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Tracking Tropical Cyclone Based on Deterministic Meteorological Variables Prediction Using Novel Moving Window Inverted Vision Transformer

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ABSTRACT

Tropical cyclones are highly significant extreme weather phenomena, posing a direct threat to human lives and property. Additionally, they cause significant damage to coastal infrastructures, leading to long-lasting disruptions in livelihoods and activities. Furthermore, scientific studies have emphasized the alarming increase in the intensity of tropical cyclones, attributed to the combined influence of climate change and human activities. Given these circumstances, accurate prediction of tropical cyclone tracks has become increasingly crucial for effective disaster prevention, risk assessment, and mitigation strategies. While Transformer-based deep learning models, driven by the abundance of big data, have made notable progress in weather forecasting, their performance in accurately predicting extreme weather events remains a challenge. In this manuscript, we propose a novel model that addresses the limitations of existing approaches by utilizing a moving window inverted vision transformer as the foundational backbone for predicting tropical cyclone trajectories. This model effectively tackles the inherent complexities of multivariate correlations and temporal dependencies that are often overlooked. The model leverages variables extracted from the ERA5 dataset within a moving window length, which are then fed into the inverted vision transformer to train the comprehensive model. By generating more accurate deterministic predictions of these meteorological variables for future time steps, the model facilitates a more precise derivation of the tropical cyclone's track. To validate the effectiveness of our proposed model, we conduct a comparative analysis against a conventional vision transformer-based model. The results demonstrate that our model significantly improves meteorological variable predictions and reduces positional errors in tropical cyclone tracks. Additionally, we explore the impact of pyramid and isotropic architecture, parameter settings, and data decomposition on the model's performance, providing valuable insights for optimizing its efficacy.

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