

Disintegration of the K_1 internal tide in the South China Sea due to parametric subharmonic instability

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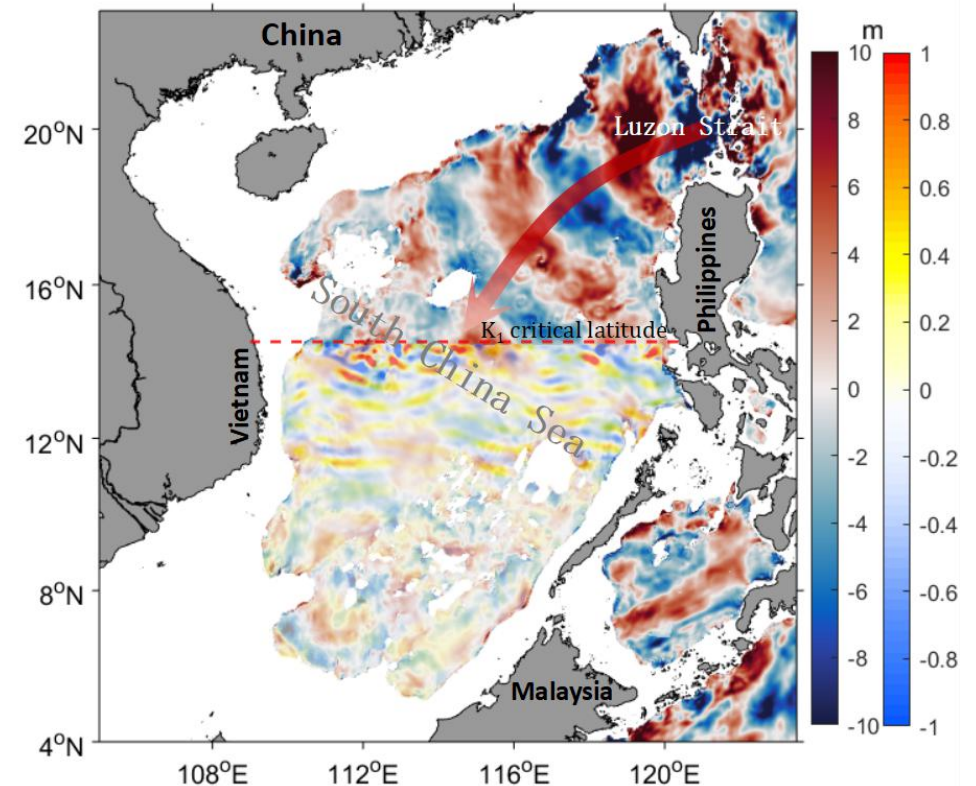


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Introduction

- The majority of the generated internal tide energy (approximately 50%–70) radiates away as low-mode internal tides, the ultimate fate of the outgoing energy remain unknown.
- Internal tide critical latitudes are believed to be potential destinations where internal tides cascade their energy to smaller scales through parametric subharmonic instability (PSI).
- The PSI of diurnal internal tides is less understood because of the leading role of semidiurnal tide in terms of the tidal energetics.
- The unique internal tide geographic position in the South China Sea (SCS) provides an ideal test bed to demonstrate the PSI dissipation mechanism and its implications for mixing.

To better understand how the internal tides dissipate in the far-field, we investigate the mechanism of PSI responsible for the far-field dissipation of Luzon Strait diurnal internal tides in the central SCS.



Near-inertial internal waves half of the tidal frequency are generated near the critical latitude due to PSI of equatorward propagating K_1 internal tides in the SCS.

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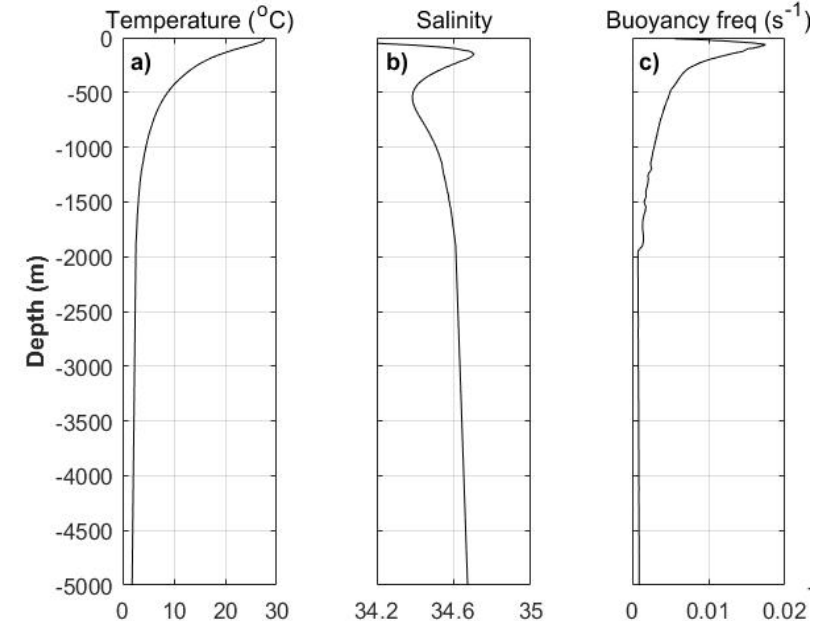
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Methodology

- Numerical simulation
 - Nonhydrostatic MITgcm with horizontal resolution of $1/30^\circ$ and 100 vertical levels;
 - Horizontally homogeneous and vertically stratified initial field (WOA18);
 - K_1 tidal forcing only (TPXO9);
 - Run for 600 tidal periods to get an equilibrium state.
- Energy budget estimation;
- Assessment of the internal tidal field equilibration;
- Spectra analysis.



Temperature, salinity, and buoyancy frequency profiles
for the initial fields of the simulation

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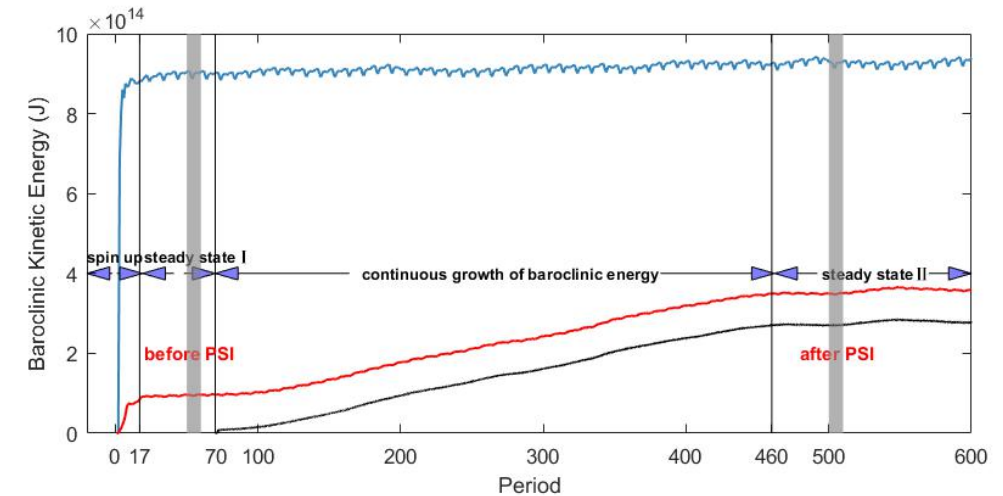
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Main Results

- Time evolution of the baroclinic kinetic energy undergo two steady states;
- In steady state I, near-inertial energy barely exists;
- Between the two steady states, near-inertial energy grows constantly;
- The time evolution of region-integrated full and near-inertial baroclinic kinetic energy near the critical latitude is almost parallel, suggesting that the continuous growth of baroclinic energy in the critical latitude zone can be attributed to the evolution of PSI.



Time evolution of the baroclinic kinetic energy in the Luzon Strait (blue line) and Critical Latitude Zone (red line), as well as the inertial bandpass filtered baroclinic kinetic energy in the Critical Latitude Zone (black line).

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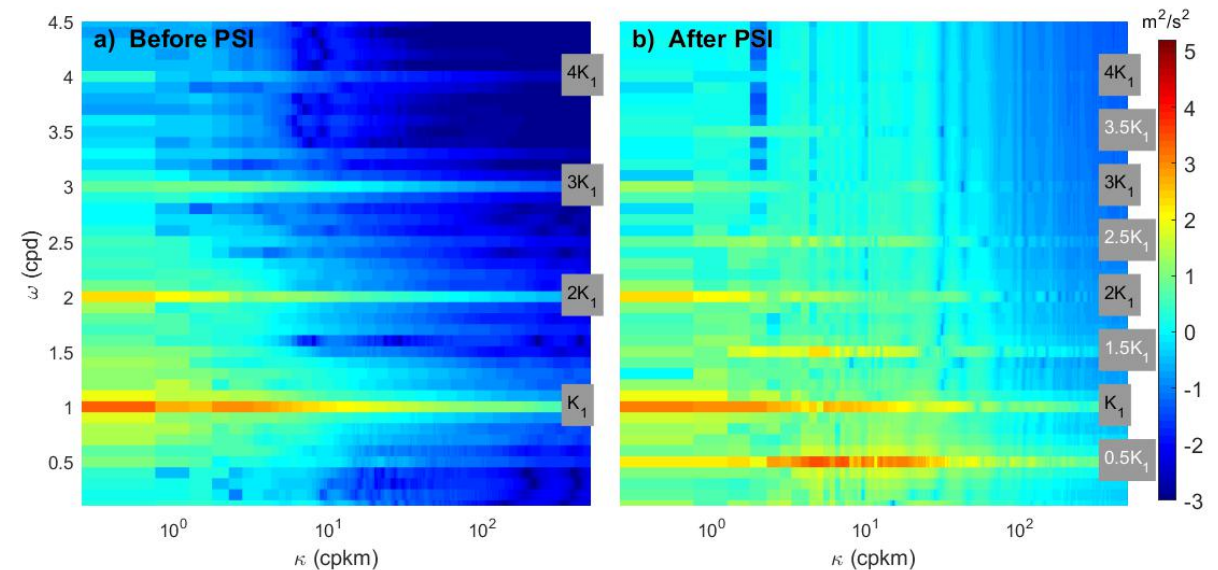
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Main Results

- During the first steady period, the internal tide oscillations are characterized by horizontal lines of high-energy density patches at the frequency K_1 and its harmonics ($2K_1$, $3K_1$, etc.);
- During the second steady period, the subharmonic peak at $0.5K_1$ can be clearly identified, confirming the occurrence of K_1 internal tide PSI;
- The subharmonic waves feature higher wavenumbers structure than the parent waves.



Vertical wavenumber–frequency spectra of zonal velocities at the crossing point based on hourly output
(a) without and (b) with the occurrence of PSI, respectively.

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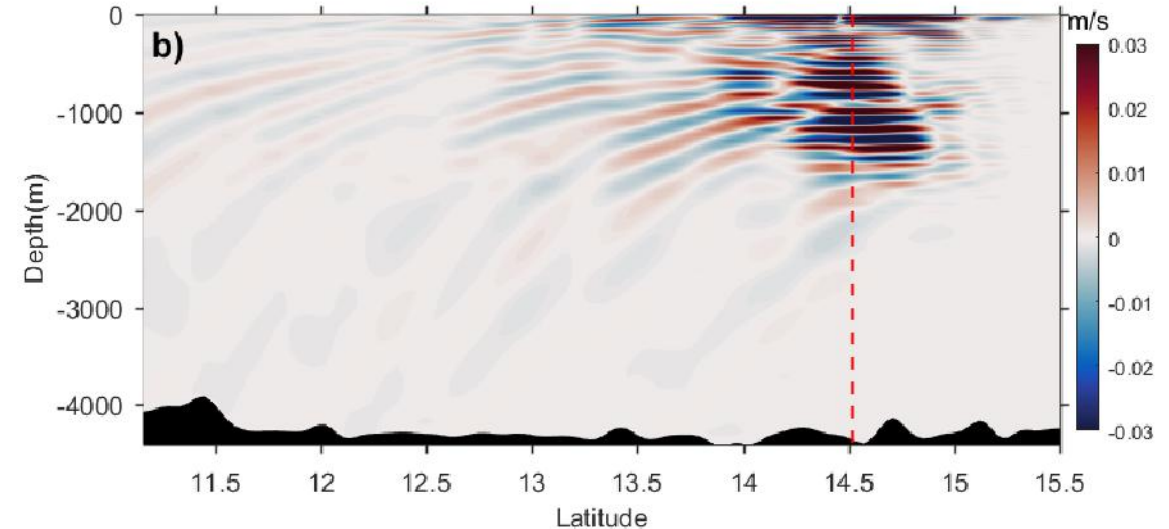
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Main Results

- The horizontal wavelengths of the simulated equatorward propagating near-inertial waves are approximately 50–80 km;
- The vertical scales ranging from approximately 50m at the near surface to approximately 180 m at a depth of 2000 m.
- The wave ray is flat, and the signals diminish within the first half wavelength.



Distribution of the instantaneous inertial bandpassed zonal baroclinic velocity along the main propagation path after PSI is developed.

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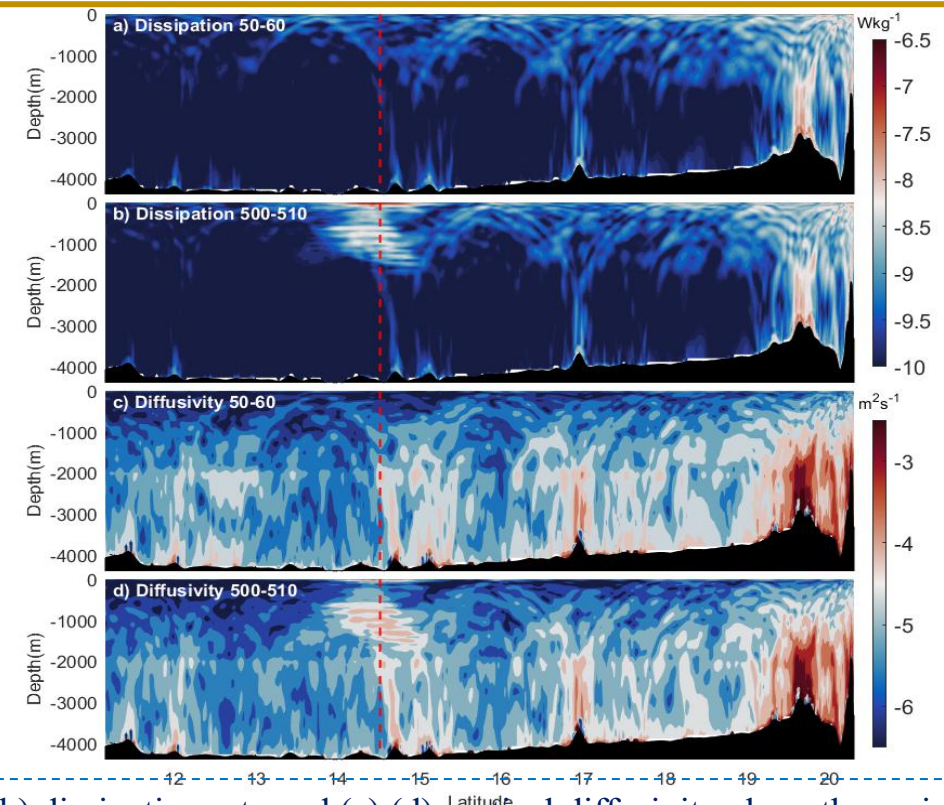
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Main Results

- The mixing hotspots are generally concentrated near the rugged topography;
- The major difference between the energy dissipation field with and without PSI lies in the upper ocean near the critical latitude, where persistently elevated energy dissipation of $O(10^{-8}) \text{ W kg}^{-1}$ due to PSI.
- Accordingly, the vertical diffusivity in this region is approximately $O(10^{-5}-10^{-4}) \text{ m}^2\text{s}^{-1}$, which is several orders of magnitude larger than the background value in the upper ocean.



Model-predicted period-averaged (a),(b) dissipation rate and (c),(d) vertical diffusivity along the main propagation path without [in (a) and (c)] and with [in (b) and (d)] the occurrence of PSI. The red dashed lines denote the location of the critical latitude.

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Conclusions

- The internal tidal dynamics within the critical latitude range in our simulations have two relatively steady states, between which PSI-induced subharmonic waves evolve constantly.
- The properties of the bandpass filtered near-inertial signals near the critical latitude agree well with the theoretical prediction of PSI-induced subharmonic waves.
- The critical latitude acts as a “virtual island chain” radiating near-inertial waves equatorward.
- In the critical latitude zone, an additional 14% of the incident baroclinic energy is lost under the influence of PSI.
- The K_1 internal tide PSI-induced mixing enhancement mainly occurs in the upper 1500 m, with a magnitude of approximately $O(10^{-5}-10^{-4}) \text{ m}^2 \text{ s}^{-1}$.
- The contribution of PSI to the internal tide energy loss and associated enhanced mixing may differ regionally and is closely dependent on the intensity and duration of background internal tide.