Ekman Transport on a sphere

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Abstract

The seminal, Ekman (1905)'s, f-plane theory of wind driven transport at the ocean surface is extended to the sphere by substituting the angular momentum for the zonal velocity in the Lagrangian equations. The addition of the meridional variation in the Coriolis frequency and the curvature of Earth's surface turns the equations nonlinear, which greatly complicates the analysis. Though rotation couples the momentum equations in the zonal and meridional directions, the transformation to angular momentum greatly simplifies the longitudinal dynamics, which yields a clear description of the meridional dynamics in terms of a slow drift compounded by fast oscillations. The zonal dynamics can be analyzed following the simplification of the meridional dynamics. A comparison between the analytical and numerical results along the equator demonstrates that the oscillation-free motion in the meridional direction (see figure below) can be described by simple algebraic expressions that can be compared to observations. An explicit expression for the wind-forced equatorial upwelling can be derived from the solutions of the oscillation-free meridional motion. For acceptable values of the model parameters the solution yields an estimate of 45 m for the depth of the Ekman layer and an upwelling rate of about 1.0 m/day into it.

Keywords: Wind, driven oceanic transport, Ekman theory on a sphere

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