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Heat Flux Analysis of Kuroshio Warm Water Intrusion Into Aligned Bays and Channels Along the Pacific Coast of Japan

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Synoptic numerical modeling using an eddy-resolving three-dimensional ocean circulation model (JCOPE2-ROMS, Uchiyama et al., 2018) was conducted to assess the oceanic influences on embayment systems along the Pacific coast of Japan. During the non-large meander phase of the Kuroshio (Kawabe, 1985), its front shifted closer to the coast, facilitating the intrusion of Kuroshio-derived warm water. To assess such oceanic influences as heat exchanges between coastal and offshore regions, a heat flux analysis was performed near the openings of Tokyo Bay, Sagami Bay, Suruga Bay, Ise Bay, and the Seto Inland Sea (SIS), which has two main openings: Kii Channel and Bungo Channel. We found that the mean heat flux (MHF), primarily representing seasonal variations, dominates the eddy heat flux component. The spatial distribution of MHF exhibits that eastern three bays (Tokyo, Sagami, and Suruga) are more strongly influenced by the spatiotemporal variations of the Kuroshio path than the western bays. When warm water bifurcates northward from the Kuroshio and reaches the Oshima West Channel, near Tokyo Bay, it readily intrudes into these eastern bays. In contrast, Ise Bay, located approximately in the middle of the study area, is hindered from variations in the Kuroshio path due to topographically constrained clockwise lateral recirculation between the Kuroshio and the coast, which restricts direct MHF at its mouth. Furthermore, heat exchange at the Kii Channel and Bungo Channel of the western-most bay (the SIS), does not vary in response to Kuroshio path variations because of the stability of the Kuroshio in those regions. These regional differences in the intensity of Kuroshio-derived warm water intrusion are further confirmed by a T-S diagram analysis, which reveals varying sensitivities of each region to the influence of the Kuroshio.

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Summer Monsoon-induced Coastal Upwelling Along the Japanese Coast

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Wind-induced coastal upwelling plays a significant role in ocean circulations and ecosystems. However, effects of coastal upwelling in the east Asian coast have not been investigated well. This study presents summer monsoon-induced coastal upwelling along the southeast of Japan mainland using a numerical simulator, ROMS, with NPZD (nutrient, phytoplankton, zooplankton, detritus) model. Model results show that temperature along the coast drops as summer monsoon increases indicating typical coastal upwelling structures. Upwelling events supply nutrient from deep layers toward the near surface photic layer, resulting in phytoplankton abundance. Both of vertical advection due to wind-induced upwelling and vertical diffusion due to mixing processes contribute to vertical nutrient supply. Upwelling does not only influence near coastal regions, but it also promotes nutrient supply into the surface Kuroshio downstream. The nutrient-phytoplankton stream appears along the surface Kuroshio downstream during strong summer monsoon periods. The modeled phytoplankton stream structures are consistent with Chl-a concentration from satellite observations.

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Impact of Point Source Variability on Residual Currents and Associated Material Transport in an Estuary: Implications for Effluent Modification in Sewage Treatment Operations

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Semi-enclosed estuaries have always been subject to anthropogenic factors that affect tidal residual currents and circulation, thereby altering material transport and influence the surrounding marine environment. These factors include the construction of jetties and breakwaters, dredging, and the discharge of land-derived waters. Among these, treated wastewater effluent can introduce time-dependent point-source variations in discharge volume and density, potentially leading to undesirable regional-scale impacts. A municipal sewage treatment plant located along the Kobe coast in Osaka Bay, Japan, serves as a prototypical example, having implemented a seawater mixing operation in 2021 to mitigate the impact of treated effluent on an adjacent seaweed farm. This study aims to quantitatively evaluate the effects of the seawater mixing operation as a point source variation on ambient tidal residual currents, effluent dispersal, and its subsequent impact on the seaweed farm using a quadruple-nested, 3D ocean circulation model coupled with a conservative tracer advection-dispersion model.A comparative numerical experiment was conducted for two scenarios: one representing normal operation with freshwater effluent only (no mixing), and the other with the effluent mixed with seawater at a 1:1 ratio. Results indicate that the reduced buoyancy and doubled volume flux caused by the mixing operation alter the near-field flow field, which subsequently induces detectable changes in far-field temperature, salinity, effluent tracer concentrations, and 3D residual currents. These changes also affect the flow and tracer around the seaweed farm located near the eastern shore of the plant. A tracer flux budget analysis in the vicinity of the farm revealed that the seawater mixing operation reduces the accumulation of effluent from the plant within the farm area by approximately 12%. Therefore, even a minor anthropogenic alteration of the point source can result in a nontrivial impact on the ambient estuarine environment by modifying residual currents.

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Notable Diurnal Internal Kelvin Waves Near the Surf Zone: a Field Observation of Shallow-water Hydrodynamics Off Kashima Coast, Japan

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Hydrodynamics and associated marine ecosystems in highly open coastal areas are influenced by various external forcing factors, including tides, internal waves, wind, and surface waves, among others. Understanding these mechanisms is crucial for elucidating their complex interactions. This study aims to assess the hydrodynamic processes and underlying mechanisms in the nearshore region under offshore influences through a 15-day field observation conducted in the summer of 2023 at the tip of the Hazaki Oceanographical Research Station (HORS) located around the surf zone, at the depth of ~5m, off Kashima Coast, Japan, facing the Pacific Ocean. Time-series and spectral analyses of the observed data reveal a pronounced dominance of diurnal fluctuations in current velocity, water temperature, and chlorophyll-a concentration, along with occasional partial stratification in response to semi-diurnal tidal variability.Strikingly, during the first half of the observation period, strong southward currents prevailed, exhibiting diurnal variability influenced by diurnal wind forcing. We infer that these intense southward currents evolve into internal Kelvin waves, which propagate southeastward along the coast with the shoreline on their right. This is supported by far-field density fields in a cross-shore section, derived from the JCOPE2M reanalysis product, which indicate a lowest-mode internal Kelvin wave phase speed of approximately 0.4 m/s, consistent with the peak southward current velocity. Given that the estimated internal Rossby deformation radius is approximately 5 km, we conclude that these internal Kelvin waves were generated near the continental shelf break, about 20 km offshore, and remained confined to the nearshore shallow region, within 5 km of the shore, as coastally trapped waves. These findings provide new insights into nearshore hydrodynamics, which have traditionally been considered to be primarily influenced by local surface waves, while large-scale inertial dynamics also play a crucial role.

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High-Resolution Tracking of Explosive Cyclogenesis and Its Impact on Oceanic Waves in the East Asian Marginal Seas

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Explosive cyclogenesis, or bomb cyclones, are rapidly intensifying extratropical cyclones that frequently lead to coastal hazards, including high waves and storm surges. Their swiftdevelopment makes prediction challenging, while conventional tracking methods using low-resolution sea-level pressure data may limit detailed impact analysis due to insufficient spatiotemporal representation. This study introduces a new tracking algorithm building upon the methodology described in Yoshida and Asuma (2004), utilizing high-resolution GPV-MSM sea-level pressure data at 5 km× 5 km, in contrast to the commonly used, coarser-resolution JRA-25 reanalysis data at 1.25°× 1.25°.Comparison with the Bomb Cyclone Database at Kyushu University, based on the JRA-25, revealed that our method detected more explosive cyclogenesis events due to the improved resolution, which allowed for more precise capture of spatial pressure variations. Notably, it identified bipolar cyclones—systems characterized by two closely spaced low-pressure centers—that generate spatially extensive and energetically intense storms. A statistical analysis classified cyclone tracks into four types (SS, NS, SN, NN) based on their origin and the location of maximum growth rate, where N (S)stands for the northern (southern) area relative to the inclined Japanese island chain. Monthly statistics indicated that SS-type cyclones dominate in winter, with a seasonal shift from NN-type (Nov–Jan) to NS-type, then to SS-type (Feb–Mar), before decreasing significantly in April.To assess the oceanic impact of explosive cyclogenesis, we analyzed significant wave heights derived from GPV-CWM wave data. Explosive cyclogenesis was found to contribute to increased wave heights in the Yellow and East China Seas, where waves are typically milder under normal conditions. In contrast, a decreasing trend in wave heights was observed along the west coast of Hokkaido and in the Sea of Okhotsk. These findings underscore the importance of high-resolution data in improving cyclone detection, classification, and impact assessment.

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Influences of Kuroshio Meanders and Winter Monsoon on Nitrate Transport and Primary Production in the Enshu-nada Sea, Japan

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Primary production is fundamental to sustaining marine ecosystems and regulating carbon sequestration in the ocean, making it crucial to understand these dynamics. This study aims to assess the influences of the Kuroshio and seasonal monsoon on winter primary production, which preconditions the spring phytoplankton bloom, in the Enshu-nada Sea on the Pacific side of Japan, and to examine its underlying mechanisms. Numerical analyses were conducted using a coupled three-dimensional regional ocean circulation model (ROMS) with a nitrogen-based NPZD ecosystem model. This approach enables the evaluation of primary production and nitrate flux transport processes during both the normal (non-meandering) and meandering phases of the Kuroshio. The analysis reveals that variations in the Kuroshio path cause significant differences in nitrate transport processes, which strongly influence primary production and its spatial distribution. While primary production across the study area tends to be higher during the meandering phase, productivity is enhanced on the northern side of the Kuroshio axis (coastal region) during the non-meandering phase. Kuroshio meandering also results in reduced primary production and lower nitrate concentrations in coastal areas, whereas offshore regions exhibit increased nitrate concentrations. Nitrate flux analysis indicated that surface nitrate is mainly transported upward via vertical diffusive flux on the northern (shoreward) side of the Kuroshio path, while mean vertical advective flux dominates upward transport in the downstream region around the Izu-Ogasawara Ridge. Furthermore, nitrate supplied to the surface layer is transported upstream of the Kuroshio by a counterclockwise rotating cyclonic eddy formed between the coast and the Kuroshio, playing a pivotal role in sustaining primary production. Additionally, coastal upwelling driven by northeasterly monsoons may further influence the regional ecosystem. These findings suggest that carbon sequestration through the biological pump may vary in response to basin-scale oceanic conditions, such as Kuroshio path variations and monsoon activity.