Storm-Graph Vision Transformer: Max-Pooling Spatial Attention for Severe Weather Nowcasting

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Extreme weather events including hail, intense precipitation, tornadoes, and hurricanes cost billions of dollars in annual damage and endanger general public safety, yet remain challenging to predict due to their rarity and inherent unpredictability. Texas alone is struck by hundreds of hailstorms each year, incurring large financial costs and leaving many individuals stranded in unoptimal locations. In such circumstances, severe weather nowcasting—or the prediction of hazardous weather 5-60 minutes in advance—becomes crucial for timely warnings that can save lives. With that, this study aims to nowcast the probabilistic footprint of hailstorms and rainfall intensity when provided with 60 minutes of multimodal observations from the SEVIR dataset. To do so, we propose Storm Graph Vision Transformer (SG-ViT), which incorporates graph neural networks, a max-pooling vision transformer, and physics law constraints, aligning the model with atmospheric processes and natural meteorological behavior of convective storms. When tested on 541 extreme-event specific data from SEVIR, SG-ViT outperformed current state of the art architectures for severe weather nowcasting, delivering a critical success index score (CSI@181) of 0.675 for hail detection and 0.606 for extreme weather predictions. Performance substantially outperformed EarthFormer 2022 by 365% and SimCast 2024 by 236% for hail detection with an additional 95% improvement over SimCast for extreme weather. These results suggest how a physics-motivated design, mapping storm cells as discrete entities, adopting a max-pooling feature for preserving peak intensities in hail detection, and atmospheric conservation constraints to enforce realistic predictions, outperform models that borrow approaches from other domains.

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