

Impacts of Horizontal Resolution on the Tropical Pacific Climatology in GFDL's CM2.x Models

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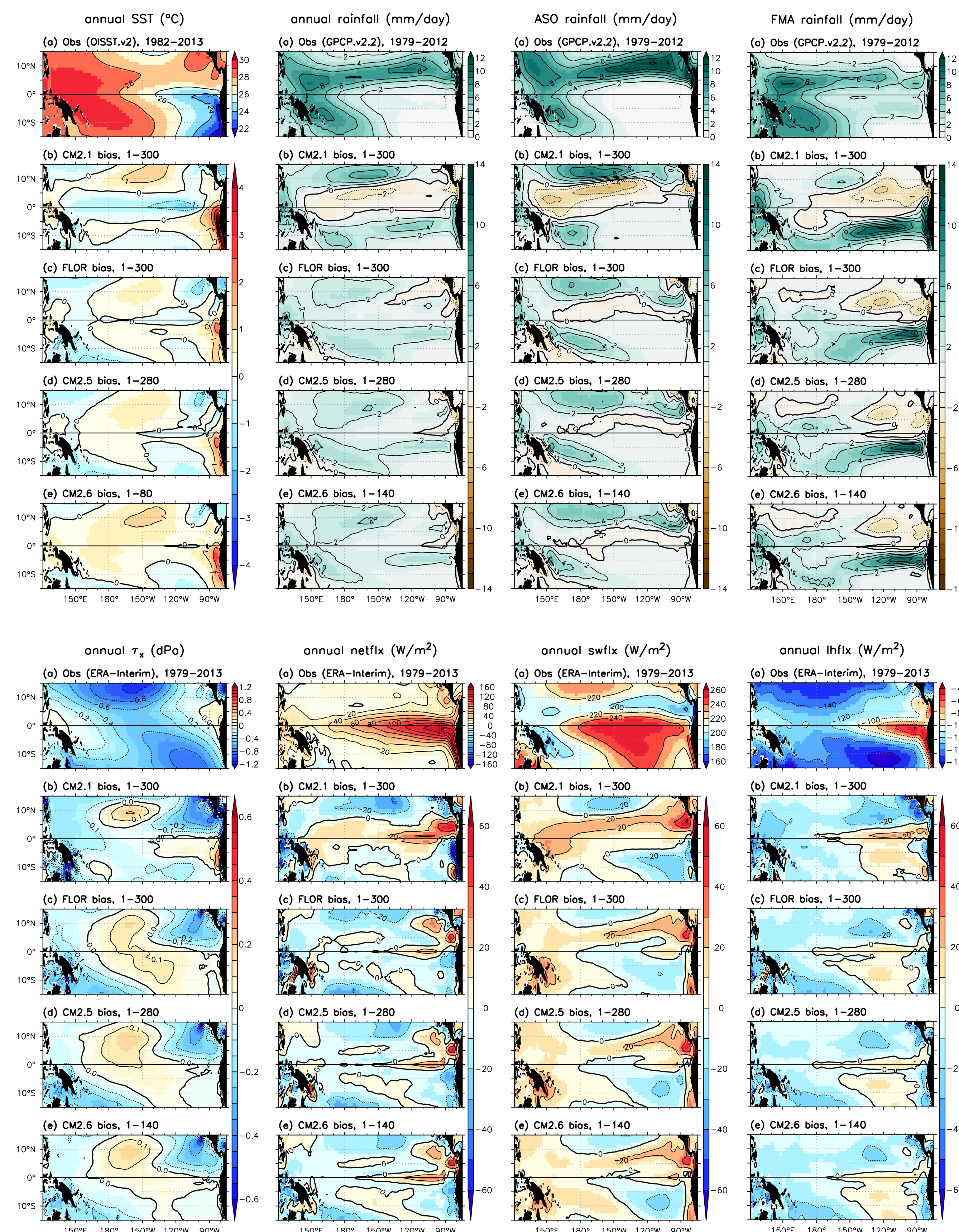
1. Introduction

We examine the climatology of the tropical Pacific in 1990 control simulations from GFDL's global coupled GCMs, in which horizontal resolution of the atmosphere & ocean have been progressively refined.

2. SST, Rainfall, and Surface Fluxes

CM2.1's climate biases included strong ocean-dynamical cooling and cold SST near the equator; weak ocean-dynamical cooling and warm SST beneath the convergence zones and near Peru; a strong and poleward-shifted ITCZ & SPCZ, a dry equator, and excessive rain near Peru; an unrealistic “southern ITCZ” during boreal spring; strong trades in the west & northeast tropical Pacific; and weak southeasterly winds in the eastern equatorial Pacific.

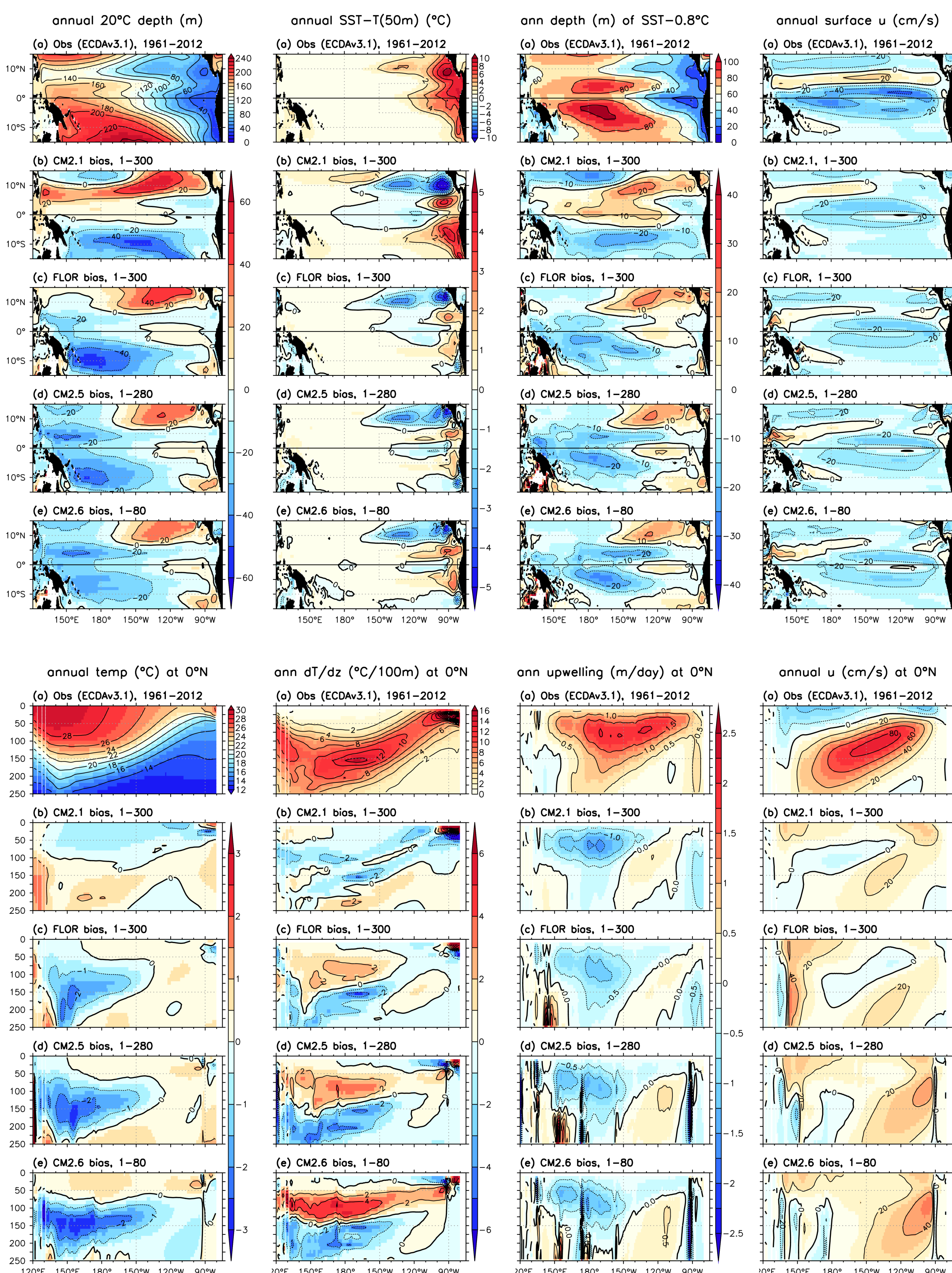
Atmospheric grid refinement (CM2.1→FLOR) greatly reduces most of these biases – though it also overly strengthens the trade winds, evaporation, and cyclonic wind stress curl in the southwestern tropical Pacific. Oceanic refinement (FLOR→CM2.6) slightly strengthens the ocean-dynamical cooling of SST almost everywhere except near Peru, and slightly reduces the equatorial cold bias and double-ITCZ – but worsens the warm SST biases and ITCZ/SPCZ rainfall biases.



3. Upper-Ocean Temperature and Currents

CM2.1's thermocline was too deep at 8-10°N, weakening its North Equatorial Current & Countercurrent. At the equator, CM2.1's thermocline and Equatorial Undercurrent (EUC) were too diffuse, and the zonal slope of the thermocline was slightly too strong, contributing to excessive near-surface stratification near South America. CM2.1's mixed layer was too deep in the western and central equatorial Pacific, too shallow along 8-10°S, and too flat along 12°N. CM2.1 also had weak upwelling in the western equatorial Pacific, a weak South Equatorial Current, and very little meridional shear between the zonal surface currents north of the equator.

Atmospheric refinement weakens the equatorial trade winds and flattens the equatorial thermocline in FLOR, reducing the stratification near South America. Despite its weaker equatorial trade winds, FLOR's equatorial upwelling actually strengthens slightly relative to CM2.1. Both atmospheric & oceanic refinement improve tropical Pacific thermocline depths off-equator, but they also excessively shoal the thermocline & mixed layer in the western equatorial Pacific, and do little to improve the EUC and surface currents. Oceanic refinement causes the EUC to terminate too far to the east, and also tightens and intensifies the equatorial thermocline, leading to excessive stratification at 50-100m depths. This suggests that in the eddying regimes permitted by higher resolution, the ocean component's physical parameterizations may need to be revisited.

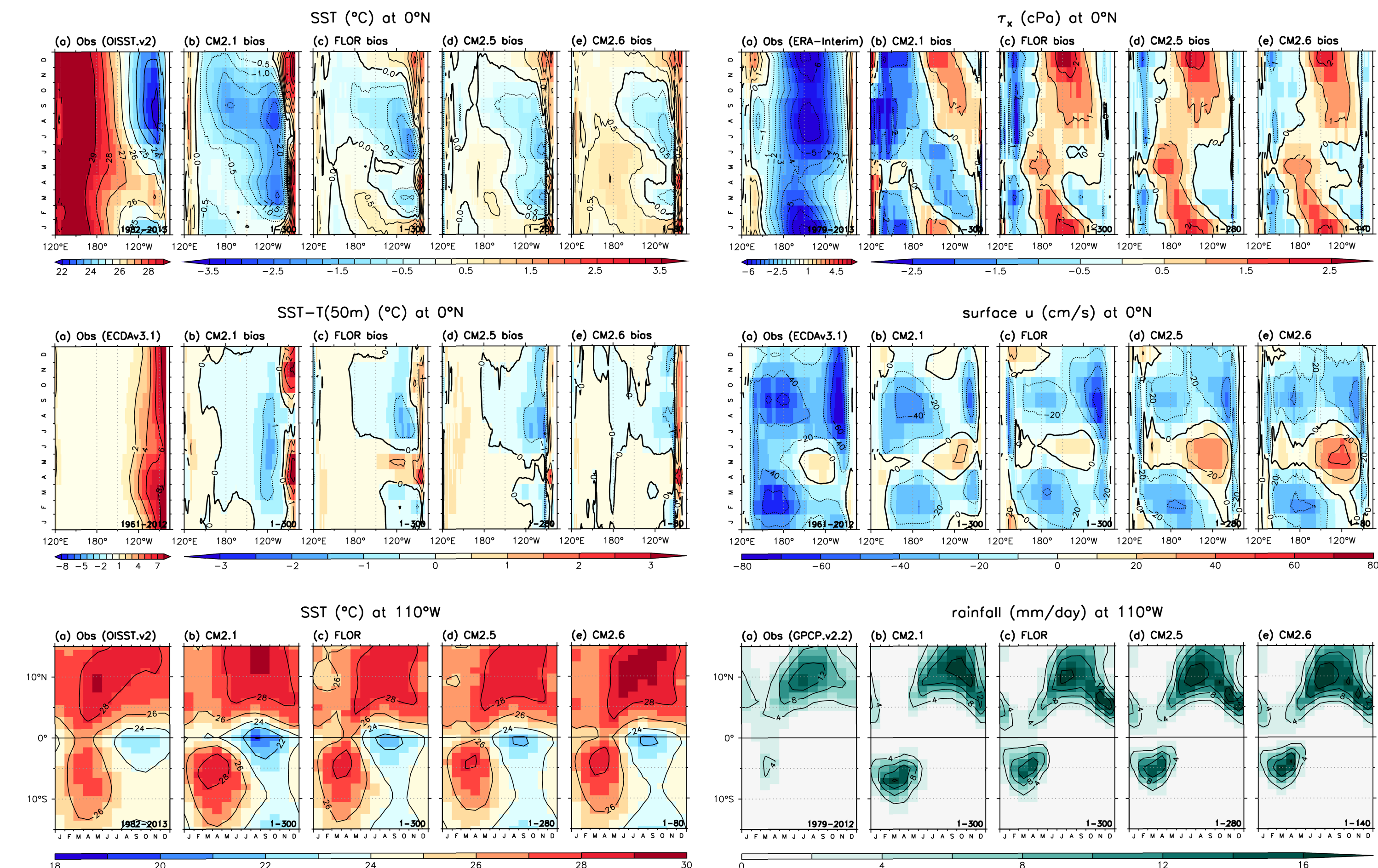


4. Seasonal Cycle

CM2.1's equatorial cold SST bias was strongest during the Aug-Sep cold season, while east of the Galápagos a warm bias is evident all year. Atmospheric refinement greatly reduces these biases – although in the east Pacific, FLOR is still too cold during Jun-Oct, and slightly too warm during Dec-Feb. Oceanic refinement further reduces the equatorial cold SST biases, but worsens the warm biases in the western/central Pacific during Dec-Aug.

CM2.1's strong trade winds in the western Pacific strengthened the slope of the equatorial thermocline, boosting the surface stratification near South America almost all year. Farther west at 120°W, the stratification was actually too weak during Mar-Sep in CM2.1, associated with the surface cold bias and diffuse thermocline. The seasonality of the trade winds was also too weak in CM2.1, with westerly biases during Aug-Jan and easterly biases during Feb-Jul. Atmospheric refinement weakens the equatorial trade winds, generally improving them except for a weak-tradewind bias in the central Pacific during Sep-Feb; this in turn reduces the stratification biases in the eastern equatorial Pacific, except in Apr. Oceanic refinement yields additional small improvements in the equatorial winds and east Pacific ocean stratification. CM2.1's equatorial easterly surface currents were too weak year-round, and atmospheric & oceanic refinement do little to improve these currents. In fact, ocean refinement leads to an excessive westerly surge of the surface currents in the east Pacific during Apr-Jun, associated with the seasonal shoaling of the EUC.

Along 110°W, CM2.1 exhibited a Feb-May reversal of the meridional SST gradient and meridional winds, in tandem with the development of a strong southern ITCZ. Atmospheric refinement shifts the southern ITCZ equatorward (closer to its observed position), but this southern ITCZ bias and its impacts on the climatology remain too strong. Oceanic refinement yields only modest improvements in these biases.



Current work is directed at understanding the causes and consequences of the remaining biases in these models, using initialized predictions, flux adjustment, and diagnosis of the atmospheric and oceanic budgets of heat, momentum, and moisture.

Related Work

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