

Supplementary Information

American orographic control of simulated Pacific rainfall and warming patterns

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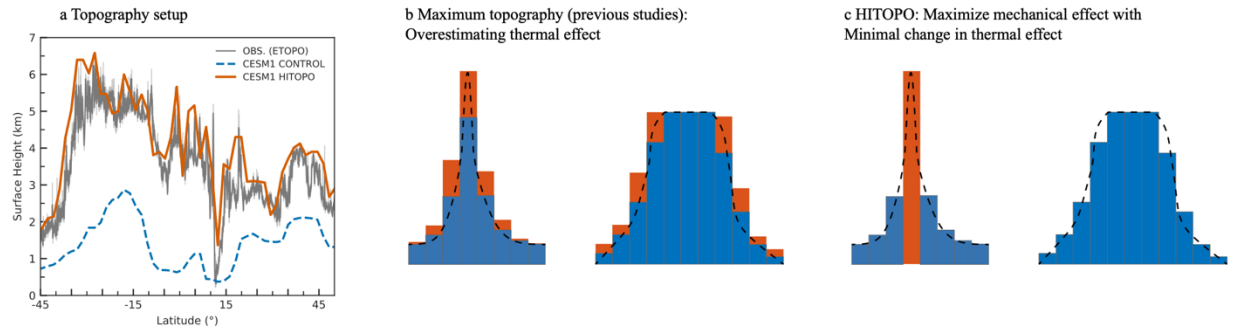
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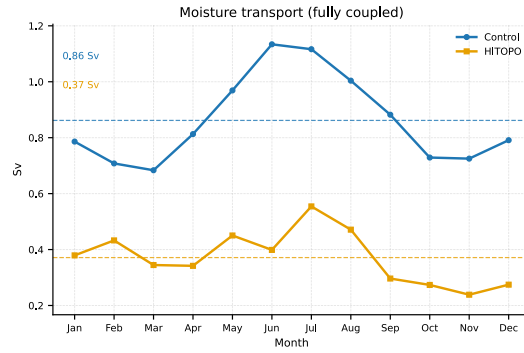
This file includes:

Supplementary Figures 1 to 5

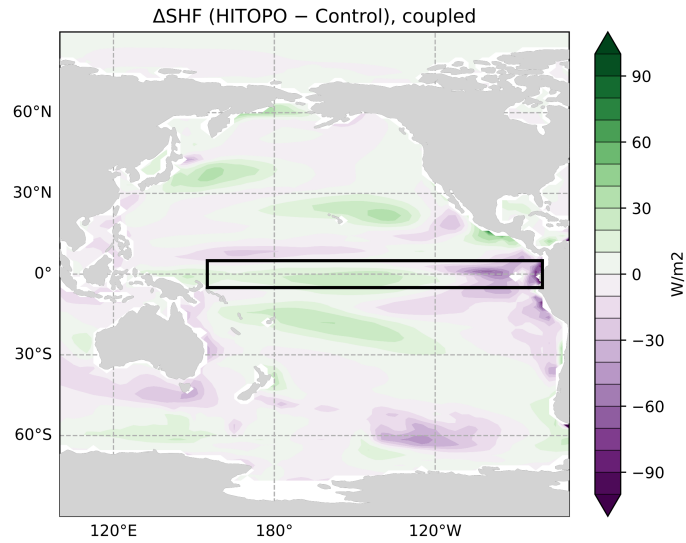
Supplementary Figures



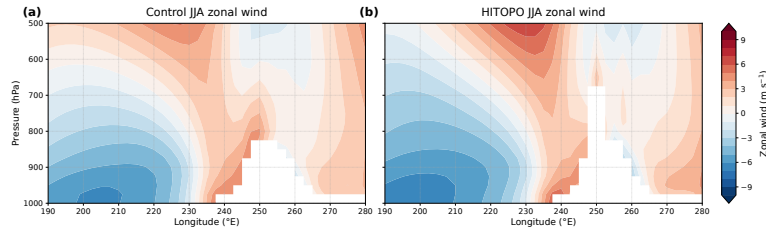
Supplementary Figure 1. Topographic configurations used in CESM1.2. a, Surface height maxima (km) as a function of latitude for the American cordillera. The grey line shows observational topography from ETOPO, the dashed blue line shows CESM1 Control topography, and the solid orange line shows CESM1 HITOPO topography. The Control configuration substantially smooths the narrow mountain ranges relative to observations, whereas HITOPO raises the model grid cells corresponding to the existing mountain crests toward observed elevations. b, Schematic of the topographic approach commonly used in previous studies, in which the maximum observed height within a model grid cell is applied, potentially introducing an additional thermal effect. c, Schematic of the HITOPO strategy, in which the grid cell containing the maximum default model elevation at each latitude is raised to the corresponding observed elevation. This enhances the mechanical influence of narrow mountain ranges while minimizing changes to their broad thermal effect.



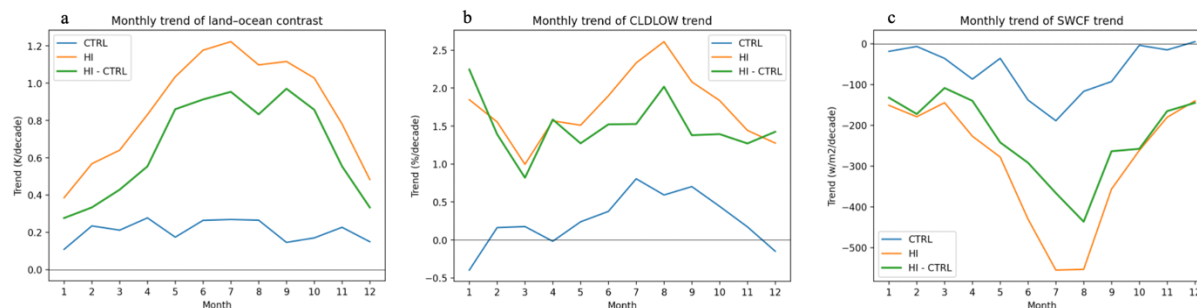
Supplementary Figure 2. Monthly vertically integrated moisture transport across the transect shown in Fig. 2a in the fully coupled simulations. Blue and orange lines indicate the Control and HITOPO simulations, respectively. Positive values indicate transport toward the Pacific, and horizontal dashed lines denote the annual-mean transport in each simulation. HITOPO reduces moisture transport into the Pacific relative to the Control, consistent with a stronger mechanical influence of topography under higher orography.



Supplementary Figure 3. Change in surface heat flux (SHF; HITOPO – Control) in the fully coupled simulations. HITOPO shows reduced ocean heat uptake over the eastern equatorial Pacific. This suggests that atmospheric surface heat-flux changes act primarily as a damping response, whereas the fundamental driver of the surface warming is a change in ocean dynamics.



Supplementary Figure 4. Low-level zonal wind across western North America in the historical simulations. Shown are 1979–2013 JJA ensemble-mean zonal wind sections for a, Control and b, HITOPO, averaged over $32.5^{\circ}\text{N} \pm 1^{\circ}$. Zonal wind is interpolated from CESM hybrid sigma levels to pressure levels with no below-surface extrapolation; white regions indicate pressure levels below the model surface. The higher HITOPO topography raises the below-ground boundary near 250°E from the lower troposphere toward about 700 hPa, closing much of the low-level pathway across the western North American mountain region. This mechanical blocking provides a physical background for the cooler, more stable, and cloudier northeastern Pacific lower-tropospheric response diagnosed in the main text.



Supplementary Figure 5. Seasonal diagnosis of the monthly trends in land-ocean thermal contrast, low cloud, and shortwave cloud radiative effect. Shown are monthly trends in a, land-ocean thermal contrast, defined as the North American land-box (250°E-280°E, 15°N-40°N) surface temperature minus the northeastern Pacific ocean-box (200°E-235°E, 15°N-40°N) surface temperature; b, low-cloud amount over the eastern Pacific ocean box; and c, shortwave cloud forcing (SWCF) over the same ocean region. Blue and orange lines indicate the Control and HITOPO simulations, respectively, and green lines indicate their difference (HITOPO – Control). HITOPO exhibits a substantially larger positive trend in land-ocean thermal contrast during late summer, accompanied by a stronger increase in low cloud and a more negative SWCF trend over the northeastern Pacific, consistent with enhanced cloud-induced shortwave cooling in that season.

