Unraveling the Dynamics of the Tsuchiya Jets

A few degrees north and south off the equator, just beneath the thermocline, two narrow currents or jets, the Pacific Subsurface Countercurrents, flow eastward. The two jets carry a significant amount of water (about 14 Sv) across the basin, with the northern jet being somewhat stronger than the southern one. First reported by Tsuchiya in the 1970s, these currents are also called Tsuchiya Jets (TJs). As they cross the basin, the jets rise in the water column and their cores shallow from about 300 m in the western ocean to 150 m in the east.

Adapted from observations of Johnson and McPhaden (1999), Figure 1a illustrates the horizontal structure of the TJs. The contours can be viewed as streamlines along which the currents flow; the closer the contours are, the faster the flow. The blue areas indicate regions of cyclonic flows in each hemisphere; the TJs are the eastward flows near the equator. Toward the east, the TJs shift away from the equator, a property first noted by Tsuchiya. The northern TJ does not appear to extend to the eastern boundary but rather to recirculate in the interior ocean. In contrast, the southern TJ does extend to the eastern boundary, the 11.5 J/kg line intersecting the coast near 12ºS. Although the TJs themselves are confined to the tropics, their cool temperature indicates that their source water lies well outside the tropics. Less clear are the sink regions of the jets. The dynamics of the TJs has been one of the least understood of any of the equatorial currents: Neither the processes that maintain the jets, nor their role in the Pacific general circulation has been clear.

Jay McCreary, IPRC Director and Professor of Oceanography, began to study the TJs with **Peng Lu** more than five years ago, while both were at Nova Southeastern University in Florida. After several years of work, they obtained solutions of the TJs in both analytical and numerical models with idealized half-basins (from 30ºS to 0º and from 0º to 30ºN) and winds: These solutions reveal that not only wind forcing is needed to sustain the TJs, but also a Pacific interocean circulation with inflow of water from the Antarctic Circumpolar Current and an outflow of water in the Indonesian passages with a transport M. In 2000, **Zuojun Yu**, associate researcher at the IPRC, joined their effort. Together, they obtained solutions to numerical models of the realistic Pacific Ocean basin forced by climatological winds and by an interocean circulation with transport $M = 10$ Sv. Their work, based on a hierarchy of models varying from 2.5-layer to 4.5-layer systems, is now in press in *Journal of Physical Oceanography*.

Their analytic solutions to the 2.5-layer model suggest that the TJs are geostrophic currents along arrested fronts. Such fronts are generated when Rossby-wave characteristics, carrying information about the ocean's density structure away from boundaries, converge or intersect in the interior ocean. The solutions indicate the following dynamics: (1) the southern TJ is driven by upwelling along the South American coast and the northern TJ by upwelling in the band of the Intertropical Convergence Zone and strengthened by a recirculation gyre extending across the basin; and (2) the TJ pathways are sensitive to parameters controlling the density structure. Numerical solutions to the 2.5- and 4.5-layer models confirm the analytic results. They demonstrate that the northern TJ is strengthened considerably by unstable waves along the eastward branch of the recirculation gyre, that the TJs are an important branch of the Pacific interocean circulation, and that their pathways are sensitive to vertical-mixing parameterizations and to the structure of the driving wind. A rather striking similarity can be seen when comparing Figure 1b derived from the 4.5-layer numerical solution with the observations in Figure 1a.

To demonstrate that the TJs are a part of the Pacific interocean circulation, the researchers tested the sensitivity of the TJs to the strength of the interocean circulation transport. When the inflow from the Antarctic Circumpolar Current and the outflow through the Indonesian Throughflow are blocked ($M = 0$), both TJs vanish in the 4.5-layer model (compare Figures 2a and 2b). Thus, the TJs exist because of the Indonesian Throughflow—a remarkable example of remote forcing on a basinwide scale.

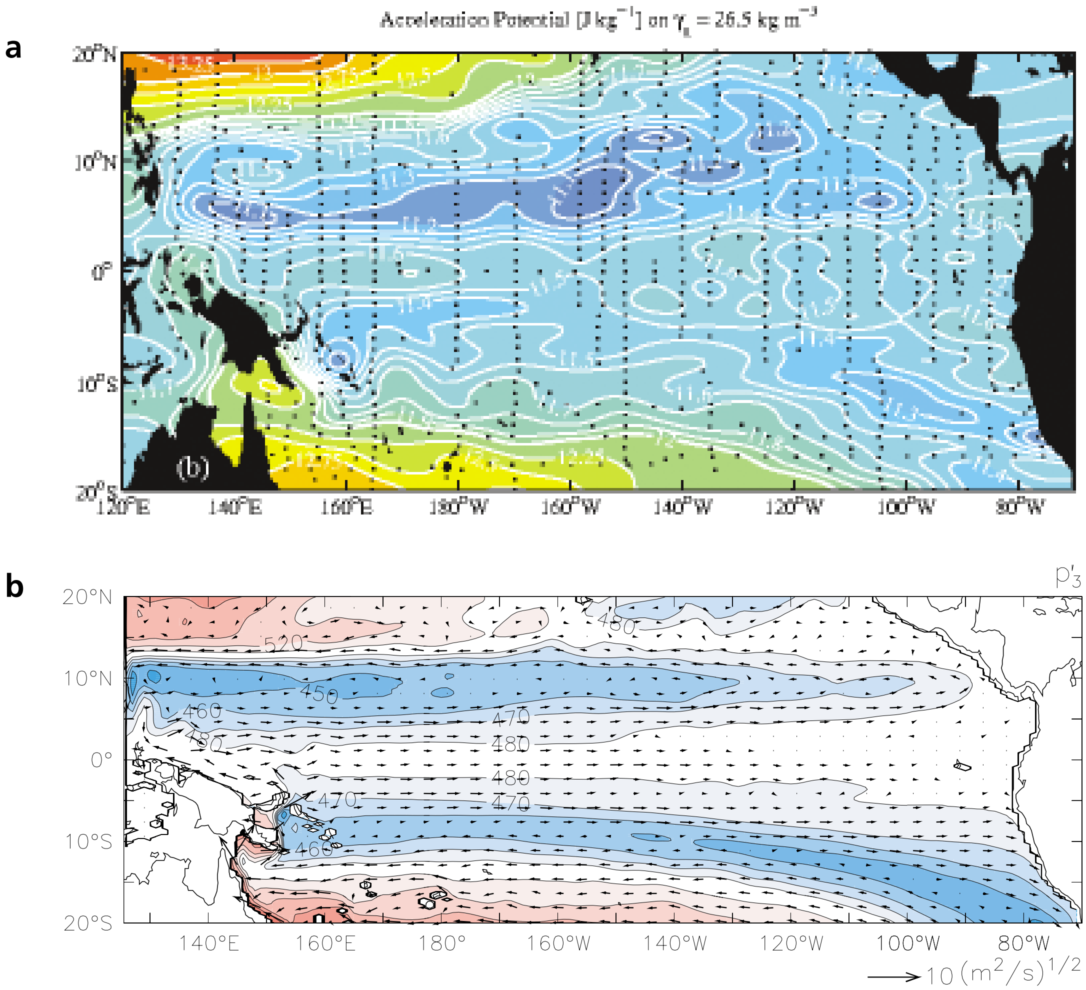

Figure 1. *(a) Acceleration potential (dynamic meters) relative to 900 dbar on the 26.5 kg/m³ neutral density surface, which lies at a depth range from about 300 m to 400 m in the tropical Pacific Ocean. Isolines tend to recirculate in the northern hemisphere but to intersect the eastern boundary in the southern hemisphere. (After Johnson and McPhaden,1999.)*

(b) Horizontal distributions of $p'_3 = p_3/g_{35}$ fields for the main run. The contour interval is 10 m.

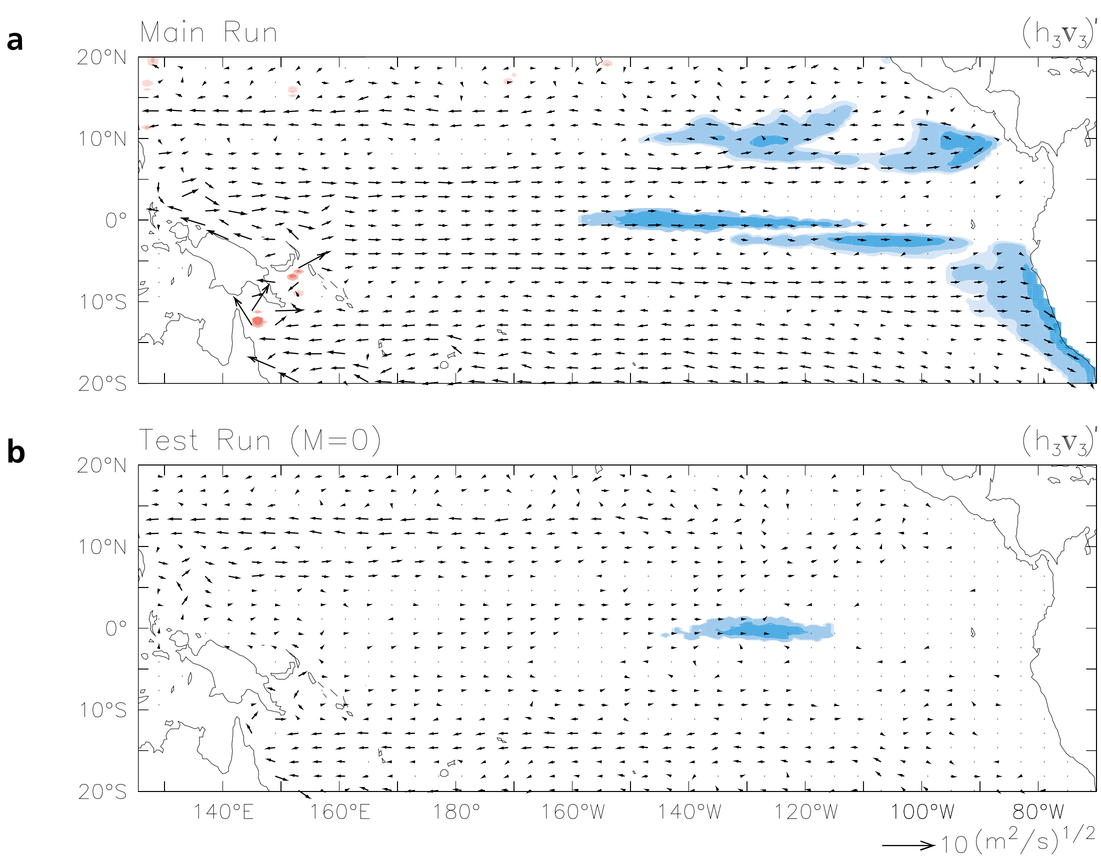

Figure 2. *Solutions in the 4.5-layer model. (a) With realistic inflow and outflow of transport = M. Horizontal distributions of $(h_3\mathbf{v}_3)'$ (shading) fields from the main run. To emphasize weaker flow, arrows are of the vector field $(h_3\mathbf{v}_3)' \equiv h_3\mathbf{v}_3/|h_3\mathbf{v}_3|^{1/2}$. Positive (negative) values of w_2 are show by blue (red) shading, and the lightest shadings indicate where w_2 is greater than 0.1 cm/day or less than -0.1 cm/day. (b) Test run with M=0. Notice the changes in upwelling regions and the disappearence of the TJs.*