以波潮耦合模式作業化系統進行颱風案例的校驗分析

Validation and Analysis of Typhoon Cases Using an Operational Wave-Tide Coupling Modeling System.

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摘 要

由於波浪與海流各有其控制方程式及對作用力的描述，傳統數值模式常各自獨立運作，但是波與流間有相互影響的作用力，為了更清楚解析海流的時空變化，需將潮汐、海流及波浪等交互作用耦合執行。因此，使用波潮流整合數值模式改進傳統波流獨立的作業預報系統。本計畫使用的波潮流整合數值模式使用WWMIII第三代波浪模式與SCHISM水動力模式做動態耦合，且須使用同一非結構式網格及相同時間步長計算，以達成動態同步的耦合。數值模式中波浪與海流耦合的計算流程是先透過計算波浪，將波浪引起的表面應力(輻射應力)傳遞至水動力模式，水動力模式將之納入計算新的流場與水位，再將三維流場中的表面流場及水位傳遞至波浪模式，進行下一時間序的計算。目前署內已建置臺灣海域波潮耦合模式作業化系統，系統內容涵蓋天文潮、暴潮、波浪及波潮耦合模式產品，氣象驅動力採用氣象署的WRF氣象預報資料進行每日兩次的作業化預報，預報時間為兩日預報場，並產出96小時波浪及暴潮預報場相關產品。模式產出的模式結果，與實測值進行比對及校驗，採用中央氣象局臺灣海象災防環境平台及資料開放平臺之水位紀錄及波浪浮標資料進行驗證。本文探討2024年凱米颱風與山陀兒颱風案例，以均方根誤差及皮爾森相關數的量化指標，進行波浪與水位的校驗分析，透過校驗分析結果呈現系統預報效能及穩定性。

關鍵字：中央氣象署、波潮流整合模式、波流耦合、異常巨浪

Abstract

Due to the distinct governing equations and force representations for waves and ocean currents, traditional numerical models often operate independently. However, interactions between waves and currents involve mutual forcing, which necessitates a coupled modeling approach to better resolve the spatiotemporal variations of ocean currents. To address this, we have integrated tides, currents, and waves into a coupled modeling system to improve upon conventional, decoupled forecasting methods.

The coupled wave-tide-current numerical model employed in this project dynamically integrates the third-generation wave model WWMIII with the hydrodynamic model SCHISM. This dynamic coupling is achieved by using a common unstructured grid and identical time steps to ensure synchronized calculations. In the coupled framework, wave fields are computed first to derive surface forcing (radiation stress), which is passed to the hydrodynamic model. The hydrodynamic model incorporates this stress to update the current and water level fields. The surface currents and water levels are then relayed back to the wave model to compute the next time step, forming a continuous two-way feedback loop.

An operational wave-tide coupled modeling system has been established for Taiwan's coastal waters. This system includes predictions of astronomical tides, storm surges, waves, and their coupled interactions. Meteorological forcing is provided by the Central Weather Administration's WRF forecast, and the system generates twice-daily

forecasts with a 96-hour lead time. The forecast outputs are validated against observational data, including tidal gauge records and wave buoy data from the Central Weather Administration's Taiwan Ocean Observation Data Service and Open Data platforms.

This study focuses on two typhoon cases in 2024—Typhoon Kaimi and Typhoon Saudel. We evaluate model performance through validation analyses of wave height and water level using quantitative metrics such as root-mean-square error (RMSE) and Pearson correlation coefficient. The results demonstrate the forecasting system's accuracy and stability.

Key words : Wave-Tide Coupling Model, Wave–Current Coupling, Extreme Wave