Proceedings of the 1st international Symposium on AI and Fluid Mechanics
Abstract No S17 A2

AI-Driven High-Resolution Precipitation Nowcasting: Insights into Atmospheric Fluid Dynamics and Spatiotemporal Correlations

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Abstract

High-resolution precipitation nowcasting plays a critical role in advancing atmospheric science and improving disaster response by predicting rainfall patterns with high spatial (500 m) and temporal (5 min) resolution. This study leverages AI-driven methods, specifically a hybrid deep learning architecture named CPrecNet, to address the challenges in predicting precipitation at these fine scales. CPrecNet integrates both temporal and spatial correlations to enhance forecasting accuracy, offering a more effective model for capturing fine-scale precipitation dynamics compared to traditional methods. We incorporate insights from integral time scales (ITS), which are derived from radar data, to interpret AI predictions across various spatial scales, including small (1 to 20 km), medium (20 to 120 km), and large (120 to 1024 km) scales. By incorporating the residual-add method, CPrecNet improves the model's ability to capture small-scale rainfall patterns, yielding better performance metrics such as RMSE and RAPSD compared to baseline models. Our results underscore the pivotal role of AI in understanding and predicting the multi-scale, dynamic nature of fluid phenomena in the atmosphere, offering insights into spatiotemporal correlations that are often challenging to capture with traditional approaches. Additionally, this study highlights the importance of using large, diverse datasets and advanced spatiotemporal augmentations to optimize model accuracy. The design of CPrecNet, informed by physical principles and robust data handling, represents a significant step forward in AI-enhanced precipitation nowcasting. By connecting AI with fluid dynamics, this work contributes to the broader intersection of machine learning and atmospheric science, providing a scalable framework for improving precipitation modeling and enhancing its interpretability.

Keywords: Explainable AI, precipitation prediction,

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