The effect of diurnal cycle of surface heat flux on the temperature structure in the ocean surface boundary layer

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It is well known that solar radiation at the surface induces diurnal variation in both atmospheric and oceanic boundary layers. Despite of this evident feature, however, little attention has been paid to the diurnal cycle of upper ocean and its impact on longer-scale atmospheric and oceanic variability through the interaction between them. Recently, Large and Carbon (2015) performed atmospheric general circulation model and showed that diurnal cycle of SST affects the longer time scale variability of sea surface heat flux and basin scale climate. This demonstrates significance of the diurnal cycle in upper ocean on longer time scale variability. However, detailed processes of upper ocean response to the diurnal cycle is not well investigated. In this study, we performed Large-eddy simulation of upper ocean under the diurnal cycle of the surface heat flux in order to understand the diurnal cycle effects on the upper ocean variability. Here two sets of simulations; one with diurnal cycle of solar radiation and the other without it, are performed for spring season. While heat gained at surface was distributed over the whole of wind-driven mixed layer in the experiment without the diurnal cycle, in experiment with the diurnal cycle, heat was trapped near the surface in daytime and it was distributed over mixed layer in night time. This induces the diurnal cycle of SST and increases daily mean SST. The diurnal cycle of the surface heat flux also affects the mixed layer depth. Noteworthy is that this effect depends on latitude; the diurnal cycle makes MLD deeper (shallower) at lower (higher) latitude. The dependence on the latitude will also be discussed.

Keywords: Diurnal Cycle, Mixed Layer, Sea Surface Heat Flux

Response of upper ocean cooling off northeastern Taiwan to typhoon passages

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In this study, all upper ocean responses to typhoons striking Taiwan from 2005 to 2013 were simulated based on Regional Oceanic Modeling System to provide a comprehensive investigation on the process of typhoons induced upper ocean responses off northeastern Taiwan. Previous study indicates that the strong northeast wind, accompanied by a typhoon, could trigger a Kuroshio intrusion (KI) event that would promote the upwelling of the Kuroshio’s subsurface water onto the shelf and thus causing cooling off northeastern Taiwan. In addition to this scenario, this study indicates another mechanism of wind-current resonance (WCR) over the continental shelf of East China Sea that can also trigger a distinct cooling (through entrainment mixing) within this region. Besides, statistic results based on 17 typhoon cases indicate that the processes of typhoon passage leading to distinct cooling NET are not as common as expected. Actually, they are conditional phenomena. By executing a series of sensitivity experiments and systematic analysis on the behaviors and background conditions (in both atmospheric and oceanic frames) of 17 typhoon cases, key criteria determining the occurrences of cooling NET through both mechanisms (KI and WCR) were elucidated individually. Once the rotation rate of local sensed wind forcing (depending mainly on moving track, translation speed, and RMWs of typhoons) off northeast Taiwan over the continental shelf of ECS is comparable to the turning rate of wind-driven local inertial motions (it is about 27.4 hours off northeast Taiwan), TCNET will be triggered through WCR. Occurrence of TCNET through the mechanism of KI is determined mainly by intensity/strength of northeast wind within local NET. Both processes are dominated by wind forcing rather than oceanic conditions. Finally, according to the possible dynamic linkage between local SST off NET and regional weather system raised in recent studies, the results elucidated in this study are believed to provide a possible advancement on improving regional weather prediction surrounding NET.

Keywords: air-sea interaction, typhoons, modeling, remote sensing

Variabilities of currents and turbulence in the Tokara Strait

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Tokara strait is a site through which the Kuroshio Current enters the deep western north Pacific from the shallow East China Sea, and considered to be an important region for the water mass modification of the Kuroshio water due to strong mixing. Although numerical studies have indicated the Tokara Strait is a hot spot of internal tide generation and mixing, observational works of internal tide and turbulence in the strait are only a few. In this study, results of turbulence measurements around the Tokara Strait are presented from a 7-day cruise in November 2015. We performed a survey of current velocity and microstructure along two sections across the Kuroshio Current using shipboard Acoustic Doppler Current Profiler (ADCP) and a free-falling microstructure profiler, TurboMAP-L. In addition, a mooring array with an upward-looking 75-kHz ADCP was deployed beneath the pathway of the Kuroshio for about 6 days to capture temporal variabilities of the Kuroshio Current as well as tidal currents. Elevated vertical shear ($S^2 > 10^{-4}$ s^{-2}) and dissipation rate of turbulent kinetic energy (epsilon > 10^{-7} Wkg^{-1}) were obtained near abrupt topographies and in the downstream side of the strait. The depth-averaged shear and dissipation rate were well correlated (R^2~0.8). Current data from the moored ADCP showed that the vertical shear is dominated by baroclinic tidal currents while mean flow at the site is dominated by the eastward Kuroshio Current (~1 ms^{-1}), indicating turbulent mixing in the strait was mainly induced by internal tide processes. We discuss the relation between enhancement of internal tide shear and the Kuroshio.

Keywords: turbulence, vertical shear, internal tide, Kuroshio, Tokara Strait

Availability of turbulence measurements using a microstructure profiler attached to a CTD frame

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Turbulence observations have been limited because of difficulty in microstructure measurements. In order to efficiently obtain much more turbulence data down to the ocean floor without spending extra ship-time, we propose a new method, a microstructure profiler attached to a CTD-frame. Since microstructure measurements of velocity shear are sensitive and fragile to vibration of the instruments, measurements have been performed with free-fall or free-rise instruments. The profiler attached to the CTD-frame can’t suppress vibrations. So the authors choose fast-response thermistors to measure micro temperature fields, less sensitive to vibrations than velocity fields. However, turbulence data from thermistors have not been common due to their insufficient temporal resolutions: High frequency components of a temperature spectrum are attenuated. In the present study, to overcome this deficiency, correction procedures for thermistor observations are firstly devised by comparing concurrently obtained energy dissipation rate εestimated from thermistors and velocity shear probes attached to a free-fall profiler. εestimated from thermistors by applying frequency correction assuming a single-pole low-pass filter function has bias which strongly depends on turbulence intensity. The correction with the form of double-pole low-pass filter derives less bias, and 3×10-3[s] of the time constant is found to be the best match withε from the shear probe. Next, this correction is applied to temperature spectra obtained from thermistors attached to the CTD-frame, and the turbulence intensity is compared with data from the free-fall profiler conducted at the same locations within 2 hours. Most of them are compatible, however, some εfrom the CTD-attached method overestimate when the variation of the fall speed of the CTD-frame, (dW/dz)/W, is large. Large (dW/dz)/W corresponds to violation of the shape of the temperature gradient spectrum in high wavenumber ranges, which makes spectrum peak obscure and possibly causes overestimation. This result indicates that large (dW/dz)/W collapses the Taylor hypothesis and turbulent eddies can’t be resolved. Turbulence intensity estimated from free-fall and CTD-attached thermistors reasonably agree by rejecting spectra with unclear peaks, and spectra with (dW/dz)/W>0.3, where violations of spectra expand to peaks at higher wavenumbers. In future, turbulence observations are expected to expand widely by applying the present method to ship observations and to floats equipped with thermistors.

Keywords: physical oceanography, turbulent mixing, turbulence observation, micro temperature fluctuation

Numerical investigation on effects of ocean surface turbulence on particle's sinking

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Biogenic small particles in the ocean can sink due to its own gravity. Marine-snow is a good example of the particle sinking in the ocean. Because dissolved carbon in the ocean is absorbed into the biogenic particle (phytoplankton) through photosynthesis, the particle sinking induces transfer of the carbon from the ocean surface to deeper ocean. This vertical transfer process of carbon is referred to as biological pump, and is considered as one important pathway of carbon from atmospheres into deeper oceans.
Fluid motion can accelerate and/or decelerate their sinking speed. Particle sinking in moving fluid is also found in atmosphere where aerosol-particles are the sinking particles. Several previous studies reported that effects of fluid motion on particle's sinking velocity depend largely on nature of turbulence and properties of particles (e.g., Cargnelutti and Portela 2007), but for particles with small inertia such as biogenic particles in the ocean and for steady isotropic turbulence, fluid motion does not affect the sinking velocity (Maxey 1987). On the other hand, numerical experiments for particles trapped in a ocean mixed layer (Noh et al. 2006) showed that ocean surface turbulence, particularly Langmuir turbulence, traps more particles in the mixed layer, leading to the conclusion that the turbulence decreases particle's sinking speed.
Here we performed numerical experiments of ocean surface turbulence and particle motion to investigate effects of turbulence on particle sinking in steady state. Large-eddy simulations are performed for wind-induced and Langmuir turbulence in which particles are released and tracked. In this study, particles sunk below the mixed layer base are removed and re-deployed at the surface. This approach, unlike the previous study (Noh et al. 2006), allow us to investigate effects of turbulence on the particle sinking in a steady state.
Our findings are (1) the particle's sinking speed is accelerated when a ratio of a terminal velocity (sinking speed of the particle in fluid of rest) to the RMS of fluid vertical velocity, referred to as the velocity ratio, is O(0.1), (2) the particle's sinking speed is decelerated when the velocity ratio is O(10), and (3) the deceleration is amplified for Langmuir turbulence.

Keywords: Ocean Suraface Turbulence, Particle Sinking

