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The Impact of Ocean Surface Currents on Sverdrup Transport in the Mid-Latitude North Pacific via the Wind Stress Formulation

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A more complete wind stress (τ_n) formulation takes into account the ocean surface currents (V_o), while the conventional wind stress (τ_c) popularly used in ocean circulation models is only a function of 10-m winds (V_10). An analytical solution is derived for the difference of Sverdrup transport induced by using τ_n instead of τ_c. A scaling analysis of the analytical solution indicates a 6% reduction of the Sverdrup transport in the North Pacific (i.e. the Kuroshio transport in the East China Sea) when Ekman velocity dominates the ocean surface currents. Due to the quadratic nature of wind stress, four nonlinear terms contribute equally to this difference: two "vorticity torque" terms and two "speed gradient torque" terms.

A pair of 12.5-year (July 2002-2014) HYbrid Coordinate Ocean Model simulations that only differ in the wind stress formulation are used to test the analytical solution. The model results (2004-2014) confirm that using τ_n instead of τ_c reduces the Sverdrup transport in the North Pacific by 8% to 17% between 23oN and 32oN. The reduction rate of the simulated 11-year mean Kuroshio transport through the East Taiwan Channel and Tokara Strait is 8.0% (-2.5 Sv) and 12.8% (-4.8 Sv), respectively, in good agreement with the Sverdrup transport reduction rate, which is 7.4% (-2.6 Sv) and 15.4% (-6.3 Sv) at the corresponding latitude.

The local effect of changing wind stress/wind work and Ekman transport due to the inclusion of V_o in the wind stress formulation is negligible compared to the Kuroshio volume transport change estimated in this study.