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Diagnostic Model of the Three-Dimensional Circulation in the Upper Equatorial Pacific Ocean

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ABSTRACT

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To investigate the processes that maintain the large-scale, annual-average thermal structure of the equatorial Pacific, the three-dimensional ocean circulation for a large area is determined from a diagnostic model applied to repeated, meridional hydrographic sections along 150°W and 11O°W from 5°N to 5°S. Geostrophic balances are used to determine velocity profiles from 0 to 500 db across the boundaries of the region: zonal velocities across 150°W and 110°W at approximately 1° -lattitude intervals from 5°N to 5°S and meridional velocities across 5°N and 5°S averaged over the zonal distance between 150°W and 110°W. Poleward wind-driven flows across 5°N and 5°S based on climatological zonal wind stress are added to the geostrophic velocities in the mixed layers. To achieve overall mass conservation, the reference dynamic height field at 500 db is adjusted at four of the 21 stations by about 1 dyn cm. Horizontal nondivergence is used to determine meridional velocities between 0.75° and 5° latitudes. Three-dimensional nondivergence is used between 0.75° N and 0.75°S to determine a vertical profile of vertical velocity at the equator. The resulting model circulation, which is generally consistent with previous interpretations, is then analyzed to estimate the heat budget for the region and the zonal momentum balance at the equator.

The model circulation requires an annual-average hem gain from the atmosphere of 57 W m^{-2}, which is consistent with existing estimates of air-sea heat exchange from bulk formula. The beat gain converts about 35 × 10^6 m^3 s^{-1} of water flowing into the region with temperatures between 19 and 26°C into an equal amount of 27 to 28°C water flowing out of the region. Little of the heat gain warms the locally upwelled waters at the equator, however, rather, about half acts to increase the temperature of the westward flowing South Equatorial Current as it traverses the region and about half warms the poleward flow of water away from the equator. There is large upwelling at the

equator extending down to 180 db with a maximum upward velocity of 2.9×10^{-3} cm s^{-1} and upward transport of 22×10^{6} m^{3} 2^{-1} across the 62.5 db surface. Because this upwelling occurs in conjunction with the eastward flow of the Equatorial Undercurrent which shallows to the east, the flow is predominantly along isotherms and the maximum cross-isotherm transport is only 7×10^{6} m^{3} 2^{-1} across the 23°C isotherm. Thus, the eastward and upward flow acts to decrease the surface water temperature to the east. In combination with the atmospheric warming of the poleward surface flow away from the equator, this eastward and upward flow along isotherms creates the Cold Tongue in the equatorial Pacific, which is characterized by minimum surface temperature at the equator in any meridional section and colder surface waters to the east.

For the zonal momentum balance at the equator, the vertically integrated zonal pressure gradient balances about 80 percent of the climatological westward wind stress. Eastward and vertical advection of zonal momentum each acts to balance about 20 percent of the wind stress. The sum of eastward and vertical advection indicates a deceleration of the eastward flow at all depths above 300 db. The inferred eastward stress profile suggests that eddy mixing of zonal momentum extends down to at least 200 m depth on the equator, well below the core of the Undercurrent.

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