海面熱フラックスの日周変動が海洋表層の水温構造に与える影響

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

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太陽放射の日周変動によって大気海洋の境界層は日周変動しているが、海洋表層の日周変動や日変動の時間規模の大気海洋相互作用にはあまり注意を向けられていなかった。しかしながら、近年の研究ではその重要性が示唆されている。例えば、Large and Carbon(2015)では大気大循環モデルを用いて、太陽放射の日周変動がSSTの日周変動を通して海面熱フラックスの中長期変動に影響を与えることを示しており、日周変動は大気海洋の中長期変動に影響を与えていると考えられる。しかし、日周変動がどのようなプロセスを通じてSSTを変化させるのかは十分に解明されていない。そこで本研究では熱フラックスの日周変動が海洋表層境界層の水温構造に与える影響とそのプロセスに着目して数値実験を行った。実験にはLESモデルを用いて、海面加熱期の熱フラックスの日周変動の有無による違いを調べた。日周変動がない実験では海面での加熱が風に起因する鉛直混合によって混合層全体に分配されていたが、熱フラックスに日周変動を与えた実験では昼の強い加熱期には高温の偏差が海面付近にトラップされる一方で、冷却期には低温の偏差が混合層に分配されるため、SSTの日周変動が見られた。この結果、SSTの日平均値は日周変動によって増加した。海面熱フラックスの日周変動は混合層深度にも影響を与える。その影響は緯度に依存し、日周変動は低(高)緯度で混合層を深く(浅く)する。講演では、混合層深度の緯度依存性についても議論を行う。

キーワード：日周変動、混合層、海面熱フラックス
Keywords: Diurnal Cycle, Mixed Layer, Sea Surface Heat Flux

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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

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トカラ海峡における流れと乱れの変動特性
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.

キーワード：乱れ、鉛直シア、内部潮汐、黒潮、トカラ海峡
Keywords: turbulence, vertical shear, internal tide, Kuroshio, Tokara Strait

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高速水温計を用いたCTDフレーム搭載型乱流観測の有用性検証

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.

キーワード：海洋物理学、乱流混合、乱流観測、水温微細構造
Keywords: physical oceanography, turbulent mixing, turbulence observation, micro temperature fluctuation

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海洋表層乱流が粒子沈降に及ぼす影響に関する数値実験

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

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海洋表層の植物プランクトンは、海洋中の食物連鎖を経て、最終的にはマリンスノーなどと呼ばれる沈降粒子として海洋深層へと沈む。この際、光合成により吸収した海洋表層の二酸化炭素も海洋深層へと輸送する。この過程は生物ポンプと呼ばれ、海洋中の炭素循環を担う重要な過程の一つとされる。粒子の沈降に、その粒子の大きさや密度に加えて、流体の乱れ（乱流）が関与するのは、大気中のエアロゾルの沈降過程など、他の流体中における粒子の沈降過程と同様である。
先行研究によれば、乱流が粒子の沈降速度に与える影響は乱流の様子や粒子の性質により様々である（例えばCargnelutti and Portela 2007）。しかし、植物プランクトンのように粒子の慣性が小さく（流体運動にすぐに馴染む）、乱流が等方・準定常的あるならば、乱流は沈降速度に影響を与えないとの指摘がある（Maxey 1987）。一方、海洋混合層に取り残される植物プランクトンに着目した数値実験（Noh et al. 2006）では、乱流がより多くの粒子を混合層に留める（粒子の沈降速度を減少させる）こと、とりわけラングミュア乱流と呼ばれる波浪に起因する乱流はその効果が大きいことが示されている。このように、海洋表層の乱流が粒子の沈降に与える影響についても不明な点が多い。
本研究では、先行研究と同様に海上の風に伴う乱流とラングミュア乱流が海洋表層混合層に作る乱流場を、ラージエディシミュレーションを行うことで再現し、さらに仮想粒子の追跡も行うことで、海水中の粒子の沈降速度に与える乱流の影響を評価した。その際、Noh et al. (2006)のように混合層に取り残された粒子のみを解析するのではなく、混合層下に沈んだ粒子を海面付近に再配置することで、混合層下に沈む粒子も含めた全ての粒子の定常的な沈降過程を解析する。これにより、乱流が沈降粒子に準定常的に与える影響を明らかにする。
実験の結果、乱流が沈降速度に与える定常的な影響は、静止流体中の粒子の沈降速度と乱流強度を代表する鉛直流速のRMSとの比（流速比と呼ぶ）を用いて、(1)流速比が0.1程度では乱流により粒子の沈降が加速されること、(2)流速比が10程度では粒子の沈降が減速されること、(3)流速比10程度での沈降速度の減速はラングミュア乱流により強化されること、などが明かになった。

キーワード：海洋表層乱流、沈降粒子
Keywords: Ocean Suraface Turbulence, Particle Sinking

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