Supporting Information for "Shallow Thermocline Bias in the Southern Tropical Pacific in CMIP5/6 Models"

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Contents

A1	Assessment of the inherent uncertainty in our estimations of thermocline depth, in the Ztc and Z20 indices	3
S1	Seasonal cycle of tropical south Pacific thermocline depth (Ztc) and 20°C isotherm depth (Z20)	4
S2	Zonally varying tropical Pacific Z20 and local vertical potential temperature gradient profiles in the tropical central and eastern Pacific	5
S3	Global and Pacific mean vertical potential temperature gradient at the depth of the thermocline	6
S4	Zonally varying Ztc in tropical north Pacific and equatorial Pacific regions in the partitioned model groups and reanalyses	7
S5	Pacific zonal mean zonal Ekman mass transport in the partitioned model groups and reanalyses	8
S6	Meridionally varying Ztc and Z20 in the Eastern and Western Pacific in the partitioned model groups and reanalyses	9
T1	CMIP5 model names, affiliations, and partitioning	10
T2	CMIP6 model names, affiliations, and partitioning	11
References		12

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A1: Uncertainty in thermocline depth estimation

The uncertainty in the calculated depth of Ztc is proportional to the vertical grid spacing. The smoothing procedure we use does not mathematically reduce this uncertainty. To minimize errors, vertical operations were performed on the original vertical grids, which are dataset-speci c. Thus, the uncertainty is not uniform between the compared datasets. Since the vertical resolution of ocean grids decreases with depth, the uncertainty is greater the deeper the thermocline is found, with typical grid increments in the upper 100 meters no greater than 10 meters, doubling in the 100-200 meter depth range, and reaching as high as 100 meters in the 200-300 meter range (the maximal thermocline depth in the tropics) for the HadCM3 model. Great uncertainty, and noisy signals may result, in particular in regions of thermocline deepening and results must be interpreted accordingly. Moreover, for given potential temperature uncertainty ϵ, the uncertainty in the gradient is double that.

Z20, computed through linear interpolation of the potential temperature, is inherently easier to estimate than Ztc and will have smaller errors, assuming, as is reasonable, that temperature inversions are rare. Considering the realistic constraint that the temperature does not drop faster than 0.5°C per meter, the potential deviation from the interpolated linear slope is constrained, and the uncertainty in Z20 is e ectively smaller by up to a few tens of meters than the vertical increment at Z20.

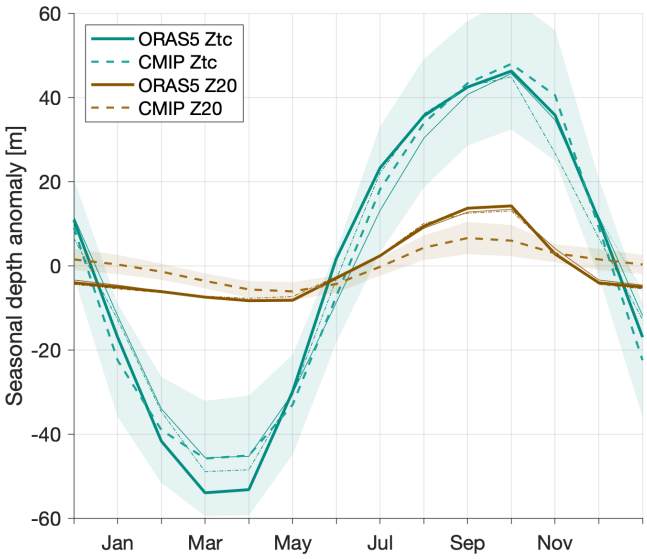

Figure S1. The seasonal anomaly of thermocline depth (Ztc, turquoise) and of 20 C isotherm depth (Z20, brown) averaged over 10–20 S and 150–285 E. Datasets denoted as in Fig. 1. Individual models have a biased seasonal cycle in Ztc, but no seasonal bias is robust across the ensemble in the southern hemisphere. Z20 seasonal variations are very small relative to Ztc, and appear to be smaller in models than observations. The apparent bias in the Z20 seasonal amplitude is only up to 7 meters, whereas the vertical grid increment, at the depth of Z20 in this region (200 meters) is between 10–60 meters (depending on the dataset), casting doubt on how robust this bias really is.

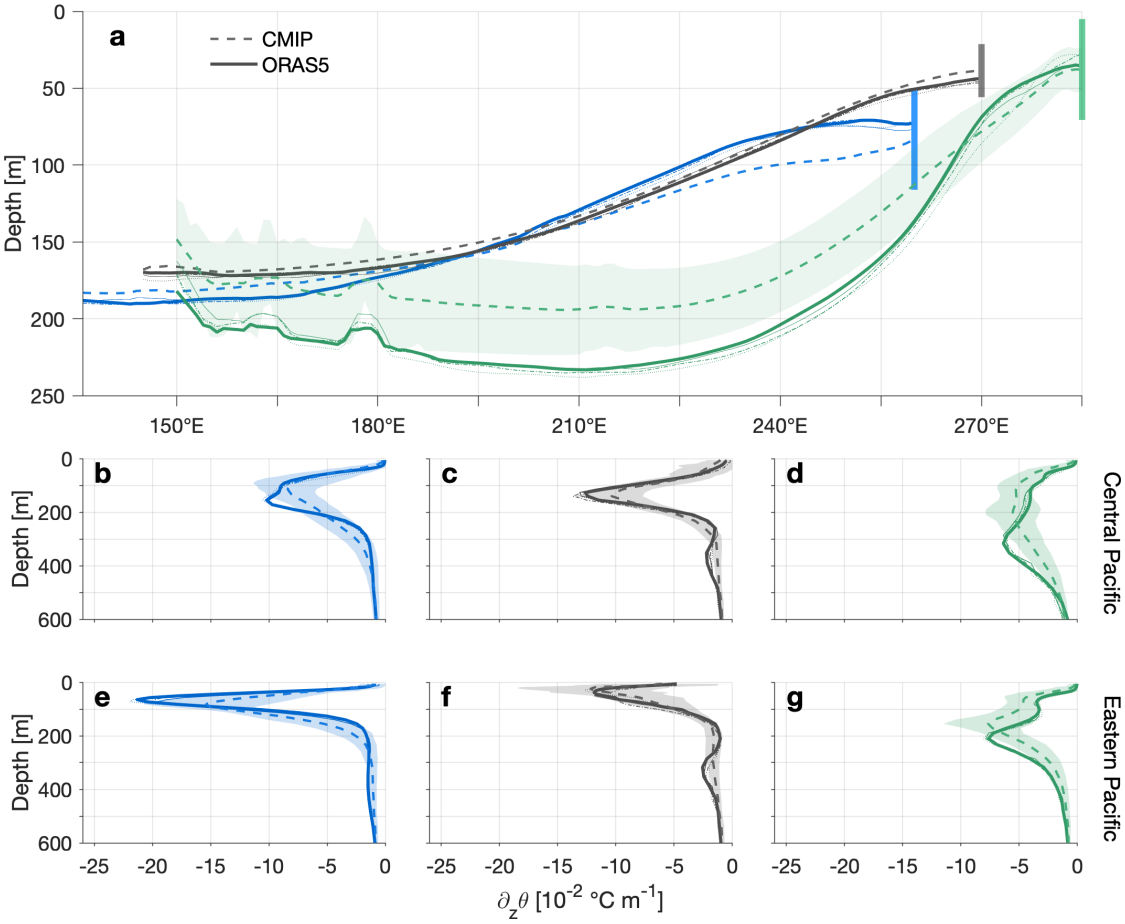

Figure S2. (**a**) As in Fig. 2a, but for Z20. (**b**–**g**) As in Fig. 2b–d, but taken at: (**b**,**e**) 15.5 N, (**d**,**g**) 15.5 S, and (**c**,**f**) 0.5 S–0.5 N; averaged in (**b**–**d**) in the Central Pacific (205–215 E), and in (**e**–**g**) in the Eastern Pacific (250–260 E).

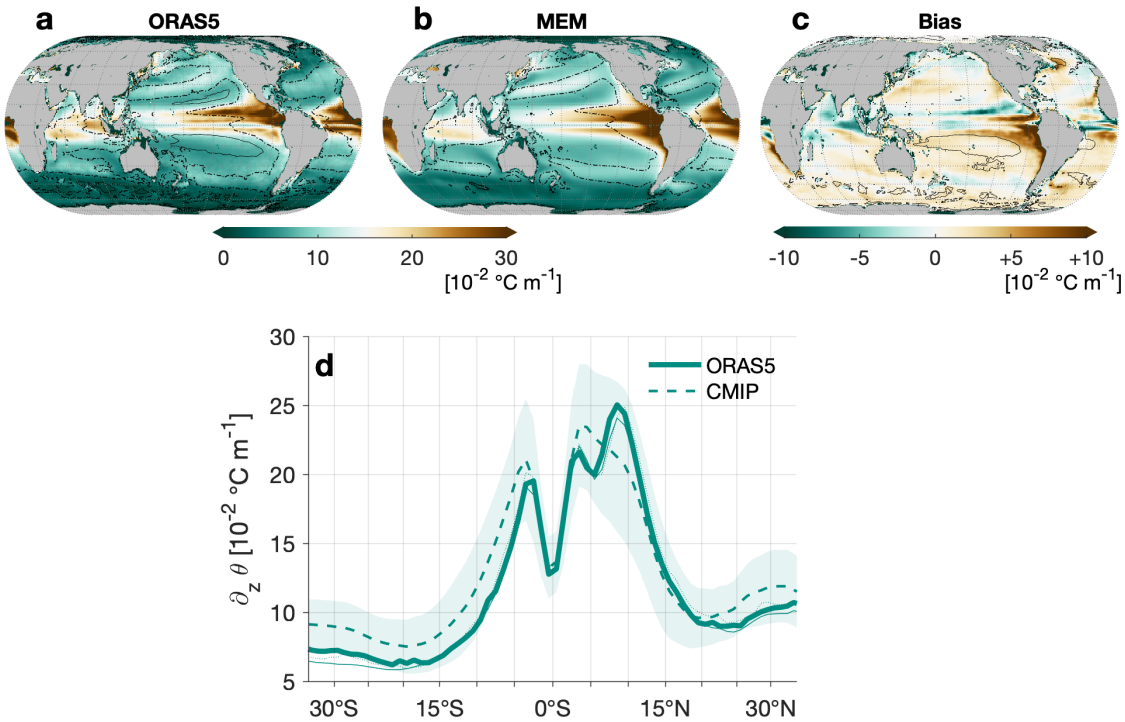

Figure S3. Annual mean vertical potential temperature gradient at the depth of the thermocline ($@_z\ j_{z=\mathrm{Ztc}}$, color contours) and thermocline depth (Ztc, line contours) in (**a**) ORAS5, (**b**) CMIP model ensemble mean (MEM), and (**c**) MEM bias. Solid (dash-dotted) Ztc contours indicate values greater than 200 (100) meters in panels (a,b) and 50 meters in panel (c). (**d**) $@_z\ j_{z=\mathrm{Ztc}}$ averaged in the Pacific (160-260 E). Datasets denoted as in Fig. 1d.

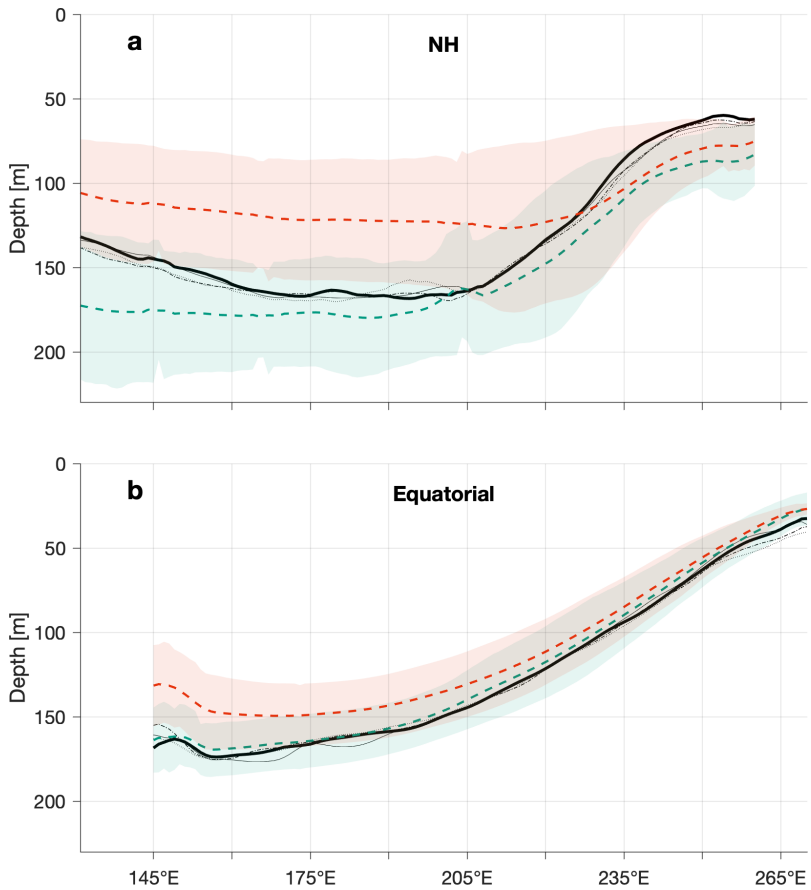

Figure S4. As in Fig. 4a, but for (**a**) the northern hemisphere and (**b**) equatorial sections defined in Fig. 2.