



Supplement of

Energetic near-inertial waves induced by winter storms and mesoscale eddies in the subtropical Northwestern Pacific Ocean

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Supplement

Text S1

Data comparisons between the CPLDA reanalysis product and the subsurface mooring observations are shown in Fig. S1. The results suggest that the reanalysis data and observations have nearly the same patterns in mean flows, potential density, and squared buoyancy frequency. Therefore, the CPLDA data can be used to analyze the variation of stratification and background velocities in this study.

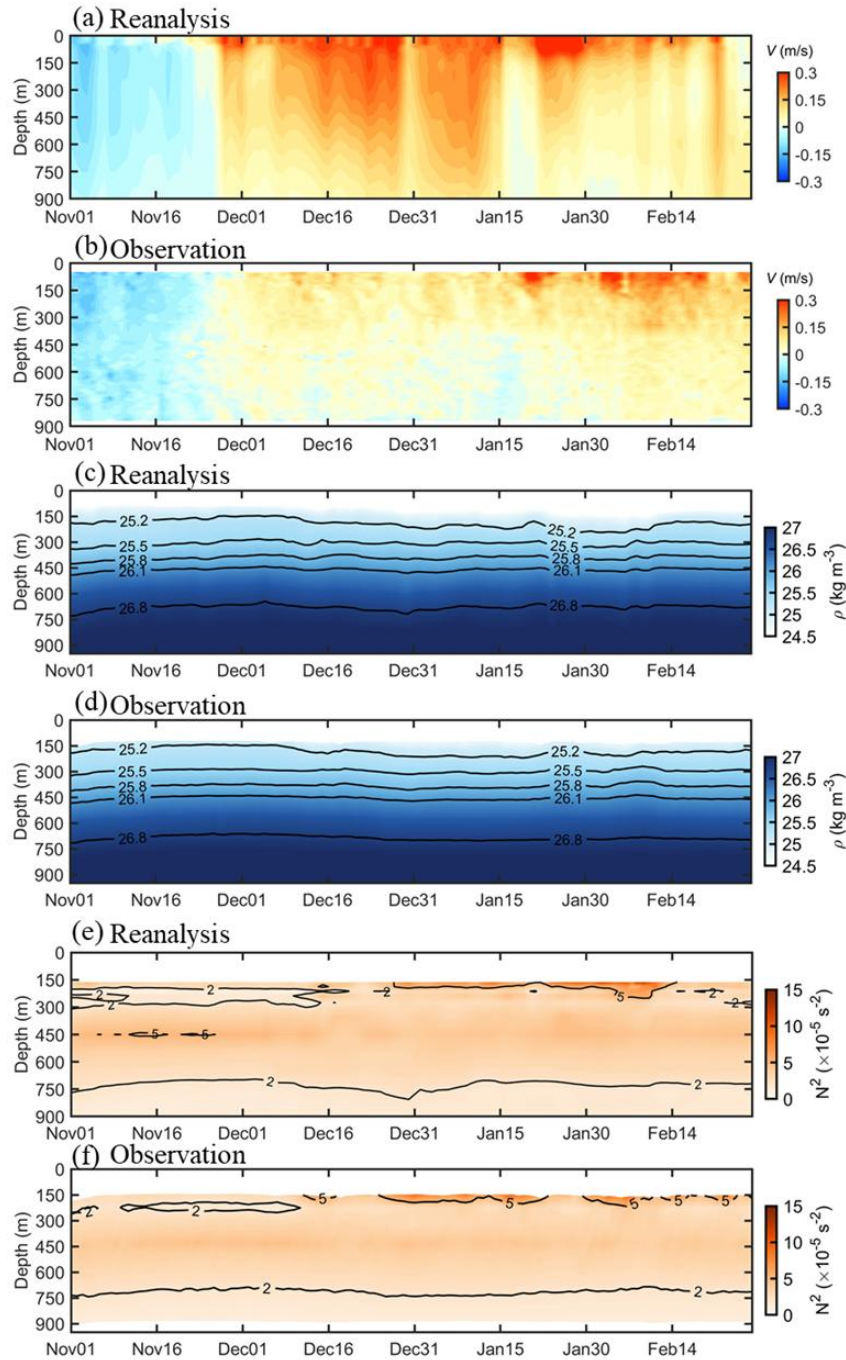


Figure S1. Comparison of background horizontal velocity (V), potential density (ρ), and squared buoyancy frequency (N^2) between the reanalysis product and subsurface mooring observations from 1 November 2017 to 28 February 2018. (a, b) The meridional velocity from the reanalysis product and observations, respectively. (c, d) and (e, f) The same as (a, b), but for ρ and N^2 .

20 Text S2

Figure S2 compares the near-inertial zonal velocity (u_{ni}) derived from the slab model with the u_{ni} from the mooring observations during WS1 and WS2. Because direct current observations were not available within the mixed layer, the observed near-inertial velocity at 50 m depth was used for comparison with the slab model derived velocity. The comparison results show that the near-inertial velocities obtained from the slab model are essentially consistent with the observed results in amplitude and phase.

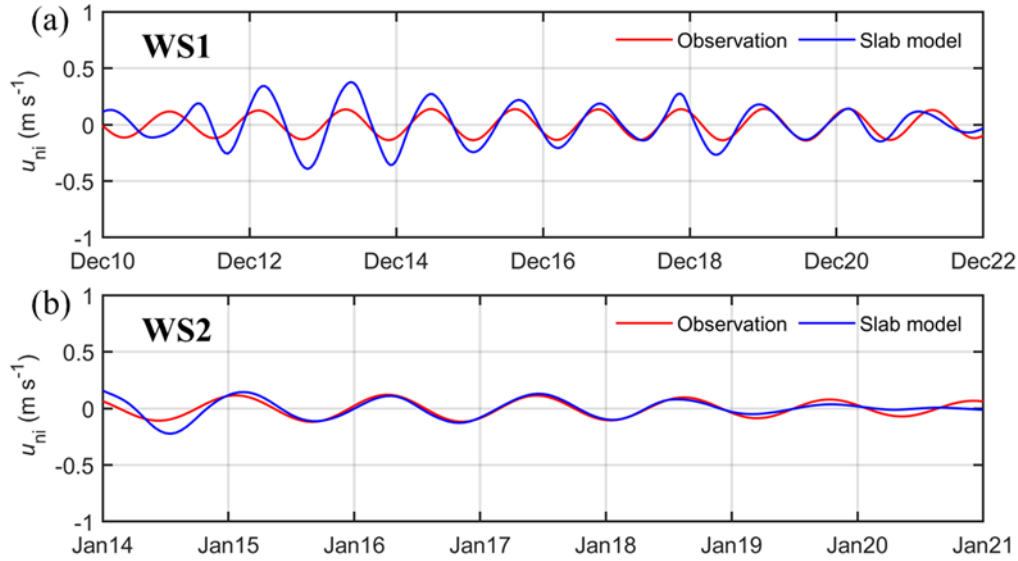


Figure S2. Comparison of the near-inertial zonal velocity (u_{ni}) derived from the slab model (blue lines) and the observational u_{ni} (red lines) at the depth of 50 m during WS1 (a) and WS2 (b).

Text S3

To evaluate the robustness of the diagnosed energy transfer rate P , sensitivity experiments were conducted using different temporal low-pass windows for the background velocity fields and different averaging windows for the near-inertial velocity terms. The background-flow low-pass window was varied among 3, 5, and 7 days, while the averaging window was varied among 2, 3, and 4 inertial periods. The resulting P time series are shown in Fig. S3. Although the averaging window slightly effects the magnitude of P , the main temporal evolution and contrasting signs during WS1 and WS2 remain unchanged.

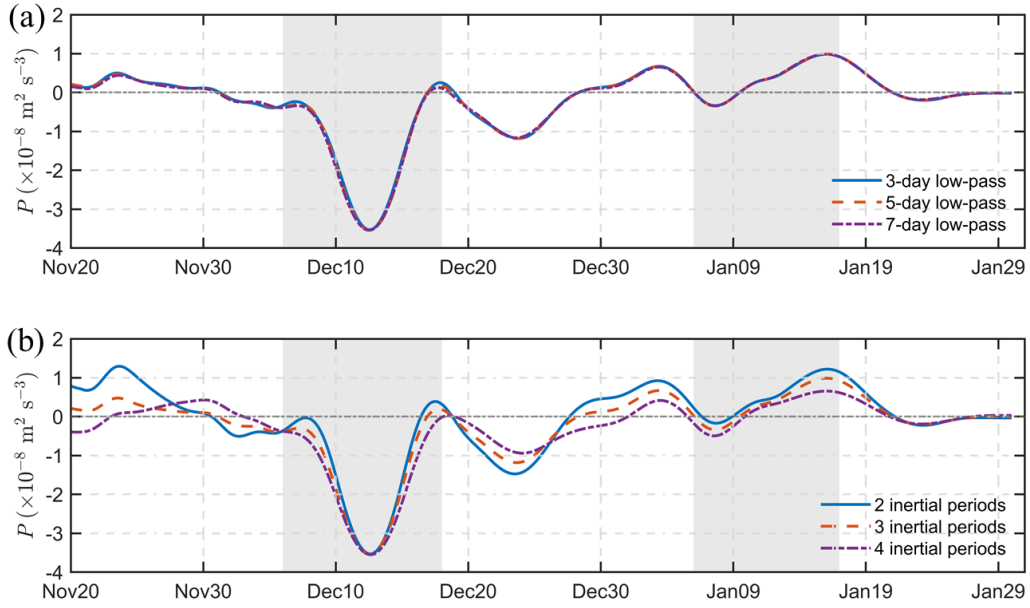


Figure S3. (a) P calculated using 3-, 5-, and 7-day temporal low-pass filters for the background horizontal velocity fields. (b) P calculated using averaging windows of 2, 3, and 4 inertial periods. The grey shading indicates the WS1 and WS2 periods.

Text S4

40 In the GHP fine-scale parameterization, the vertical shear components u_z and v_z were obtained from the observed horizontal velocity. The shear profiles were interpolated onto a uniform vertical grid with a vertical resolution of 10 m and then divided into 240-m-long segments with a half overlap. Within each segment, the segment mean buoyancy frequency was calculated as

$$\overline{N} = \left\langle \sqrt{N^2} \right\rangle. \quad (S1)$$

45 A linear fit was removed independently from both the zonal and meridional shear profiles to remove the large-scale background vertical structure and isolate the finescale shear component. The detrended shear components were then normalized by the segment-mean buoyancy frequency as,

$$u_z^* = \frac{u_z - \overline{u_z}}{\overline{N}}, v_z^* = \frac{v_z - \overline{v_z}}{\overline{N}}, \quad (S2)$$

where $\overline{u_z}$ and $\overline{v_z}$ denote the fitted linear trends within each segment. This treatment follows the finescale-processing procedure used in previous GHP parameterization, in which the large-scale vertical structure is removed before spectral analysis (Kunze et al., 2006).

Before spectral estimation, a 10% sin2 taper was applied to both ends of each segment to reduce spectral leakage. The buoyancy-normalized shear spectra were then estimated using Welch's method. Following Kunze et al. (2006), the normalized shear spectrum was

$$S\left[\frac{V_z}{N}\right](k_z) = \frac{k_z^2[U_r^2(k_z) + U_i^2(k_z) + V_r^2(k_z) + V_i^2(k_z)]}{N^2} S_{\text{correc}}(k_z), \quad (S3)$$

where k_z is the vertical wavenumber, U_r and U_i are the real and imaginary Fourier coefficients of u_z^* , V_r and V_i are those of v_z^* , and S_{correc} represents the spectral correction for attenuation at high vertical wavenumbers.

The normalized shear variance was obtained by integrating the corrected shear spectrum over vertical wavelengths of 60–180 m:

$$\left\langle \frac{V_z^2}{N^2} \right\rangle_{\text{obs}} = \int_{\frac{2\pi}{180}}^{\frac{2\pi}{60}} S\left[\frac{V_z}{N}\right](k_z) dk_z. \quad (S4)$$

The wavelength range of 60–180 m was selected to isolate the finescale internal-wave band while limiting contamination from both lower-wavenumber background structure and higher-wavenumber noise (Kunze et al., 2006; Sheen et al., 2013; Waterman et al., 2013; Takahashi and Hibiya, 2021).

To normalize the observed shear variance, the corresponding GM reference shear spectrum was

$$S_{\text{GM}}(k_z) = \frac{3\pi E_0 b j_*}{2} \frac{k_z^2}{(k_z + k_*)^2}, \quad (S5)$$

where

$$k_* = \frac{\pi j_* \bar{N}}{N_0 b}. \quad (S6)$$

The parameters were set to $E_0 = 6.3 \times 10^{-5}$, $b = 1300$ m, $j_* = 3$, $N_0 = 5.2 \times 10^{-3}$ rad s⁻¹.

The corresponding GM normalized shear variance was then calculated over the same wavenumber interval as

$$\left\langle \frac{V_z^2}{N^2} \right\rangle_{\text{GM}} = \int_{\frac{2\pi}{180}}^{\frac{2\pi}{60}} S_{\text{GM}}(k_z) dk_z. \quad (S7)$$

The normalized shear level was

$$E_{\text{sh}} = \frac{\left\langle \frac{V_z^2}{N^2} \right\rangle_{\text{obs}}}{\left\langle \frac{V_z^2}{N^2} \right\rangle_{\text{GM}}}. \quad (S8)$$

The turbulent kinetic energy dissipation rate was estimated as,

$$\varepsilon = \varepsilon_0 \left(\frac{\bar{N}}{N_0} \right)^2 E_{\text{sh}} h_1(R_\omega) j\left(\frac{f}{\bar{N}}\right), \quad (S9)$$

where the reference dissipation level used in this study was $\varepsilon_0 = 1.0 \times 10^{-10}$ Wkg⁻¹, and

$$h_1(R_\omega) = \frac{3(R_\omega + 1)}{2\sqrt{2}R_\omega\sqrt{R_\omega - 1}}. \quad (S10)$$

The shear-to-strain variance ratio was set to $R_\omega = 7$, following Kunze et al. (2006), who showed that this value is representative of the observed open-ocean internal wave field.

The latitude and stratification dependent correction term was

$$j\left(\frac{f}{N}\right) = \frac{f \cosh^{-1}\left(\frac{N}{f}\right)}{f_0 \cosh^{-1}\left(\frac{N_0}{f_0}\right)}, \quad (S11)$$

where f is the Coriolis frequency, and $f_0 = f(25^\circ)$.

Combining the above expressions, the estimated turbulent dissipation rate is expressed as

$$\varepsilon = 10^{-10} \left(\frac{\bar{N}}{5.2 \times 10^{-3}} \right)^2 \left[\frac{\int_{\frac{2\pi}{180}}^{\frac{2\pi}{60}} S_{V_z}(k_z) dk_z}{\int_{\frac{2\pi}{180}}^{\frac{2\pi}{60}} S_{GM}(k_z) dk_z} \right]^2 h_1(7) j\left(\frac{f}{N}\right), \quad (S12)$$