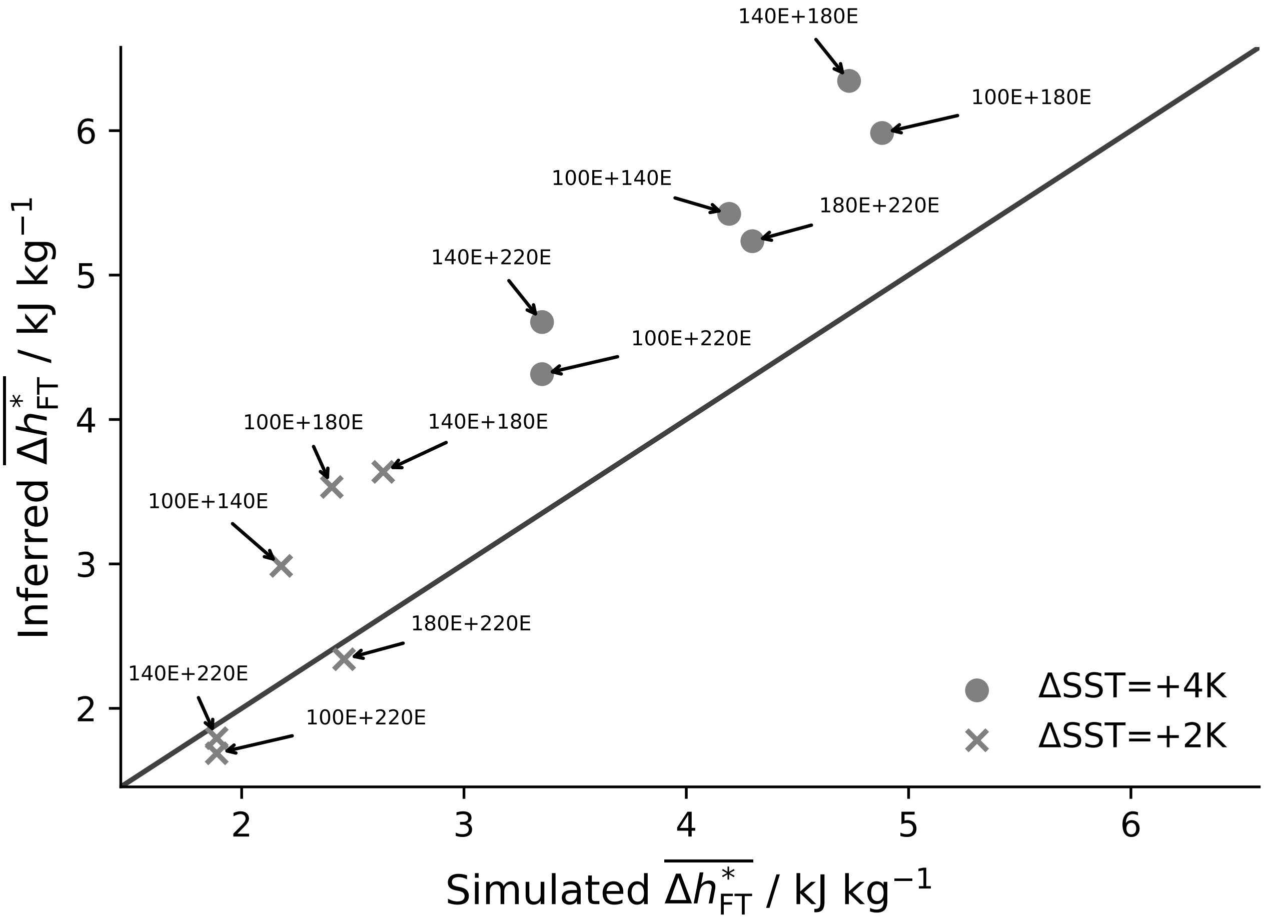

Figure S9. Results from "two-patch" experiments using the four equatorial patch locations highlighted in Fig. 2 of the main text. Plotted are the changes in tropically-averaged saturation moist static energy of the free-troposphere ($\overline{\Delta h^*_{\mathrm{FT}}}$) from simulations with two patches imposed simultaneously (x-axis), and the "inferred" values of $\overline{\Delta h^*_{\mathrm{FT}}}$ obtained by adding the changes from two simulations with each patch imposed separately (y-axis). The longitudes of the two patches are marked in each case (latitude is 0° in all experiments), and the magnitude of the patch experiments is either +2K (crosses) or +4K (circles). The one-to-one line is shown. Note that in this figure, h^*_{FT} is defined using a bulk average of h^* between 700-300 hPa, as opposed to the 500hPa level as used in the main text.