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Using a balloon-borne accelerometer to improve understanding of the turbulent structure of the atmosphere for aviation.

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This work describes the instrument development, characterisation and data analysis from 51 radiosondes specially equipped with accelerometers to measure atmospheric turbulence. Turbulence is hazardous to aircraft as it cannot be observed in advance. It is estimated that turbulence costs the airline industry millions of US dollars a year through damage to aircraft and injuries to passengers and crew. To avoid turbulence pilots and passengers rely on Clear Air Turbulence forecasts, which have limited skill. One limitation in this area is lack of quantitative unbiased observations. The main source of turbulence observations is from commercial airline pilot reports, which are subjective, biased by the size of aircraft and pilot experience.

This work seeks to improve understanding of turbulence through a standardised method of turbulence observations amenable throughout the troposphere. A sensing package has been developed to measure the acceleration of the radiosonde as it swings in response to turbulent agitation of its carrier balloon. The accelerometer radiosonde has been compared against multiple turbulence remote sensing methods to characterise its measurements including calibration with Doppler lidar eddy dissipation rate in the boundary layer. A further relationship has been found by comparison with the spectral width of a Mesospheric, Stratospheric and Tropospheric (MST) radar. From the full dataset of accelerometer sonde ascents a standard deviation of 5 m s^{-2} is defined as a threshold for significant turbulence. The dataset spans turbulence generated in meteorological phenomena such as jet streams, clouds and in the presence of convection. The analysis revealed that 77% of observed turbulence could be explained by the aforementioned phenomena. In jet streams, turbulence generation was often caused by horizontal processes such as deformation. In convection, turbulence is found to form when CAPE >150 J $kg^{-1.}$ Deeper clouds were found to be more turbulent due to the increased intensity of in-cloud processes. The accelerometer data were used to verify the skill of turbulence diagnostics, in order to assess which diagnostics are best at forecasting turbulence. It was found using a Receiver Operating Characteristics curve analysis that turbulence diagnostics calculated using ECMWF high resolution data that featured wind speed, deformation and relative vorticity advection predicted turbulence best with area under curve values of 0.7,0.66 and 0.62 respectively. This work provides a new, safe and inexpensive method to retrieve in-situ information about the turbulent structure of the atmosphere. It can inform the aviation industry through identifying turbulence generation regions and assess which predictive diagnostics are the most skilful.