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Validating ADS-B Data for Use in Noise Modeling Applications

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Aircraft noise continues to be a major environmental issue impacting airports and their surrounding communities. Beyond being an annoyance, aircraft noise has also been found to have potentially adverse health effects on humans and animals. Thus, international, national, and local regulations have been adopted to quantify, limit, and mitigate aircraft noise. Software developed by the Federal Aviation Administration to estimate the impacts of airport noise relies on operations information that may be difficult to obtain for aircraft operating under visual flight rules at non-towered airports. Hence, leveraging the use of ADS-B as a low-cost source of operations data may improve noise estimation methods at such airports. To validate this approach, ADS-B data was compared to GPS records from aircraft avionics. With an average error of 57.72 feet laterally, 112.36 feet vertically, and 126.32 feet combined, resulting noise estimation errors as a result of ADS-B position errors are expected to be less than seven decibels. It was also found that ADS-B data can be significantly improved by incorporating atmospheric data to improve altitude information, leading to a reduction in estimation errors. The results of this study highlight the potential applicability of ADS-B usage in noise estimation and other applications.

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Introduction

Noise is a negative byproduct of aircraft operations that affects not only individuals at airports, but also in surrounding communities. In addition to being an annoyance, environmental noise such as that from flying aircraft has been found to have detrimental effects on the health and development of humans and animals. Thus, noise mitigation, abatement procedures, policies, and regulations have been studied and implemented at airports around the world. Aside from sound meters, noise models based on flight track data and aircraft information are used to study aircraft noise. However, non-towered airports, which comprise the largest proportion of U.S. airports, do not have access to these pertinent data due to the lack of radar services and tower facilities. As such, the use of ADS-B data collected from low-cost devices has been proposed as a method to collect information necessary to model noise, enabling non-towered airports to leverage noise modeling systems (Yang & Mott, 2022). Huynh et al. (2022) have similarly used ADS-B data to model aircraft approach performance to evaluate the benefit of delayed deceleration approaches on aircraft noise impacts, while Gagliardi et al. (2017) have used ADS-B data to evaluate the compliance rate and effect of noise abatement procedures.

This study provides a quantification of the errors associated with ADS-B data when compared to recorded onboard position information and was performed to provide a sense of the errors from noise estimation that may be attributable to the use of ADS-B as the data source. A total of 246,349 position reports from a sample of 60 flights conducted by all 13 Piper Archers of the Purdue University fleet over a five-month period were used. Errors were calculated by comparing received ADS-B data with corresponding data collected from onboard flight recorders built into the aircraft's Garmin G1000Nxi avionics package.

Background

In a review conducted by Basner et al. (2014), acute and chronic exposure to noise has been established to cause adverse auditory effects in humans, including hearing loss and symptoms such as tinnitus. In addition, noise exposure has been found to increase the risk of cardiovascular disease, decrease cognitive performance, and negatively affect the quality of sleep. Negative impacts on sleep further affect risks for cardiovascular diseases, diabetes, and weight gain and obesity (Swift, 2010). Meta-analyses have shown a 7% to 17% increase in the risk of cardiovascular conditions and diseases per 10 dB increase in exposure to transportation noise, after adjusting for known risk factors (Basner et al., 2014). Studies have also shown negative effects of transportation noise such as those from air and road traffic on children's learning outcomes, cognitive performance, reading ability, memory, standardized testing performance, and endocrine responses (Basner et al., 2014; Stansfeld & Clark, 2015). Thus, efforts to reduce noise exposure are expected to reduce annoyance, improve children's development, improve sleep, and lower the prevalence of cardiovascular diseases, while improvements in noise modeling and monitoring can only further improve our understanding of noise and its effects (Basner et al., 2014; Stansfeld & Clark, 2015).

In an older study by Manci et al. (1988), noise effects on different domestic and wild animals were established to include fright, hearing loss, decreased fertility, and hypertension. Thus, the effect of aircraft noise on wildlife and the environment must also be considered.

Pertinent Regulations and Standards

Due to the apparent and potential effects of aircraft noise exposure, the United States has federal noise control regulations and guidance in place, identifying public health as the physiological and psychological well-being of the public, the effects of noise and the common interest of the community are to be considered (Penn State, n.d.). Similarly, the International Civil Aviation Organization (ICAO) has adopted Annex 16, Volume I – Aircraft Noise as a standard for aircraft noise regulations (ICAO, n.d.).

To quantify aircraft noise exposure, the Federal Aviation Administration (FAA) uses the Day-Night Average Sound Level (DNL) as a primary metric, in addition to other commonly used metrics such as Sound Exposure Level (SEL), Sound Pressure Level (SPL), Equivalent Sound Level (L_{eq}), Maximum A-weighted Sound Level (L_{max}), Time Above a Specified Sound Level (TA), and Number of Events Above a Specified Noise Level (NA) (Penn State, n.d.). These metrics are calculated through sound level meters deployed around airports, around aircraft flight paths or through models that estimate the amount of noise received at a specific location based on air traffic. Meanwhile, the ICAO and FAA use Effective Perceived Noise Level (EPNL) for the purpose of aircraft noise compliance certification (Appendix A to Noise Standards, 2021; ICAO, n.d.).

With regard to aircraft type certification, Title 14 of the Code of Federal Regulations (14 CFR) Part 36 contains the noise limits to which different categories of aircraft must conform for type certification. In addition, it outlines the procedures and adjustments to be made during the data collection process. (Appendix A to Noise Standards, 2021).

For airports, 14 CFR Part 150 contains regulations pertaining to the development and use of airport noise exposure maps and airport compatibility programs, in addition to information and regulations defining compatible land use around airports as a result of noise created by aircraft operations. Noise measurement standards are outlined in the appendix of the regulation (Appendix A to Airport Noise Compatibility Planning, 2021). For example, appendix A of Part 150 specifies the use and calculation of Yearly Day-Night Average Level (YDNL) and the need for continuous 65, 70, and 75 YDNL contours to be developed for an airport through measurement or estimation. Using these noise contours, the determination as to whether the land use is “compatible” based on Federal regulations as seen in Figure 1, or pertinent local laws, can be made. Appendix A of Part 150 further specifies that to develop a computer-modeled noise exposure map, flight tracks, fleet mix, operational data and trends, and approach paths must be collected, among other parameters, for use with an FAA-approved method or software.

Figure 1
Table 1 of Appendix A of 14 CFR Part 150

TABLE 1—LAND USE COMPATIBILITY* WITH YEARLY DAY-NIGHT AVERAGE SOUND LEVELS

Land use	Yearly day-night average sound level (L_{dn}) in decibels					
	Below 65	65-70	70-75	75-80	80-85	Over 85
RESIDENTIAL						
Residential, other than mobile homes and transient lodgings	Y	N(1)	N(1)	N	N	N
Mobile home parks	Y	N	N	N	N	N
Transient lodgings	Y	N(1)	N(1)	N(1)	N	N
PUBLIC USE						
Schools	Y	N(1)	N(1)	N	N	N
Hospitals and nursing homes	Y	25	30	N	N	N
Churches, auditoriums, and concert halls	Y	25	30	N	N	N
Governmental services	Y	Y	25	30	N	N
Transportation	Y	Y	Y(2)	Y(3)	Y(4)	Y(4)
Parking	Y	Y	Y(2)	Y(3)	Y(4)	N
COMMERCIAL USE						
Offices, business and professional	Y	Y	25	30	N	N
Wholesale and retail—building materials, hardware and farm equipment	Y	Y	Y(2)	Y(3)	Y(4)	N
Retail trade—general	Y	Y	25	30	N	N
Utilities	Y	Y	Y(2)	Y(3)	Y(4)	N
Communication	Y	Y	25	30	N	N
MANUFACTURING AND PRODUCTION						
Manufacturing, general	Y	Y	Y(2)	Y(3)	Y(4)	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	Y(6)	Y(7)	Y(8)	Y(8)	Y(8)
Livestock farming and breeding	Y	Y(6)	Y(7)	N	N	N
Mining and fishing, resource production and extraction	Y	Y	Y	Y	Y	Y
RECREATIONAL						
Outdoor sports arenas and spectator sports	Y	Y(5)	Y(5)	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts and camps	Y	Y	Y	N	N	N
Golf courses, riding stables and water recreation	Y	Y	25	30	N	N

Note. This figure shows the maximum allowable Yearly Day-Night Average Levels (YDNL) for different types of land uses. Y indicates the land use is allowable at that YDNL and N indicates that it is not. Parentheses indicate notes (included in the appendix of the regulation) while the numbers 25, 30, or 35 indicate the noise level attenuation designed or built into the structure to be acceptable. Table adapted from "Appendix A to Airport Noise Compatibility Planning", 14 C.F.R. § A150, 2021 (https://www.ecfr.gov/current/title-14/chapter-I/subchapter-I/part-150).

Current Methods

The primary noise model that the FAA uses is part of the Aviation Environmental Design Tool (AEDT) software available for airport operators and related users that support modeling and estimation of environmental impacts such as fuel consumption, emissions, air quality impacts, and noise of individual flights, or flights on a larger regional or national scale (FAA, n.d.-a). The noise model part of AEDT replaced the Integrated Noise Model (INM) previously used by the FAA and specified in 14 CFR Part 150 (FAA, 2019). AEDT is comprehensive and can be extremely detailed. Information such as the number and type of ground service equipment utilized for a specific operation can be provided to improve estimates of its environmental impacts, while for noise modeling, an acoustic impedance adjustment option is available to correct for noise propagation characteristics due to non-standard meteorological conditions (FAA, 2021a; FAA, 2021b)

Users of AEDT add flights to a study by specifying events and conditions, including the amount of time spent on the ground and taxiing, the flight track, the type of operation, the aircraft and its engines, the takeoff thrust settings used, the percentage of flights that perform touch and goes, and in multi-aircraft studies, the fleet mix (FAA, 2021a). This information is used by AEDT to calculate estimated noise impacts on the surrounding areas. AEDT does this by utilizing information from European Organisation for the Safety of Air Navigation's (EUROCONTROL's) Base of Aircraft Data (BADA) to approximate the actual performance and flight profiles of the aircraft as realistically as possible based on the input data. The approximated flight paths and climb/descent profiles are then used in conjunction with EUROCONTROL's Aircraft Noise and Performance (ANP) database to estimate noise exposure metrics and impacts (FAA, 2021b). These features allow users to produce detailed and accurate environmental impact estimates based on the input data.

While AEDT is an established tool that gives airport operators and stakeholders detailed estimates of the environmental impacts of airport operations, its output is only as good as its input. Thus to be accurate and complete, information is needed from the user. However, for non-towered airports, information such as fleet mix and number of operations are often limited to estimates and approximations as compared to towered airports that have air traffic controllers that tally the number of operations. Additionally, as aircraft flying under Visual Flight Rules (VFR) are often not on any standard or published routes, the precise path of VFR aircraft is usually unknown or unrecorded by the airport operator. Hence, the aggregate trends of VFR aircraft used for developing noise models are often approximate, as well. Thus, a method of tracking and recording aircraft flight paths is beneficial for use with noise modeling tools to improve the accuracy of the input data, especially for VFR aircraft and aircraft at non-towered airports. Rather than using estimates, approximations, and standard/published procedures (for flight under Instrument Flight Rules (IFR)), the actual tracks of aircraft can be used as input. The increased knowledge and accuracy of aircraft flight paths will enhance the accuracy of noise estimates. This effect is magnified given that most noise metrics are average-based, and an incorrect assumption of the typical flight path can lead to significantly different metrics calculated for a specific position. Further, the knowledge of the actual aircraft used, rather than a predicted aircraft, can ensure that the software uses the best model for that aircraft.

Automatic Dependent Surveillance-Broadcast (ADS-B)

Automatic Dependent Surveillance-Broadcast (ADS-B) is an aircraft surveillance system introduced as part of the FAA's NextGen program, designed to supplement, and improve current aircraft surveillance methods. The implementation of ADS-B has enabled new technologies in areas such as aircraft collision avoidance and operation counts by reducing the costs of locating and monitoring aircraft (Kunzi & Hansman, 2013; McNamara, et al., 2016). Costs are reduced due to the design of the system; equipped aircraft have transponders that transmit position information at least once per second while airborne and at least once per five seconds while on the ground, which are then received by ground stations on the 1,090 or 978 MHz frequency, eliminating the need for RADAR systems to detect and estimate the position of different aircraft (Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment performance requirements, 2010). While operating ADS-B transponders is not required for all aircraft, they are required for aircraft flying in and around most types of controlled airspace in the United States and are also required in multiple international airspaces (Aircraft Owners and Pilots Association, 2015). Thus, most aircraft, especially those that operate in busier environments, are equipped with ADS-B. As of August 1, 2021, 155,471 out of the approximately 220,000 aircraft (around 70%) in the US are equipped with ADS-B transponders (Bureau of Transportation Statistics, 2020; FAA, n.d.-b). US regulations require the accuracy of ADS-B systems utilized for aerial navigation to be within 0.05 nautical miles (approximately 300 feet) and have a maximum transmission latency of 0.6 seconds if uncompensated, and 2.0 seconds when compensated through extrapolation (Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment performance requirements, 2010).

ADS-B transponders transmit aircraft identification, surface position, airborne position, airborne velocities, aircraft status, target state and status information, and aircraft operation status, and can be received by an appropriately configured receiver (Sun, 2021). Using aircraft identification, the corresponding aircraft type and engine, relevant to noise models, can be identified using information from the FAA's aircraft registry. Position information transmitted is derived from the Global Navigation Satellite System (GNSS), while altitude data transmitted include both GNSS-derived and barometrically derived altitude. ADS-B transmissions also include a navigation uncertainty category (NUC) with regard to position and velocities, with codes corresponding to different levels of uncertainty bounds. The NUC information can be used to exclude data when not expected to meet the desired specifications.

By using easily and inexpensively collectible ADS-B data, airport operators, especially of non-towered airports, can collect aircraft trajectory data for use with noise estimation models and software such as AEDT. This method potentially offers significantly improved local noise monitoring without the need for expensive data collection tools such as community sound level meters.

To test the concept, a pilot study funded by an Airport Cooperative Research Program Next Step award was conducted at the Purdue University airport. The study was divided into two stages. The first stage, reported in this article, focused on validating and measuring the accuracy of ADS-B data and was intended to answer the research question: how accurate is ADS-B data from one receiver? The second stage, described elsewhere, will report the accuracy of the noise estimates using the collected ADS-B data in conjunction with a simplified noise propagation model in comparison to physically recorded sound levels.

Methodology

Data Collection

To collect ADS-B data for use with the noise estimation method, an ADS-B receiver at the airport being studied was repurposed. The ADS-B receiver used was a Raspberry Pi 3B with a software-defined radio (SDR) connected to a dipole antenna mounted on the roof of the airport's terminal. The receiver utilized the open-source dump1090 software to decode received signals which were then saved using socket30003 software and regularly uploaded to a cloud storage network (Adsbxchange, 2018; Sluis, 2017). The receiver's amplifier gain was adjusted to ensure that ADS-B signals from aircraft within 10 nautical miles of the airport were consistently being received and were neither too weak to be decoded nor too strong that they were filtered out by the software.

To validate the accuracy of the four-dimensional (longitude, latitude, altitude, and time) ADS-B data collected by the receiver, data from 13 G1000NXi units of Purdue University Piper Archer training aircraft were extracted for comparison to serve as the baseline. The G1000NXi Integrated Flight Deck is an avionics package manufactured by Garmin that is comprised of displays, computers, and sensors, replacing traditional analog aircraft instruments and systems.

Beyond providing flight and navigation data for the pilots of the aircraft, the G1000NXi also contains a flight data logging system that records flight and engine data onto an SD card every second. This data contains information including, but not limited to, the local date and time (to the nearest second), UTC offset, latitude (degrees), longitude (degrees), indicated barometric altitude (feet, as adjusted by the altimeter setting) and GPS altitude (feet above mean sea level [MSL]). Each log produced by the system begins as the system boots up and ends when the system is shut off and is periodically uploaded to an online repository via a cellular device installed in the aircraft. Each recorded log usually corresponds to one continuous flight from when the avionics master switch is turned on until it is turned off. This one "flight" may include more than one takeoff and landing such as when "touch and goes" are performed or when landings at multiple airports occur.

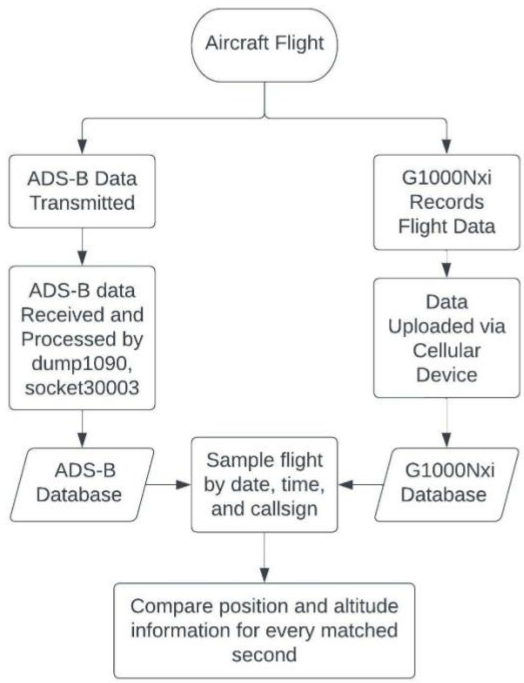
Validation Process

Software was developed and used to calculate the mean error between ADS-B and G1000NXi positions at a given time, measured as the distance or difference in altitude between both reported points, in feet. For every G1000NXi log entry, a corresponding ADS-B record for the date and time was selected, and if more than one ADS-B record for a given second of G1000NXi entry was found, the entry closest to the whole-second (rounded down) was used for the comparison (see Figure 2).

To find the distance between the reported latitude and longitude coordinates, the geodesic distance (based on the WGS-84 ellipsoid model of the earth) was calculated based on an algorithm provided by Karney (2013). While this method assumes the two positions are on the surface of the earth, the altitude of the aircraft was insignificant due to its range (no more than 12,000 feet). This distance based on the latitude and longitude coordinates of the two different records is considered the "lateral" position error.

The vertical (altitude) error and vertical (altitude) absolute error were calculated separately and were provided based on the two different altitude fields recorded by the G1000NXi (indicated barometric altitude and GPS altitude above MSL). The raw error values were found to show the potential positive or negative bias between the ADS-B-reported barometric altitude and the G1000NXi-reported altitude, while the absolute error was also calculated to quantify the error in general. GNSS-derived ADS-B altitude was not used for comparison; only ADS-B-reported barometric altitude was used as that was the only altitude data collected by the utilized software.

Figure 2
Flowchart of ADS-B Data Validation Process



Results

Approximately 3,400 G1000NXi logs from June 3, 2021, to October 31, 2021, were available on the online repository of the Purdue University fleet. A total of 77 random samples were chosen using a randomized index from across the 3,400 total logs. Because 17 of the randomly selected logs had issues preventing their processing (including ground operations not received by the ADS-B receiver, unusable time data due to the limitations of the error-calculating program, or unknown data errors), only 60 of the logs were utilized for comparison.

The 60 sampled logs were from all 13 Piper Archers in the Purdue fleet and included data from June 4, 2021, to October 31, 2021. The sampled logs also encompassed all types of regular movements of university aircraft, including touch and goes, practice maneuvers, and cross-country flights, with an average duration of 78.53 minutes per flight. A total of 246,349 ADS-B and G1000NXi points from the 60 samples used were tabulated and compared to infer the parameters of the lateral and vertical errors.

The sample lateral error had a mean of 57.72 feet with a standard deviation of 44.66 feet, a minimum of 0.07 feet, a median of 47.47 feet, and a maximum of 471.17 feet. With 95% confidence, the mean of lateral errors in the studied population was between 57.55 and 57.90 feet.

The sample absolute vertical error based on the indicated altitude recorded by the G1000NXi had a mean of 112.36 feet with a standard deviation of 69.55 feet, a minimum of 0.00 feet, a median of 121.00 feet, and a maximum of 324.90 feet. With 95% confidence, the mean absolute vertical error based on the indicated altitude recorded by the G1000NXi was between 112.09 and 112.64 feet.

The sample absolute error based on the GPS altitude reported by the G1000NXi had a mean of 142.83 feet, with a standard deviation of 92.92 feet, a minimum of 0.00 feet, a median of 141.10 feet, and a maximum of 462.30 feet. With 95% confidence, the mean raw vertical error based on the GPS altitude reported by the G1000NXi was between 142.46 and 143.20 feet.

The sample raw vertical error based on the indicated altitude parameter had a mean of -81.66 feet with a standard deviation of 103.90 feet, a minimum of -324.90 feet, a median of -109.90 feet, and a maximum of 280.40 feet. With 95% confidence, the mean raw vertical error based on the indicated altitude recorded by the G1000NXi was between -82.07 and -81.25 feet. Based on these data, the G1000NXi reported altitudes above the ADS-B reported altitudes more often than below the ADS-B reported altitudes.

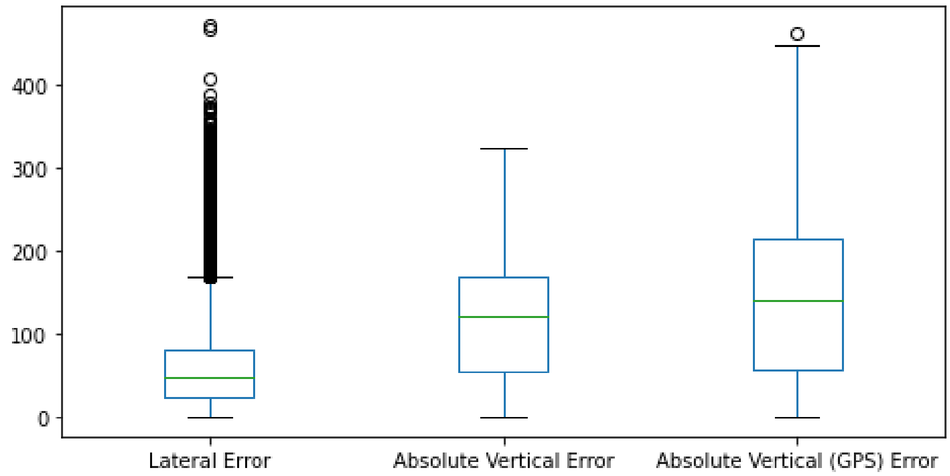
The sample raw vertical error based on the GPS-reported altitude had a mean of -124.23, with a standard deviation of 116.63, a minimum of -462.30 feet, a median of 134.00 feet, and a maximum of 352.20 feet. With 95% confidence, the mean raw vertical error based on the GPS altitude reported by the G1000NXi was between -124.70 and -123.77 feet.

A summary of the sample statistics can be found in Table 1 while boxplots comparing the lateral and absolute vertical errors can be seen in Figure 3.

Table 1
Summary Statistics of Errors

	Mean	Standard Deviation	Minimum	Median	Maximum
Lateral error	57.72	44.66	0.07	47.50	471.17
Absolute vertical error (indicated)	112.36	69.55	0.00	121.00	324.90
Absolute vertical error (GPS)	142.83	92.92	0.00	141.10	462.30
Vertical error (indicated)	-81.66	103.90	-324.90	-109.80	280.40
Vertical error (GPS)	-124.23	116.63	-462.30	-134.40	352.20

Figure 3
Boxplots of Lateral and Absolute Vertical Errors (in feet)



Discussion

Based on the sample data and inferences about the population means, the vertical error between the ADS-B barometric data usually reported lower altitudes than the indicated or GPS altitude recorded by the G1000NXi. Additionally, the error between the ADS-B-reported altitude and the G1000NXi-reported GPS altitude was greater and had higher variability than the error between the ADS-B-reported altitude and the G1000NXi-reported indicated altitude. The lateral error was less than the vertical errors and had lesser variability but with numerous outliers.

Some error is due to a time precision issue as data from the G1000NXi is reported to the nearest second while ADS-B data are reported to the nearest millisecond, and the error calculation program utilized for this project compares data points reported closest to the same second, rounded down. Assuming a groundspeed of 100 knots, an aircraft would travel approximately 169 feet in a given second, allowing an inherent error to exist through this validation procedure even if the data were perfectly accurate. However, errors in altitude, especially when the aircraft is not climbing, or descending, cannot be explained by a precision error in time. Rather, some of the altitude error is due to a precision error in the reported altitude. ADS-B data contains altitude reported in 25-foot increments while the G1000NXi records altitude to the tenth of a foot. Further, the wide spread of error between the recorded ADS-B altitudes and G1000NXi indicated altitudes (altitude adjusted according to the altimeter setting) is due to the ADS-B altitude not being adjusted for non-standard altitude and temperature. This systematic error was previously identified by Mott et al. (2020) who developed a regression model to accurately compensate for the unadjusted ADS-B altitude data. This issue is also probably compounded by calibration and accuracy issues of reporting transponders. Lastly, some error is likely due to the delay between the time the position data is transmitted from the aircraft's transponder to the time it is received and processed by the ADS-B receiver. This issue is most pronounced for aircraft flying further away from the receiver.

Laterally, the mean error of 57.72 feet is about 1.65 times the wingspan of a Piper Archer and it takes approximately 0.34 seconds for an airplane to fly at a groundspeed of 100 knots (assuming it is in the same axis as the error). This calculated error is within the maximum inherent error of the calculation method (one second of flight, approximately 169 feet) and may completely be accounted for by this systematic error. The altitude error could also be further reduced by implementing corrections for atmospheric pressure as described by Mott et al. (2020).

The overall error of the reported ADS-B data based on the G1000NXi data can be described by calculating the resultant "slant" distance from the lateral and vertical errors. Assuming the lateral and vertical errors are independent, the mean slant distance between reported positions can be approximated using the Pythagorean theorem as the square root of the product of the lateral and vertical errors squared, further assuming that any errors resulting from the curvature of the earth are insignificant. Based on this method, the mean slant distance between the ADS-B reported points and the G1000NXi data, using the reported indicated altitude, is 126.32 feet. This result is consistent with the 33-meter (approximately 108 feet) minimum error found in a previous study by Zhang et al. (2011). In the context of noise estimation, this error can lead to an estimation error of up to seven decibels at distances between 200 and 400 feet based on data from the EUROCONTROL NPD database for PA28 aircraft (EUROCONTROL, 2020). At greater distances, due to the logarithmic function of sound levels, this position error would lead to lower noise estimate errors. Given that the lateral error is most likely attributable to a systematic error in the comparison while the altitude error is most likely due to systematic errors from the received ADS-B data, implementing the atmospheric adjustments for the received ADS-B data should be the first step in improving the ADS-B data for noise modeling purposes.

Assumptions and Limitations

A few assumptions and limitations were present in this study. First, given that G1000NXi data were used as the point of comparison for the first stage validation of the ADS-B data, it was assumed that the recorded G1000NXi position and time data were true and accurate. Given that ADS-B and the G1000NXi are GNSS-based systems, the accuracy of the position data will be contingent upon the accuracy and operability of GNSS services during the operations being studied. Second, as no meteorological data was collected as part of this validation process, adjustments to the altitude reported by ADS-B could not be applied nor tested. Additionally, the G1000NXi and ADS-B data came from only one aircraft make, type, and model. The equipment (avionics and transponder) of all the aircraft studied were identical, and as such, errors resulting from the use of different equipment are not captured by the study. The results from this study are representative of Piper Archer aircraft equipped like Purdue University's. Reporting errors (position and latency) of different ADS-B reporting transponders may be different given the higher margin of error accepted by regulations, and as such may warrant further study.

Conclusions

The availability and use of accurate and precise aircraft position data obtained through the operation of cost-effective ADS-B receivers will enable non-towered airports to use noise estimation models and software to estimate airport noise impacts. The historical data provided by ADS-B may also lead to improved noise exposure models when compared to current methods, especially for VFR traffic, by eliminating the need to estimate aircraft flight paths. This article reported calculated ADS-B position errors in comparison with position data from onboard avionics equipment. With an average position error of 57.72 feet laterally, 112.36 feet vertically, and 126.32 feet combined, errors associated with raw ADS-B data should result in noise estimation errors of less than seven decibels at the closest distances (EUROCONTROL, 2020). Position information can be most significantly improved by accounting for atmospheric conditions and adjusting ADS-B reported altitude.

The findings of this study provide additional information on the performance and accuracy of ADS-B. This information can provide an idea of the margin of error associated with ADS-B data use for applications such as those by Huynh et al. (2022) and Gagliardi et al. (2017).

The application of ADS-B in noise modeling can be used in noise impact studies and noise abatement programs at airports and their communities around the US and the world. Further, with the push towards the increased use of air transportation through the integration of Unmanned Aerial Systems, Urban Air Mobility, and Advanced Air Mobility, the same model and concepts from this application can be used to study the noise impacts of such systems. Lastly, the findings related to the accuracy of raw ADS-B data and the need for compensation for atmospheric conditions can be used to guide the development of other uses of ADS-B data.

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