Turbulence Measurements Derived from ADS-B Reports

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Encounters with atmospheric turbulence continues to be a serious concern for the aviation community. The problems include passenger and flight attendant injuries, deleterious effects on the efficient use of airspace, and the shortened lifespan of aircraft due to fatigue effects. Enhanced and more accurate observations of turbulence would help improve the physical understanding of the turbulence phenomenon as well as its operational predictability. However, dense, routine, and quantitative observations of turbulence are still lacking, and without them it is difficult to provide complete and accurate information about the turbulent state of the atmosphere for use in tactical and strategic turbulence avoidance. Additionally, observations are required for verification and tuning of automated turbulence forecast systems such as the Graphical Turbulence Guidance System (GTG). Routine observations of turbulence are available through verbal reports from pilots (PIREPs) and through automated *in situ* measurements on some aircraft. Inference of turbulence from radar and satellite imagery is also available. Many of these observations are included in a nowcast version of GTG, GTGN, but all of these combined sources are still not sufficient to provide timely and complete representations of turbulence.

One viable option to augment existing turbulence observations is to use the Automatic Dependent Surveillance – Broadcast (ADS-B) data to indicate the presence of turbulence. This information can be collected by ground station receivers and can also be accessed by other aircraft to provide situational awareness. A key advantage in using these data is that it avoids the problem of installing additional software and/or hardware on aircraft to make and transmit observations. ADS–B is an element of the U.S. NextGen and Europe's SESAR enhancements of the airspace system. ADS–B has been required on most aircraft in controlled U.S. airspace as of 2020, and as of 2017 it became mandatory for some aircraft in Europe. The amount of data potentially available from ADS-B is significant. For example, as of July 1, 2023 in U.S. airspace, there are approximately 160,000 aircraft equipped with ADS-B datalink units, of which approximately 105,000 are General Aviation aircraft. Besides networks of ground-based receivers for collecting the ADS-B signals, there is a satellite network that also picks up the signals, which allows for coverage over oceanic and other remote regions.

The National Center for Atmospheric Research (NCAR), sponsored by the Federal Aviation Administration's (FAA) Weather Technology in the Cockpit (WTIC) program, has developed an operationally useful turbulence detection algorithm using routine ADS-B reports. These efforts began in 2019 and have matured to the point where operational demonstrations are being undertaken, and planning for operational deployment and use in the U.S. is underway. Furthermore, efforts have recently begun with Aireon, a private company that operates a satellite-based ADS-B (SBA) network to investigate the feasibility of applying the FAA-sponsored

algorithms to the SBA data feed. We will discuss the algorithmic challenges and how they have been overcome, as well as presenting encouraging results from the various R&D activities, and indicating the path ahead towards operational deployment.

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