Data-Driven Forecasting of Residual Currents in Coastal Bays Using High-Frequency Radar Observations

The Upper Gulf of Thailand (UGoT) is one of Thailand's most critical marine coastal ecosystems, but it faces numerous environmental challenges. Effective management of these ecosystems requires tracking dynamic behaviors, such as residual currents. In this study, we introduce a novel approach to forecast residual currents in coastal bays using high-frequency radar observations and data-driven methods. By employing Dynamic Mode Decomposition (DMD) modes derived from high-frequency surface wave radar (HFSWR) data and simulated datasets from the Finite Volume Coastal Ocean Model (FVCOM), we identify the governing mechanisms of residual currents in the UGoT. Our analysis indicates that residual current dynamics in the UGoT are predominantly influenced by dominant modes associated with sub-monthly to monthly timescales, which significantly impact variations in response to wind changes. Additionally, modes with daily timescales are essential for understanding the daily fluctuations of non-tidal currents, primarily driven by seiche modes in the Gulf of Thailand. By examining both observed and simulated data, we find that the most dynamically dominant DMD modes reveal the characteristics of wind-driven currents and their interaction with the UGoT's topographic features. One of the key findings of our study is that the predominant topographic influence in the UGoT is wind-driven flow rather than geostrophic flow. This insight provides a sophisticated method for determining residual currents in coastal bays and offers a practical, data-driven approach for forecasting these currents. Our methodology leverages the strengths of DMD to distill complex hydrodynamic data into actionable insights, which can be instrumental for coastal management and planning. Furthermore, we have developed and validated a numerical model for the UGoT to enhance the prediction system. This model is particularly beneficial for communities that depend on accurate tracking and prediction of residual currents, aiding in effective management and mitigation of environmental impacts. To demonstrate the broader applicability of our approach, we also applied it to future projections using the GeoMIP datasets. This case study highlights the utility of our methodology in various scenarios, providing valuable insights into potential future changes in sea currents under different climatic conditions. Integrating GeoMIP data helps enhance the understanding of current dynamics and provides insights into future oceanographic conditions. In conclusion, our novel approach to forecasting residual currents using high-frequency radar observations and data-driven methods, validated through present observations and applicable for future projections, represents an advancement in coastal oceanography. This versatile tool not only enhances our understanding of current dynamics but also equips coastal managers with the predictive capabilities necessary for sustainable ecosystem management.

Sirod Sirisup, Saifhon Tomkratoke, Pornampai Narenpitak and Siriwat Kongkulsiri , Data-Driven Simulation and Systems Research Team, National Electronics and Computer Technology Center, National Science and Technology Development Agency, Khlong Luang, Pathum Thani 12120 Thailand