Heat Budget Diagnosis of the Equatorial Pacific Cold Tongue in the GFDL FLOR Global Coupled GCM

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We examine the upper-ocean heat budget in GFDL's FLOR global coupled GCM, using an exact mixed layer heat budget diagnosed directly from the FLOR model at hourly time scales. The heat budget framework is applied to evaluate FLOR against observations, with an eye toward improving simulations, reanalyses, observations, and understanding of tropical Pacific climate.

Beginning with an exact hourly heat budget for a layer of time-varying thickness, we examine the heat budgets of two adjacent vertical layers: (1) a surface mixed layer (THIN-ML) whose temperature is highly correlated with SST, and for which the air-sea heat flux is largely balanced by submonthly-scale advection and vertical diffusion of heat across the THIN-ML base, and (2) an underlying advective-diffusive layer (ADL), in which advection by monthly-scale currents nearly balances the submonthly advective and vertical diffusive fluxes received from the THIN-ML. Together the THIN-ML and ADL comprise a thicker advective layer (THICK-ML), for which the net surface heat flux is mainly balanced by monthly-scale advective fluxes, with internal redistribution of heat by submonthly advection and diffusion. For all three layers, the annual-mean heat budget is well approximated by the corresponding budget for a stationary (but spatially-varying) layer with the same time-mean depth; this simplifies the analysis by eliminating the need to consider entrainment terms arising from changing layer thicknesses.

Analysis of FLOR indicates that in the ECT, the ML budget terms are most intense during boreal summer and autumn of La Nina years, when strong cooling from vertical and meridional monthly advection and vertical diffusion are countered by strong heating from surface fluxes and submonthly meridional and vertical advection. The surface heat flux and vertical diffusion also have strong diurnal cycles, with daytime solar surface heating being diffused downward at night. Because submonthly variations in thermal stratification and vertical diffusivity are anticorrelated, the vertical diffusive transport is much weaker than what would be inferred from the monthly-mean diffusivity and stratification. Compared to observations, FLOR shows downward-displaced monthly vertical advective cooling, and weaker zonal advective warming due to its weaker equatorial undercurrent. Using surface flux adjustments to correct the climatological SST and wind stress improves FLOR's surface fields, but overly deepens the equatorial thermocline and undercurrent, weakening the vertical advective cooling of the ECT ML. This suggests that FLOR near the equator has excessive downward diffusion of heat -- compensated by excessive advective cooling in the ADL -- and motivates further attention to FLOR's vertical diffusion parameterization.