以深度學習方法與衛星雲圖估計並分析颱風風場結構

Estimating and analyzing tropical cyclone structure by satellite imagery utilizing deep learning model

蕭純珉[1] (Hsiao C.-M.) 陳柏孚[2] (Chen B.-F.) 郭鴻基[1,2] (Kuo H.-C.) 李清勝[1,2] (Lee C.-S.)

[1]國立臺灣大學 大氣科學系 [2]國立臺灣大學 氣候天氣災害研究中心
[1]Dept. of Atmospheric Sciences, National Taiwan University
[2]Center for Weather Climate and Disaster Research, National Taiwan University

摘　要

熱帶氣旋（TC）結構的估計與分析為重要之颱風研究及防災議題。然而因觀測的限制，JTWC及NHC所分析之最佳路徑資料於2004年之後才開始提供較完整之颱風結構參數估計。為研發一套客觀、具全球一致性之颱風結構分析方法，本研究藉由深度學習方法建立模式，並以衛星觀測資料進行颱風結構估計，以期解決現今颱風結構觀測資料在時空解析度上不足的問題。

本研究使用卷積神經網路（CNN）建立一個能夠由紅外線衛星雲圖估計颱風軸對稱近地面風速剖面的深度學習模式。CNN為一種監督式學習演算法，需標籤資料方可計算損失函數並進行訓練，故本研究先利用最佳路徑資料之各項結構參數、及一個參數化風速模型，初估颱風軸對稱風速結構，並使用ERA5再分析資料修正外圍風場。利用這組標籤資料，我們以2004−2016年的資料訓練CNN模式；利用ASCAT及SAR海表風觀測對2017−2018颱風進行獨立校驗顯示。結果顯示，深度學習模式能合理估計颱風結構，所估計之颱風強度與暴風半徑之平均絕對誤差，分別為8.48 kt及44.5 km。

最後，我們取得1981−2003年的全球衛星觀測資料，以客觀且穩定的方式重建近40年的颱風結構長期再分析資料。應用此組資料，本研究將分析此技術在不同環境條件下的誤差分布，討論其估計颱風結構之能力，並探討未來應用其在即時颱風結構估計的可行性。

關鍵字：熱帶氣旋結構，卷積神經網路，衛星觀測

Abstract

The estimation and analysis of tropical cyclone (TC) structure are very important for typhoon research and disaster prevention. However, due to observational limitations, the best track data analyzed by JTWC and NHC provide more complete typhoon structure parameter estimations only after 2004. To develop an objective and globally consistent typhoon structure analysis method, this study uses deep learning to establish a model which can estimate typhoon structure using satellite observation data. It is expected that this model can help solve the problem of insufficient temporal and spatial resolution of typhoon structure observations.

This study uses the convolutional neural network (CNN) to build a deep learning model to estimate the axisymmetric radial wind speed profile from infrared satellite imagery. Since CNN is a supervised learning algorithm, labeling data are required to compute the loss function and train it. Therefore, this study first uses the structural parameters of the best track data and a physically-based parametric wind model to estimate the axisymmetric wind speed structure of the typhoon, and use ERA5 reanalysis data to correct the outer wind field. Using this set of labeling data, we train the CNN model with the data from 2004 to 2016. Independent verification of the 2017-2018 typhoons using ASCAT and SAR sea surface wind observations shows that the deep learning model can reasonably estimate

the typhoon structure, and the average absolute error of intensity and storm radius are 8.48 kt and 44.5 km, respectively.

Finally, we used this objective and stable method and the global satellite observation data from 1981 to 2003 to reconstructed a long-term reanalysis dataset of the typhoon structure for the past 40 years. Using this dataset, this study will analyze the error distribution of this method under different environmental conditions. Besides examining the capability of this model in estimating typhoon structure, and the feasibility of applying this model in real-time typhoon structure estimation in the future will be assessed.

Key words: TC structure, CNN, satellite observations