應用影像超解析度技術於全球模式台灣降雨降尺度研究
A Study of Using Single Image Super-Resolution Technique for Downscaling GCM Rainfall in Taiwan

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摘　　要

　　本研究利用全球環流模式(GCM)的降雨資料，以多尺度殘差網絡(MSRN)演算法重建台灣附近二維降雨降尺度資料。MSRN是一種通常用於圖像超解析度的深度學習算法。本研究提出採用兩個串聯的MSRN模組，可逐步將解析度提高4倍和5倍，最終達到20倍的提升，該階層式方法可將台灣地區的GCM降雨數據從0.25度解析度提升至0.0125度高解析度網格。校驗結果顯示，這種階層式MSRN在重建高解析度日降雨量方面優於單次提升20倍解析度的MSRN以及傳統線性內插方法，在各種降雨門檻值下都能具有較準確的高解析度重建降雨，且系統性偏差最小。對於極端降雨事件，階層式MSRN在日雨量350公釐和500公釐的門檻值時，預兆得分(Threat score)可分別超過0.54和0.46，優於上述兩種其他方法。本技術也應用於歐洲中期天氣預報中心(ECMWF)全球模式的台灣地區日降雨預報資料，針對於1至3天的預報在日雨量超過100公釐的門檻值下時可表現出顯著改進。

關鍵字：雨量降尺度、超解析度、極端降雨、深度學習

Abstract

　　This research introduces a novel technique for downscaling global circulation model (GCM) rainfall data using the Multi-Scale Residual Network (MSRN), a deep learning algorithm typically used for image super-resolution. The method enhances GCM rainfall data from a 0.25-degree resolution to a high-resolution 0.0125-degree grid for Taiwan, representing a 20-fold increase. The approach employs two concatenated MSRN modules, each increasing resolution by 4 and 5 times respectively. Results show that this hierarchical MSRN outperforms both single-step MSRN and linear interpolation in reconstructing high-resolution daily rainfall. It excels in accurately reproducing rainfall across various thresholds with minimal bias. For extreme rainfall events, the hierarchical MSRN achieves impressive threat scores exceeding 0.54 and 0.46 for 350 mm and 500 mm daily thresholds, surpassing alternative methods. When applied to ECMWF's operational global model for daily rainfall forecasts over Taiwan, the technique demonstrates significant improvements for rainfall thresholds above 100 mm per day, particularly for 1- to 3-day lead forecasts.

Keywords : Rainfall downscaling, single image super-resolution, extreme rainfall, deep learning