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A New Diagnostic for Improved Forecasting of Aviation Turbulence Hazards

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Turbulence is a major aviation hazard responsible for the majority of weather-related aircraft accidents. The recent fatal turbulence event on a commercial flight from London to Singapore underscores the growing risk turbulence poses to aviation safety. As climate change is expected to strengthen upper-level jet streams, turbulence is projected to intensify in both frequency and severity, making its reliable forecasting more important than ever.

Operational turbulence forecasting often relies on the Richardson number (Ri), a classical diagnostic representing the balance between turbulent kinetic energy (TKE) generation by vertical wind shear and its suppression by stable stratification. However, the conventional Ri formulation neglects horizontal shear, which can be a crucial source of turbulence near jet streams, upper-level fronts, and regions of strong horizontal deformation.

In this study, we develop a new Ri formulation based on the full TKE budget that explicitly includes the effects of horizontal shear. We apply this diagnostic to ERA5 reanalysis dataset and evaluate its performance against in situ turbulence observations from commercial aircraft using eddy dissipation rate (EDR) as a reference. We also compare it with the conventional Ri and other widely used turbulence diagnostics. Our results show that the new Ri performs better than the conventional Ri and other indices. Furthermore, combining the new Ri with additional diagnostics leads to significant improvements in upper-level turbulence forecasting. These findings suggest that integrating this refined Ri formulation into operational forecasting systems may likely improve aviation safety, reduce flight delays, and optimise fuel consumption through better route planning.

This work demonstrates the value of revisiting classical diagnostics using a physically complete framework and highlights the importance of refining turbulence forecasting tools in a changing climate where upper-level aviation hazards are likely to become more frequent and intense.