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News and Views

The largest CPIES array in the marginal sea: abundant dynamics in the northeast South China Sea

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The South China Sea (SCS) is a marginal sea connecting the Pacific and Indian oceans and has gained much attention in recent decades. The dynamics in the northeast SCS are considerably influenced by topography, monsoons, tropical cyclones, the Kuroshio intrusion, and water exchange through the Luzon Strait (LS). Recently, an array of 38 current and pressure-recording inverted echo sounders (CPIES) and two moorings are deployed in the northeast SCS from 2016 to 2019 (Fig. 1), constituting the largest CPIES array in the marginal sea to date. We report scientific observations of fundamental dynamics in the northeast SCS based on this large CPIES array, including circulations, eddies, internal waves, and intraseasonal variabilities, as well as their connections and interactions (Fig. 2).

The upper northeast SCS is characterized by the Kuroshio intrusion and active eddies. Studies have reported that the Kuroshio intrudes the SCS via looping, leaking, and leaping paths which contribute to the regional oceanic environment (Nan et al., 2011). Recently, a new kind of summer Kuroshio water intrusion is revealed based on observations. Wind-induced anticyclonic eddies north of Luzon Island known as North Luzon warm eddies (NLWEs) move northwestward in summer 2018 and carry Kuroshio water into the SCS (Zhao et al., 2023). NLWEs contribute to nearly half of the westward LS transport during summer and are critical for regional circulation. Historical statistics indicate that NLWEs occur only from April to October and are strongly related to local winds. Monsoon provides favorable conditions for eddy growth, whereas strong negative wind stress curl is directly responsible for eddy generation. The eddy heat transport (EHT) across the LS was determined based on observational data, and a novel methodology was developed to extend the time series of EHT from sea surface height (Zhao et al., 2024). Additionally, the variability and underlying mechanisms of EHT on both seasonal and interannual time scales were examined.

Internal tides (ITs) and near-inertial waves (NIWs) are two types of energetic internal waves. Semi-diurnal and diurnal ITs, generated by energetic barotropic tides traveling across steep ridges in the LS, have been analyzed in detail (Wang et al., 2023b, c). Most energetic diurnal ITs radiate from the middle and southern LS and extend southwestward. The energy of K_1 and O_1 ITs radiate into the SCS is 2.67 GW and 1.54 GW, respectively—roughly twice as large as the values obtained via satellite observations. Additionally, the M_2 ITs are characterized by the presence of standing waves formed by a northwestward beam from the LS and a southeastward beam from the southern slope of the Taiwan Strait. Influenced by the eddy-induced background flow, two oppositely propagating beams undergo clockwise rotation upon entering the anticyclonic eddy. Such a rotation causes deflection of the nodes and antinodes of standing waves, leading to variability in the standing wave amplitude. Typhoon Mangkhut (2018) crosses the SCS and induces energetic NIWs that travel equatorward for hundreds of kilometers and propagate downward, dominated by Modes 2 and 3 (Zheng et al., 2023). The wavelengths and phase speeds of different modes, which are difficult to obtain from traditional observations, are captured. The NIWs southwest of Taiwan are trapped by a westward-propagating eddy. The bottom-reaching NIWs contribute considerably to the upper and deep dynamics.

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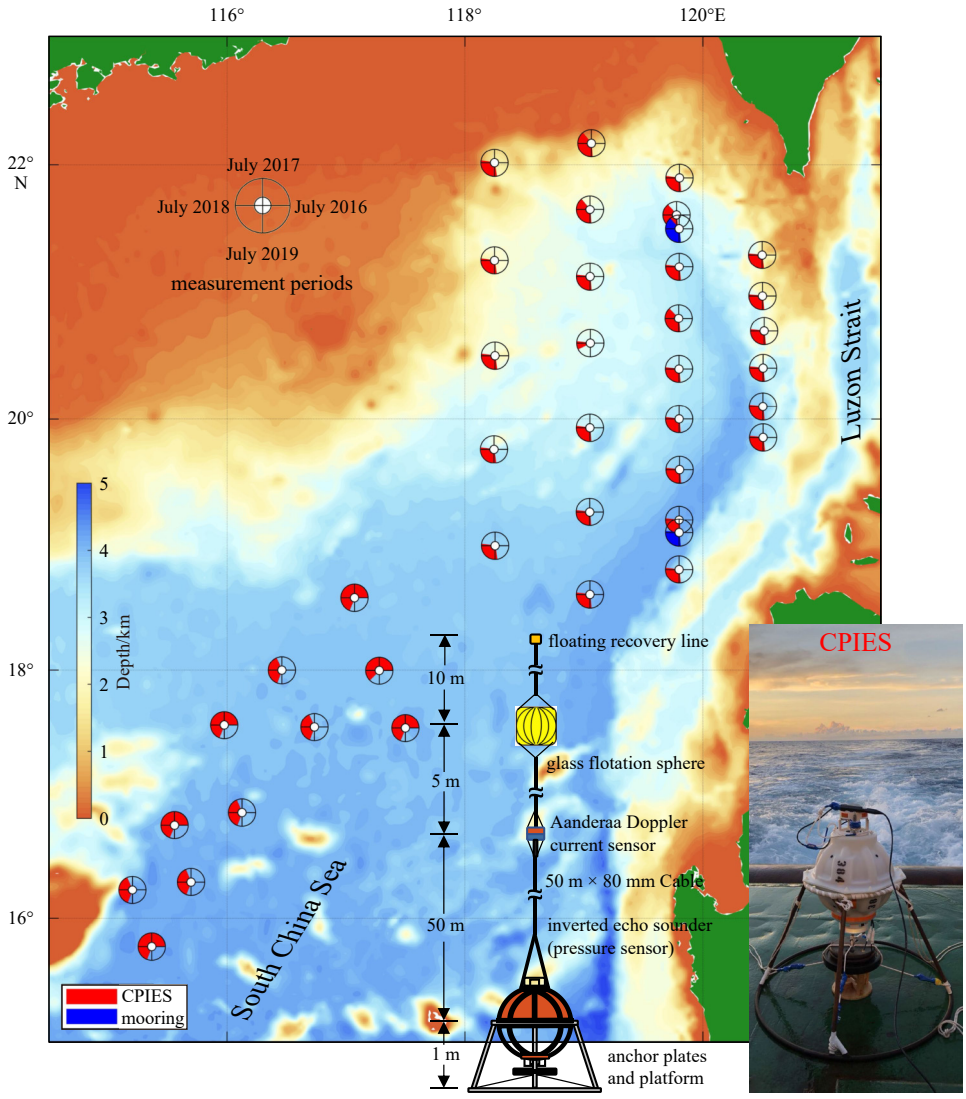

Fig. 1. Positions (dots) and measurement periods (cycles) of current and pressure-recording inverted echo sounders (CPIES) array in the Northeast South China Sea.

Deep-water overflow driven by a pressure gradient across the LS contributes to SCS abyssal circulation. Based on these observations, abyssal circulations in the northeast SCS have been described (Zheng et al., 2021a, 2022b, 2024), and measurements from the Gravity Recovery and Climate Experiment have been evaluated (Wang et al., 2023a). Deep water flows northward after entering the SCS and then turns southwestward following the deep boundary, forming a cyclonic circulation. The current is narrow and strong near the steep eastern boundary and near the Zhongsha Islands, whereas the current near the subdued northwestern boundary is wide and weak. The current near the LS is enhanced in autumn and early winter, whereas that in the interior SCS is stronger in summer. These different seasonal patterns are caused by the propagation of seasonal variations. Planetary vorticity flux and bottom pressure torque maintain the first-order deep vorticity balance, reflecting the outer and inner forcing of the abyssal circulation.

Abundant abyssal intraseasonal variability has been attributed to topographic Rossby waves (TRWs), with dominant periods increasing from the LS to the interior SCS (Zheng et al., 2021b, 2022a). Nearly 65-day TRWs east of the Zhongsha Islands propagate along the isobaths with a slightly downslope group velocity, showing the dynamic response of abyssal currents to mesoscale perturbations southwest of Taiwan Island. Additionally, nearly 21-day TRWs driven by the Kuroshio meandering and upper eddies are trapped by the Manila Trench. These findings suggest that TRWs act as a mechanism that connects upper-ocean mesoscale perturbations and deep-ocean dynamics.

In conclusion, the dynamics of ITs and abyssal circulation are analyzed in detail based on the large CPIES array. Active upper-layer mesoscale perturbations are found to contribute to the Kuroshio intrusion, adjust the propagation of ITs and NIWs, and induce TRWs. This paper reports the systematic evaluation of northeast SCS dynamics based on unprecedented observations that have great scientific significance for improving our understanding of the spatiotemporal circulation structure and multi-scale dynamic processes in the SCS. In addition, these successful observations in the northeast SCS indicate that a CPIES array is economical and practical for large-scale and long-term oceanic observations.

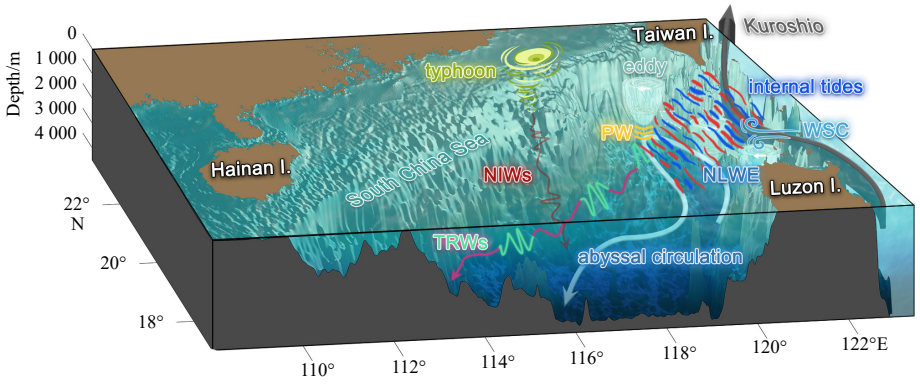

Fig. 2. Abundant dynamics in the northeast South China Sea. WSC: wind stress curl; NLWE: North Luzon warm eddy; TRWs: topographic Rossby waves; NIWs: near-inertial waves; PW: pressure work.

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