Why are there upwellings on the northern shelf of Taiwan under northeasterly winds?*

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Outline:

Introduction – Ekman transport, upwelling, & effects of strong currents

A simple model of upwelling at the western edge of Kuroshio in East China Sea

Observational evidence from Long-Tung buoy

Conclusion


# YLC is grateful to have received a fellowship from the Graduate Student Study Abroad Program of NSC
In the N-H, Ekman transport is to the right of the wind.
Upwelling due to Non-Uniform Wind

\[ U = \frac{\tau_0}{f} > 0 \]

\[ U < 0 \]

Ekman Layer

Wind from north

\[ \tau_0^y < 0 \]

Wind from south

\[ \tau_0^y > 0 \]

Upwelling
Upwelling in the Presence of Non-Uniform Coriolis $f$

Trade Wind $\tau_o^y < 0$

$U = \tau_o^y / f < 0$

$U = \tau_o^y / f > 0$
Coastal Downwelling
Over the outer shelf & shelf break of East China Sea, observations show upwelling under northeasterly winds (Liu et al. 1992; Wong et al. 2004) – Why?
In the Presence of a Spatially Non-uniform Ocean Current \( \nu_o(x) \), the Ekman transport

\[
U = \frac{\tau_o \hat{y}}{f}, \text{ where } f = f_0 + \zeta_o; \quad \zeta_o = \frac{\partial \nu_o}{\partial x}
\]
Rossby number \((R_o)\)

\[
U_e = \frac{\tau_o^y}{f + \zeta} = \frac{\tau_o^y}{f(1 + \frac{\zeta}{f})}
\]

Southward wind: \(\tau_o^y < 0\)

\(R_o\downarrow, U_e\uparrow\)

\(R_o\uparrow, U_e\downarrow\)
A Simple Model

\[ \frac{\partial T}{\partial t} = \frac{\tau_0^y}{(f\delta_E)} \left[ -\frac{\partial T_0}{\partial x} + \frac{\partial \zeta_s}{\partial x} \Delta T/f \right] + Q_s - \alpha_N T \]

For \( \tau_0^y < 0 \):

- Warming
- Cooling

Consider Oscillatory Wind: \( \frac{\partial T}{\partial t} = A e^{i\omega t} \)

\( \frac{\partial T}{\partial t} \) is in phase with wind if \( A > 0 \);

\( \frac{\partial T}{\partial t} \) is 180\(^0\) out of phase with wind if \( A < 0 \).
\[ \frac{\partial T}{\partial t} = \tau_0 \gamma / (f \delta_E). [-\frac{\partial T_o}{\partial x} + \frac{\partial \zeta_s}{\partial x} \Delta T / f] \]

\[ \frac{\partial T}{\partial t} \sim \tau_o \gamma(t) \left[ \frac{\partial \zeta_s}{\partial x} \Delta T / f \right] \]

\[ \frac{\partial T}{\partial t} \sim -\tau_o \gamma(t) \left[ \frac{\partial T_o}{\partial x} \right] \]
Effects of Kuroshio: Long-Tung SST & wind stress

\[ \frac{\partial T}{\partial t} \sim \tau^y(t)/(f\delta E)[-\frac{\partial T_\sigma}{\partial x} + \frac{\partial \zeta}{\partial x} \Delta T/f] \]
Conclusion

Current shears near strong ocean jets play a significant role in controlling the vertical motions in the ocean.
Thank you!

Poster:
Chang & Oey: Why can wind delay the shedding of Loop Current eddies? JPO, in press.

Friday (Jul/02) Seminar by Dr. Oey @ NCU
Kuroshio Power(?), Taiwan Ocean Prediction System (TOPS) & the 2010 Oil Spill
Effects of TWC:
Observed upwelling and downwelling

Chen and Wang (2006)
Coastal Upwelling

Coast

$\tau_y$

Wind

$U$

Warm

Cool

T
\[ U_e = \frac{\tau_o^y}{f + \zeta} \]
In the Presence of a Spatially Non-uniform Ocean Current $v_o(x)$, the Ekman transport

$$U = \frac{\tau_o^y}{f}, \text{ where } f = f_o + \zeta_o; \quad \zeta_o = \partial v_o / \partial x$$
Coastal Downwelling

Coast

Wind

$\tau_0 y$

T

T

U

Warm

Cool