DeepGAD: Enhancing Rainfall Forecast Accuracy in Taiwan through Deep Learning Downscaling Approaches

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Abstract

This study focuses on improving rainfall forecasting in Taiwan by utilizing deep learning techniques. The study addresses the limitations of the European Centre for Medium-Range Weather Forecasts (ECMWF) forecast, which tends to underestimate heavy rainfall and over-predict light rain. We employ U-net and Generative Adversarial Network (GAN) neural networks for downscaling. Training and validation datasets are created using precipitation forecast data from the ECMWF at a resolution of 9 km for 2021, while labeled data is obtained from the Central Weather Bureau. The models' performance is evaluated using a separate testing dataset for 2022.

The proposed model incorporates a geographical attention layer (GAL) within the U-net architecture to capture Taiwan's geospatial characteristics. A scale-separated loss function is designed to optimize the models by partitioning the rainfall data into large-scale smoothing fields and small-scale disturbance fields. Results indicate that the GAN model consistently outperforms the baseline model, while the GAL model demonstrates distinct forecasting patterns and confidence in predicting heavy rain. The integration of all models in the DeepGAD model provides detailed rainfall distribution. This study introduces a scale separation concept, and the DeepGAD_r model emerges as the most accurate downscaling model. The importance of case analysis alongside critical success index scores is highlighted for understanding the capabilities of each model. Overall, this research contributes to enhancing rainfall forecast accuracy in Taiwan through deep learning approaches.

Key word: deep learning downscaling, geographical attention, scale-separated loss function