Geophysical Research Abstracts, Vol. 9, 10678, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-10678

Frictional bottom boundary layers for tides: observations, theory, and modeling from the northern Adriatic

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From September 2002 to May 2003, fifteen, bottom-mounted, Acoustic Doppler Current Profilers (ADCPs) were used to measure the currents of the Northern Adriatic basin. Tidal fluctuations at all seven of the major Adriatic frequencies (O_1, P_1, K_1, N_2, M_2, S_2, and K_2) were well determined when synthesized from a response tidal analysis of these measurements. The ADCPs all successfully measured these fluctuations 3.5 meters from the ocean bottom or closer; hence, they captured tidal fluctuations within the upper portion of the frictional bottom boundary layer. In particular, the vertical variation of the M_2, K_1, and S_2 tides near the bottom are strong and qualitatively agree with the structure expected from the elegant theory of time-dependent, tidally-forced, bottom Ekman layers using a constant eddy viscosity. A best-fit to this theory was made for data from the twelve deeper sites by using different eddy viscosity values and computing the resulting velocity errors. The results for M_2, K_1, and S_2 were vertical eddy viscosity values of 8.7, 7.7, and 9.6 cm^2/s, with a typical site-to-site variability of 2, 4, and 4 cm^2/s, respectively. However, despite relatively low best-fit residual errors (e.g., 0.38 cm/s average for M_2), the best fit suggests that the basic theory is too simple, since the amount of tidal ellipse shortening and broadening relative to the amount of tilt and phase rotation with depth does not match well. Therefore, two different existing numerical simulations of the Adriatic were compared with the ADCP results. The models are the finite-difference Navy Coastal Ocean Model (NCOM) and the finite-element QUODDY model, which use Mellor-Yamada Level 2 and 2.5 closure schemes respectively. Early results from the NCOM comparisons suggest that these more complicated frictional dissipation schemes do indeed better represent the observed vertical structure of the bottom boundary layer.