基於集成學習改善卷積神經網路之系集定量降水預報後處理方法

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摘　要

氣候變遷使得更加準確的定量降水預報更為重要，過去基於卷積神經網路之系集定量降水預報後處理方法展現出優於傳統統計方法之預報結果，但降雨空間捕捉能力與累積降雨量仍有修正空間，因此，本研究透過比較不同降雨類型資料以及不同加權損失函數進行預訓練，再以集成模型與加入平均絕對誤差（Mean Absolute Error, MAE）作為損失函數，對現有的卷積神經網路（Convolutional Neural Network, CNN）與空間注意力模組（Channel block Attention Module, CBAM）之後處理方法進行改進，並分析隨著累積降雨量變化，模型之預報泛化能力。

研究發現在加入集成學習並應用 MAE 進行訓練，相比先前的 CNN+CBAM 後處理方法，在不加入偏差修正下，分別在 RMSE、SSIM、CRPS 分別改善了 13.33%、5.03%、14.47%，而在加入偏差修正下，則改善了 6.68%、2.5%、5.58%，顯示模型有效降低預報誤差，並在降雨量快速變化之個案，未加入偏差修正效果較好，而降雨量增加速度較為穩定之個案，加入偏差修正可改善預報能力。

關鍵字：定量降水預報、系集預報、卷積神經網路、集成學習、加權損失、數值天氣預報

Abstract

Climate change has made more accurate quantitative precipitation forecasting increasingly important. Previously, ensemble quantitative precipitation forecast post-processing methods based on Convolutional Neural Networks (CNNs) have shown better results than traditional statistical methods. However, there is still room for improvement in capturing spatial rainfall patterns and cumulative rainfall amounts. This study compares different types of rainfall data and weighted loss functions for pre-training. An ensemble model with the Mean Absolute Error (MAE) as the loss function is then used to improve existing CNN and Channel Block Attention Module (CBAM) post-processing methods. The study also analyzes the model's generalization ability as cumulative rainfall changes.

The study found that incorporating ensemble learning and applying MAE for training improved the Root Mean Square Error (RMSE), Structural Similarity Index Measure (SSIM), and Continuous Ranked Probability Score (CRPS) by 13.33%, 5.03%, and 14.47% respectively, compared to the previous CNN+CBAM post-processing method without bias correction. With bias correction added, the improvements were 6.68%, 2.5%, and 5.58%. This demonstrates that the model effectively reduces forecast errors. In cases of rapid changes in rainfall, the model performs better without bias correction, while in cases of more stable increases in rainfall, adding bias correction improves the forecasting ability.

Keywords: Quantitative Precipitation Forecasting, Ensemble Forecasting, Convolutional Neural Network, Ensemble Learning, Weighted Loss, Numerical Weather Prediction