Upper-ocean internal waves, tides and mixing at Santa Catalina Island in the Southern California Bight

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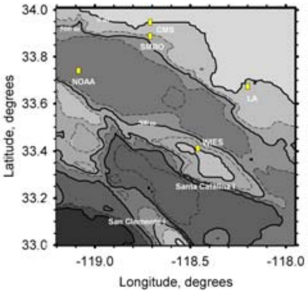
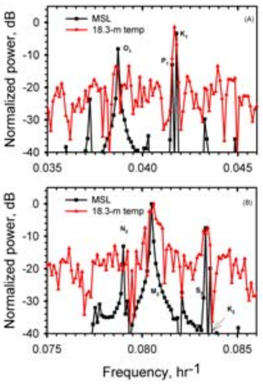
Abstract

Internal waves and tides produce prominent temperature variations throughout the upper-ocean (5-30 m) off the islands in the Southern California Bight. Analysis of Santa Catalina Island temperature records indicates that power is about equally distributed among the diurnal and semidiurnal bands. However, the mechanisms which drive the two regimes are very different and also vary with depth. The semi-diurnal variations are a broadband response, produced by advection of the vertical temperature gradient at tidal frequencies convolved with the seasonal temperature gradient. In contrast, the diurnal variations are narrowband and appear to be due to a meteorological forcing, including solar warming of the upper-surface mixed-layer; and, at depth, advection of the horizontal temperature gradient, that is ultimately forced by the narrowband sea breeze. Energy dissipation is measured from the current spiral generated by the diurnal wind and is found to be roughly equal to the power required for turbulent mixing determined from the seasonal temperature dynamics.

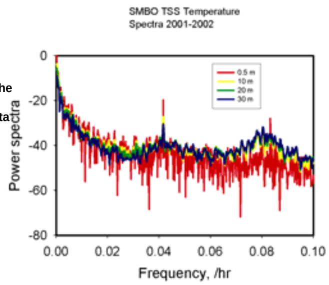
1. Data for the study are thermograph measurements on Santa Catalina Island at 5,10,18 and 30 m (WIES), UCLA temperature and current sensors moored in 400 m depth (SMBO), NOAA buoy data and tide measurements (LA). Additionally, decades of CalCOFI temperature measurements from local stations were used.



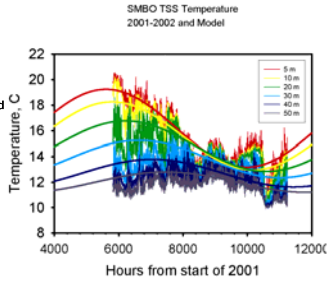
2. Diurnal and semidiurnal temperature variations are always present on Bight Island slopes. Spectra generated from 1 year of hourly samples at WIES are shown here. The diurnal frequency is exactly 1/24 hours and not at the tidal frequencies found in the mean sea level (MSL) data.



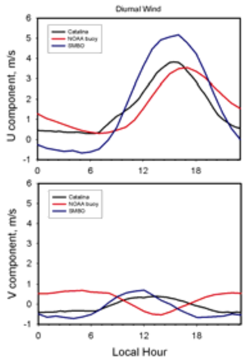
3. Data from the 2001-2003 deployment of the UCLA SMBO were used to study the diurnal temperature modulations. The SMBO data exhibit the same frequency characteristics, namely narrowband diurnal and broadband semidiurnal variations.



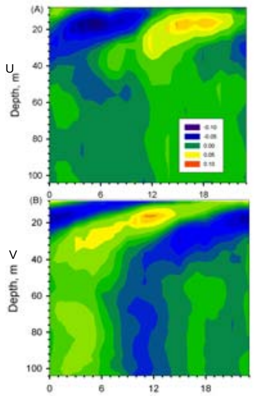
4. SMBO temperature data exhibit the same seasonal variation as 10 years of Catalina data[1], summarized here as the output of a diffusion model with retrieved vertical eddy diffusion coefficient, K_v, = 1.1 x 10^{-4} $m^2 s^{-1}$.



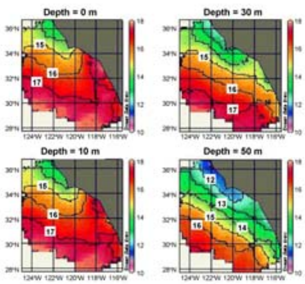
5. Wind at the mooring, buoy and Catalina WIES are narrowband variations at the diurnal frequency. The hour-averages indicate wind out of the west develops in the afternoon.



6. Hour-averages of SMBO currents indicate near-surface u is in phase with the wind, current at depth rotates with 24-hour period, with phase speed of 40 m/day.



7. The horizontal currents advect the non-seasonal temperature gradients, shown here computed from CalCOFI data in a previous study[1].



8. The momentum equation written with eddy viscosity and neglecting the geostrophic pressure terms, can be solved for diurnal frequencies. The momentum diffusion coefficient can be computed from the vertical phase velocity or the decay of current with depth.

$$\frac{\partial}{\partial t}(u+iv)+if(u+iv)=K_M\frac{\partial^2}{\partial z^2}(u+iv)$$

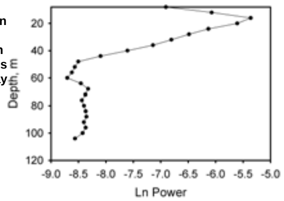
$$u+iv=Ce^{-\sqrt{\frac{f-\omega}{2K_M}}z}e^{-i\left[\sqrt{\frac{f-\omega}{2K_M}}z+\omega t\right]}$$

u,v current components

f,ω Coriolis parameter and angular velocity

K_M momentum diffusion coefficient

9. The data in Figure 6 can be used to compute the decay in current strength with depth. We use depths of 16 to 48 m for the decay calculation.



K_M = 1.5 x 10^{-4} $m^2 s^{-1}$ from phase velocity

15.4 x 10^{-4} $m^2 s^{-1}$ current decay

K_v = 1.1 x 10^{-4} $m^2 s^{-1}$ from temperature analysis

Summary

Narrowband diurnal temperature modulations are found throughout the inner Bight in the upper 30 m. They are also measured from a deepwater mooring. Diurnal currents, in phase with diurnal wind, are also narrowband and may advect horizontal temperature gradients to produce the signal. Measurement of the momentum diffusion coefficient from the diurnal current characteristics yield values similar to the temperature eddy diffusion coefficient found in a previous study[1].

Acknowledgements

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[1]Seasonal temperature dynamics of the upper ocean in the Southern California Bight , C. G. Gelpi and K. E. Norris, J. Geophys. Res., 113, C4, doi:10.1029/2006JC003820, 2008

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