Abstract View

Volume 17, Issue 7 (July 1987)

Journal of Physical Oceanography
Article: pp. 1032–1043 | Abstract | PDF (953K)

Evanescent Pressure Gradient Response in the Upper Ocean to Subinertial Wind Stress Forcing of Finite Wavelength

Warren B. White and Gerard McNally

Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093

(Manuscript received May 27, 1986, in final form December 29, 1986)

DOI: 10.1175/1520-0485(1987)017<1032:EPGRIT>2.0.CO;2

ABSTRACT

The idea that Ekman transport driven by the mean synoptic wind stress on the f_0-plane is a robust result is true only for infinite scale lengths of the wind stress forcing. For finite scale wavelengths [O(100 km)] and for a range of subinertial frequencies ranging from 2–10 pendulum days, Ekman transport must compete with the transport associated with pressure gradient flow associated with wind-driven evanescent waves that develop in the pycnocline below the mixed layer. This is demonstrated in a schematic model of the upper ocean at midlatitude where the surface mixed layer of depth H lies above a pycnocline of uniform stratification N^2, driven by schematic wind stress that approximates that associated with the passage of storm fronts. It is shown that subinertial response to transient wind forcing at these periods even at infinite wavelength scales favors the anticyclonic response over the cyclonic one; this tendency is maximum at a period of 1 pendulum day, disappearing at 10 pendulum days as the transient subinertial response approaches the exact equilibrium state Ekman response. However, for transient wind stress of finite wavelength, due to the propagation of atmospheric frontal disturbances of wavelength L and period T at speed C_{pz}, the wind-driven response of the mixed layer penetrates downward into the pycnocline. Divergence in mixed layer motions at subinertial frequencies produce evanescent (i.e., vertical attenuating) motion within the upper portion of the pycnocline. The evanescent horizontal motions are directly out of phase with those in the mixed layer; the evanescent vertical motion alters the density field of the pycnocline and, hence, the pressure field over the entire upper ocean. The resulting transient pressure gradient (i.e., geostrophic) response in the mixed layer is directed in the downwind direction, lagging the cross-wind transient Ekman response by 90°. At subinertial periods of 2–10 pendulum days and wavelengths of O(100 km), the magnitude of this transient geostrophic response is on the same order as that of the transient wind-driven Ekman response. Approaching equilibrium state at 10 pendulum days, the ratio of the equilibrium state geostrophic response to the equilibrium state Ekman response in this schematic model is NH/C_{pz}; i.e., the ratio of the internal wave speed scale to the speed scale of propagation of the atmosphere frontal disturbance. Therefore, in the real ocean drive by wind stress of finite wavelength at subinertial frequencies, the transient Ekman response to wind stress forcing represents only part of the total response; a transient geostrophic response also exists

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that ca be as large or larger than the transient Ekman response.