Change of Upper Ocean Multifractal Structure due to Internal Soliton Propagation

Peter C. Chu

Department of Oceanography, Naval Postgraduate School
Monterey, California 93943, USA

The isotropic turbulence has its statistical characteristics such as power-law in the energy spectrum and multifractal characteristics in the structure function. Thus, preservation of power-law in the energy spectrum and multifractal characteristics in the structure function can be treated as the necessary condition for the Gaussianity of the turbulent flows. As internal wave (IW) or internal soliton (IS) propagating in the turbulent fluid, the anisotropic characteristics occur, and the statistical characteristics of the isotropic turbulence are distorted and in turn the Gaussianity is lost.

Upper layer (above 140 m depth) temperature in the western Philippine Sea near Taiwan was sampled using a coastal monitoring buoy (CMB) with attached 15 thermistors during July 28 – August 7, 2005. The data were collected every 15 seconds at 15 different depths between 25 m and 140 m in order to observe turbulent thermal structure. IW and IS were also identified using the empirical orthogonal function analysis.

Without IW and IS (i.e., turbulence-dominated), the power spectra, structure functions, and singular measures (representing the intermittency) of temperature field satisfy the power law with multi-scale characteristics at all depths. The spectral exponents are in the range of (1, 2) and thus the temperature field is nonstationary with stationary increments. The temperature fluctuation has maximum values at the surface, decreases with depth to mid-depths (60-65 m deep), and then increases with depth to 140 m deep. Such depth dependent (decreasing then increasing) pattern preserves during the internal wave propagation during 1000-1500 GMT July 29, 2005. With IW propagation, the power spectra, structure functions, and singular measures of temperature field are basically kept the same as the turbulence-dominated case, i.e., the Gaussianity preserves. The IWs only increase the power of the structure function especially for high moments.

With IS propagation, the power spectrum changes and the spectral exponent is less than 1 for the low wavenumber domain, and the multifractal characteristics is
destroyed. The power law is broken approximately at the lag of 8 min, which is nearly half period of the IS (with frequency of 4 CPH). The internal waves do not change the basic characteristics of the multifractal structure. However, the internal solitons change the power exponent of the power spectra drastically especially in the low wave number domain; break down the power law of the structure function; and increase the intermittency parameter. The physical mechanisms causing these different effects are also presented.