以COMCOT-SS與Splash3D分析港灣遮蔽效應於潮汐水位之影響

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摘　要

風暴潮預報之重要性在於即時掌握海水倒灌範圍、河川排洪規劃、及港灣風險控制。針對台灣之特殊性，如多颱風、多高山、範圍較小卻人口稠密、需要高解析度與高精確度暴潮預報需求等，中央氣象局於綜合比較多種國際間所使用之風暴潮數值模式後，決定自主研發適合於台灣之COMCOT-SS風暴潮預報系統。COMCOT-SS風暴潮模式以COMCOT海嘯模式為基礎，並導入風暴潮模擬所需之動力邊界而成。該模式求解非線性球座標方程式，具有可局部加密解析度，可納入潮汐邊界條件，及計算局部海水溢淹，以及高準確度之特色。

眾所周知，任何模擬現狀之數值模式皆須經過反覆模式校驗，並針對該地區之特色，進行模式調校。風暴潮校驗主要方式為與將模擬結果與觀測資料進行比對，並從觀測數據中濾除天文潮並提取風暴潮之水位時序歷線進行比對。觀測資料之主要來源為中央氣象局設立於港灣內之34個潮位站。天文潮之濾除可透過扣除調和分析或TPXO8之天文潮預測、低通濾波等。然而於校驗風暴潮水位時，常有部分潮位站之水位資料在扣除調和分析之模擬水位後，仍有週期性擺盪之殘差，且不論風暴潮現象有無發生，週期性擺盪於濾波後皆存在，此結果易導致無法精確便是風暴潮水位。

本研究為了解潮位站觀測水位與調和分析殘差值之週期性擺盪，並提升分析颱風暴潮時可校驗資料之品質。進行二維COMCOT-SS與三維Splash3D模擬。Splash3D求解三維Navier-Stokes方程式，因此不受限於淺水波之假設，並可展現三維水流結構。本研究提升模式內地形資料及數值網格之解析度，並比對二維COMCOT-SS與三維Splash3D之模擬結果，分析設置於港灣內潮位計受港口海堤遮蔽效應之影響程度，以瞭解殘差值之誤差來源。

模擬結果顯示，於台中港，三維Splasd3D與二維COMCOT-SS模擬結果近似，顯示潮汐進入台中港後，並未產生明顯之三維效應。港灣遮蔽效應確實存在，並以潮汐延遲方式呈現，且此現象必須高解析度模擬才得以解析。

關鍵字：港灣遮蔽效應、COMCOT-SS、Splash3D、TPXO8

Analyzing the Impact of Harbor Shielding Effects on Astronomical Tide Elevation with COMCOT-SS and Splash3D

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Abstract

The importance of storm surge forecasting lies in the ability to immediately grasp the extent of seawater inundation, plan river flood control, and manage risks in harbors. Considering Taiwan's unique characteristics, such as frequent typhoons, numerous high mountains, a relatively small but densely populated area, and the need for high-resolution and high-precision storm surge predictions, the Central Weather Bureau (CWB) has decided to develop its storm surge forecasting system suitable for Taiwan, called the COMCOT-SS (Cornell Multi-grid Coupled Tsunami Model with Storm Surge) system.

As is well-known, any numerical model simulating real-world phenomena needs to undergo iterative model validation and be adjusted to the characteristics of the specific region. Storm surge validation primarily involves comparing simulated results with observed data and extracting the time series of storm surge elevation from the observed data while filtering out astronomical tides. The main source of observed data is the 34 tidal stations established by the CWB in harbors. Astronomical tides can be removed through subtractions from harmonic analysis, the astronomical tide prediction of TPXO8, or low-pass filtering. However, residual periodic oscillations often remain in the elevation data of some tidal stations during the validation of storm surge water levels, even after subtracting the simulated elevation from harmonic analysis. These periodic oscillations persist after filtering, regardless of storm surge events, leading to inaccurate water level estimations.

This study aims to understand the periodic oscillations in observed elevations at tidal stations and residual values after subtracting harmonic analysis to improve data quality for validating storm surges during typhoon events. Two-dimensional COMCOT-SS and three-dimensional Splash3D simulations were conducted. Splash3D solves the three-dimensional Navier-Stokes equations, thereby not being limited by the assumptions of shallow water waves and being able to display three-dimensional flow structures. This study improved the resolution of the internal terrain data and numerical grids within the models and compared the simulated results of the two-dimensional COMCOT-SS and three-dimensional Splash3D models to analyze the influence of harbor embankments on tidal gauges placed within the harbors in order to understand the source of errors in the residual values.

The simulation results show that the three-dimensional Splash3D and two-dimensional COMCOT-SS simulations in Taichung Port are similar, indicating no significant three-dimensional effect after tides enter the port. The harbor shading effect manifests as a tidal delay, and this phenomenon can only be resolved through high-resolution simulations.

Keywords: Harbor shading effect, COMCOT-SS, Splash3D, TPXO8