EGU21-8598
https://doi.org/10.5194/egusphere-egu21-8598
EGU General Assembly 2021

Validation of Multi-Model-based Deterministic and Probabilistic Clear-Air Turbulence (CAT) Forecasts

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Clear-Air Turbulence (CAT) is small-scale eddies in clear sky conditions that affect cruising aircraft directly. The current turbulence prediction systems mostly produce deterministic forecasts. To consider inherent uncertainties and provide reliable probabilities for turbulence forecasts, it is also essential to produce probabilistic turbulence forecasts. In this study, we calculate multi-model-based ensemble mean CAT forecast (MMEM) and multi-model-based probabilistic CAT forecast (MMP) based on Ellrod-Knox Index (EKI) diagnostic using seven global NWP model outputs with a 0.5^{o} x 0.5^{o} resolution from The International Grand Global Ensemble (TIGGE) database. The EKI is a representative CAT diagnostic, which adding a divergence trend term for detecting CAT related to inertia gravity waves and anticyclonic flows to a combination term of vertical wind shear and total horizontal deformation to detect CAT related to frontogenesis. The 24-h and 30-h forecasts at 200, 250, and 300 hPa levels valid at 1800 UTC for a 6-month period (2016.10–2017.03) are used to calculate the 30-h EKI forecast at 250 hPa. MMEM is simply derived by averaging EKIs from seven TIGGE NWP models at a given grid point, while MMP is derived by calculating the percentage agreement of how often EKIs exceed a certain EKI threshold for moderate-or-greater (MOG)-level turbulence among seven EKIs based on different TIGGE model outputs at a given grid point. Three EKI thresholds based on the 95^{th}-, 98^{th}-, and 99^{th}-percentile values of each of the seven EKI probability density functions are tested to represent better reliability and spread of the MMP. The performance skills of MMEM and MMP are validated based on the probability of detection method and reliability test, respectively, against turbulence observations from pilot reports and in-situ flight eddy dissipation rate (EDR) data. In the validation result of deterministic forecasts, the MMEM has better performance skills than any single-model-based EKI forecasts. In the validation result of probabilistic forecasts, all MMPs show an over-forecasting, although with better reliability when applying a higher-percentile of EKI values as a threshold.