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Numerical Simulation of Low-Frequency Current Fluctuations in Lake Michigan

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ABSTRACT

Two simple numerical models have been used to study the low-frequency (<0.6 cpd) current oscillations observed in Lake Michigan in order to learn more about what really limits our ability to simulate currents in large lakes. Both are based on the barotropic vorticity equation with the rigid-lid approximation. One model used observed wind to calculate the time-dependent response of the lake for eight months in 1976. The results agree reasonably well with observed currents, but only in the frequency range corresponding to the maximum energy in the forcing function, approximately 0.125–0.3 cpd. Over this frequency range, peaks in the energy spectrum of the forcing function also occur in both the model response and the observed currents at the same frequencies. At lower and higher frequencies, the model underestimates the observed kinetic energy of the currents. The second model calculate the response of the lake to purely oscillatory wind forcing. From 0.125 to 0.3 cpd, the spatial structure of the response is relatively insensitive to changes in forcing frequency. The response to a north–south oscillatory wind stress resembles a free topographic wave consisting of two counterrotating gyres in the southern basin of the lake, but is more complicated in the northern part. When compared to previous analytic and numerical studies of steady-state circulation, the steady-state (zero frequency) response is found to be consistent with Ekman dynamics for realistic values of linearized bottom stress. The results indicate that the barotropic rigid-lid model can simulate observed current fluctuations only in the 0.125–0.3 cpd frequency range. Over this range, the average response of the lake is nonresonant, showing no peaks in lakewide average kinetic energy. At higher and lower frequencies, baroclinicity and nonlinear effects may have to be included in order to improve the model results.

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