Deep Learning Radar Nowcasting over the Upper Tyrrhenian Sea

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The nowcasting of precipitation, defined as short-term precipitation forecasting up to 3 hours, represents a crucial challenge for several applications, including hydro-meteorological monitoring and risk management. Weather radars are the primary observational tool for nowcasting due to their high spatial and temporal resolution. However, forecasting becomes more challenging in mountainous and heterogeneous terrain, where radar coverage may be partial and spatially non-uniform. Particularly valuable in this context is information obtained opportunistically by networking radar systems operated by different regions and countries, as in the case of the cross-border radar mosaic managed within the PROTERINA 4 FUTURE project. This mosaic integrates data from S-, C-, and X-band radars across the Italy–France Maritime area, covering the Northern Tyrrhenian Sea region. For each grid point, the maximum reflectivity value observed by the available radars was selected to emphasize the most intense convective structures.

In this study, we present a deep learning–based nowcasting experiment using the radar mosaic data. Two deep learning architectures specifically designed for precipitation nowcasting were implemented: RAIN-NET and DGMR (Deep Generative Model of Radar). RAIN-NET, based on a convolutional encoder–decoder structure inspired by U-Net, provides deterministic predictions by learning spatio-temporal patterns from sequences of precipitation fields.

DGMR, a generative deep learning framework, produces forecasts of future radar fields based on past observations. The models were pre-trained on radar networks

from different countries worldwide and subsequently applied to the Tyrrhenian mosaic. They were tested on several intense rainfall events selected for their representativeness in terms of spatial distribution, evolution speed, and morphological complexity.

Results indicate that the models can generate forecasts at 30, 45, and 60 minutes while maintaining spatial coherence with observations. Performance was evaluated using metrics such as the Structural Similarity Index Measure (SSIM), the Critical Success Index (CSI), and the Mean Squared Error (MSE). Comparing RAIN-NET and DGMR highlights their complementary strengths in capturing the spatio-temporal evolution of rapidly evolving precipitation systems. The proposed approach demonstrates the feasibility and effectiveness of integrating cross-border radar data into an operational machine learning–based nowcasting framework. At the same time, it highlights critical challenges related to radar source heterogeneity, data normalization, and the representation of fast-evolving phenomena. As a final perspective, the integration of satellite observations represents a promising extension of the system. Geostationary platforms such as Meteosat Second Generation provide high-frequency multispectral imagery that can complement radar data, especially over maritime areas and regions with limited radar visibility. Satellite-derived features—such as brightness temperature fields, cloud-type identification, water vapor content enrich the input space of deep learning models, potentially improving the detection and prediction of convective initiation and offshore storm evolution. This multi-sensor integration constitutes a natural next step toward a more robust and operational nowcasting framework for the Upper Tyrrhenian region.