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An Advanced Deep Learning Rainfall Forecasts Downscaling Method in Taiwan

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Taiwan is a 35,808-km^2 island with more than 100 peaks over 3,000 meters. The complex terrain in Taiwan makes forecasters more challenging to forecast rainfall in mesoscale and storm-scale. Besides, the spatial distribution of rainfall stations is quite uneven as well. Moreover, the forecast performance of both the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Global Forecast System (GFS) is limited by Taiwan's complex terrain, having certain systematic deviations in rainfall forecasts. For example, the ECMWF forecast has underestimated heavy rainfall and over-predicted light rain in Taiwan. Consequently, to correct model deviations and provide better rainfall forecast products, advanced statistical or artificial intelligence (AI) methods should be studied.

This research applies the U-net neural network to generate downscaling rainfall prediction. We collected precipitation forecast data from the ECMWF (9 km resolution) and the GFS (22 km resolution) during 2021 as the model input. The Quantitative Precipitation Estimation and Segregation Using Multiple Sensor (QPESUMS) radar data from CWB is used as the label data. QPESUMS data can effectively help describe the complete spatial distribution of rainfall. The testing data is from the 2022 whole year. An innovative design of the proposed model is a geographical attention layer (GAL) in the U-net. The GAL helps to learn the geospatial characteristics from the QPESUMS rainfall observation. Moreover, this study uses a scale-separated loss function for model optimization, for which the rainfall is divided into large-scale smoothing and small-scale disturbance fields.

Results show that this U-net downscaling model successfully learns the feature and corrects the systematic bias in both global models, such as shifts in the rainfall caused by topographical lift and local circulation. Furthermore, based on the overall statistics of 2021, the performance diagram shows that the AI model corrects the over-prediction of light rain, while the critical success index in heavy rain is improved by 25 to 30%. The ongoing work of this research will apply generative adversarial networks to break the limitation of learning wrong features from the original forecast input data.