ForeCAT: Advancing Clear Air Turbulence Prediction for Aviation Safety With Atmospheric Physics Informed Neural Networks and Spatiotemporal Weather Data

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Unexpected turbulence, particularly Clear Air Turbulence (CAT), remains one of aviation's most serious challenges, causing passenger injuries, operational disruptions, and costing airlines $500 million annually. CAT is responsible for 70% of weather-related incidents, with climate change expected to double its frequency in the coming decades. The recent May 2024 Singapore Airlines event, which resulted in fatalities and injuries, highlights the urgency for improved prediction. Detecting CAT is inherently challenging because it occurs in clear air, rendering conventional algorithms operational in the aviation industry, like Graphical Turbulence Guidance (GTG), less effective due to their reliance on linear, empirically thresholded metrics. ForeCAT offers a breakthrough approach by integrating Artificial Intelligence with atmospheric physics. Its neural network, driven by partial differential equations (PDE)-based turbulence diagnostics, captures complex turbulence interactions to achieve 95% classification accuracy, three times higher than GTG. Moreover, ForeCAT accurately predicts Eddy Dissipation Rate (EDR), the industry-standard turbulence intensity metric. ForeCAT successfully predicted severe turbulence at the Singapore Airlines event location with 87% confidence, demonstrating its potential to mitigate such incidents. ForeCAT is integrated into LoCATe, a real-time CAT prediction app that aids pilots and air traffic controllers with proactive flight path adjustments. CATalog, a low-cost turbulence measurement device, is developed to crowdsource and democratize access to turbulence data. By leveraging AI and physics-based diagnostics, ForeCAT offers a transformative solution to advance CAT forecasting and navigate the increasingly turbulent skies of the future.

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