International Civil Aviation Organization

The Nineteenth Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/19)

Pattaya, Thailand, 27-30 May 2014

Agenda Item 5: Airspace Safety Monitoring Activities/Requirements in the Asia/Pacific Region

COMPARISON OF AVERAGE ASE FOR AIRCRAFT MONITORING GROUPS

(Presented by United States/PARMO)

SUMMARY

This paper compares results of the average estimated Altimetry System Error (ASE) for aircraft monitoring groups obtained from the Aircraft Geometric Height Measurement Element (AGHME), Automatic Dependent Surveillance – Broadcast (ADS-B) geometric height data, GPS-based Monitoring System (GMS), Height Monitoring Units (HMU) in Japan and Europe, and ADS-B geometric height data from Australia. These comparisons are used to demonstrate that the ASE results obtained from various height monitoring systems are consistent.

1. INTRODUCTION

1.1 The FAA Technical Center developed the Aircraft Geometric Height Measurement Element (AGHME) system, a ground-based multi-lateration monitoring system, to estimate the geometric height of aircraft operating in airspace in its coverage area. The geometric height data provided by the AGHME system is used in conjunction with meteorological data to produce estimates of aircraft Altimetry System Error (ASE).

1.2 To assure the AGHME-provided estimates of aircraft ASE are consistent with those provided by other monitoring systems, the PARMO compares the estimates of ASE obtained from the AGHME with those obtained from other sources. For instance, throughout the development of the AGHME system, the FAA Technical Center utilized an Enhanced GPS-based Monitoring Unit (EGMU), placed onboard research aircraft for validation purposes. For this paper, comparisons of the average estimated ASE for each aircraft monitoring group were performed using ASE estimates obtained from the AGHME, the FAA's GPS-based Monitoring System (GMS), the EuroControl and Japan Airspace Safety Monitoring Agency (JASMA) HMUs, and the FAA's and AAMA's Automatic Dependent Surveillance – Broadcast (ADS-B) geometric height data.

1.3 A notable difference between the methods in which ASE estimates are prepared between systems is that the entire ASE estimation is accomplished within the HMUs and contributing geometric heights are not kept. The positioning of the reference pressure level contributes to the overall measurement error of each system, HMU, ADS-B and AGHME. An ideal comparison would be to position two systems close to each other, prepare estimates for a calibrated aircraft or set of aircraft with known characteristics and then compare the resulting geometric height estimates. Obviously, this is not possible due to cost and logistical reasons.

1.4 A practical method of comparison, however, is to obtain large numbers of estimates for aircraft monitoring groups. Under the Central Limit Theorem, as a large number of estimates are accumulated, the mean of the underlying distribution is increasingly better estimated. Therefore, as ASE estimates are accumulated by both measurement systems, the means of individual groups should gravitate toward the same value. The purpose of this paper is to present the comparison results of the average estimated ASE for aircraft monitoring groups obtained from multiple ASE measurement systems.

2. DISCUSSION

2.1 Aircraft ASE is computed by EuroControl and the North Atlantic (NAT) Central Monitoring Agency (CMA) using the HMU, which is a ground-based system. There are four HMUs - three in contiguous Europe and one in the United Kingdom. JASMA also has one HMU is Setouchi, Japan. The HMU produces estimates of Total Vertical Error (TVE), ASE and Assigned Altitude Deviation (AAD) directly.

2.2 The AGHME system estimates only aircraft geometric height. TVE, ASE, and AAD are estimated through post-processing using meteorological and Mode S data. Currently, there are six AGHME systems operational in North America, four in the United States and two in Canada. (There is also one more in the US, however, it is still in testing.) The data shown portrays aircraft monitoring groups, defined by the ICAO Minimum Monitoring Requirements (MMR) Table, with the exception of data from the GMS comparison.

2.3 For ADS-B, an aircraft's GPS antenna sends the geometric height information in a message, which allows the ASE to be directly computed. Since the geometric height does not need to be estimated, it produces a slightly more accurate estimate of the TVE, ASE and AAD. In addition, a minor alteration was made in the comparison of the ADS-B data. Since there are fewer data, a minimum airframe count of ten was used, rather than twenty-five, which was used for the other measurement systems.

2.4 The EGMU is a portable device that collects a GPS data file during flight. Upon completion of a monitoring flight, the data is processed post-flight and then transmitted to the FAA for further processing to calculate the aircraft's ASE. Aircraft monitoring groups are not yet included in GMS data, so the comparison was completed using aircraft types.

2.5 Figure 1 contains a plot of the average ASE estimates for each aircraft monitoring group. The average ASE estimates obtained from the AGHME system are shown on the horizontal axis and the ASE estimates from EuroControl HMUs are shown on the vertical axis, adjusted for a bias of four feet estimated from the entire sample sets for each system. Perfect agreement between the average ASE estimates obtained from the AGHME and HMU systems is evident for those aircraft monitoring groups lying along the red diagonal line shown in Figure 1. For example, the average ASE estimates from the AGHME and HMU systems for the C17 aircraft monitoring group show excellent agreement. That is the estimate of the mean ASE for those groups are essentially the same and resulting conclusions about the group performance can be made irrespective of the measurement system. Additionally, the two aircraft monitoring groups in the AGHME sample with the largest number of contributing airframes and largest sample sizes, B737NX and A320 agree quite favourably.

2.6 The plots of the means of the contributing groups show very good correlation. As one system estimates the group mean ASE performance, the alternate system shows the same or similar results. Most comparisons shown in each figure show very good agreement between the results obtained from the AGHME and other monitoring systems.

2.7 A notable exception to the correlated results is the A300 group. The average ASE estimate for the A300 from the AGHME systems has a value of approximately 50 ft, whereas the average ASE estimate from the HMU system has a value of approximately 0 ft. A detailed analysis of the two contributing samples revealed that the airframes that contributed did not have common ASE characteristics. In each sample, sets were composed of two contributing sub-sets that had different mean performances. The apparent difference between the HMU and AGHME A300 sample set was a difference between the relative proportions of the contributing sub-sets. This violates the underlying assumption that an aircraft monitoring group is composed of a unimodal, exponentially decreasing probability distribution. This performance difference has been brought to the attention of Airbus officials. So, this comparative technique is also a method to reveal non-uniform characteristics of the inter-regional samples, given sufficient sample sizes. A similar conclusion may also be true for the aircraft monitoring group P180. The FAA is working with Piaggio to fix this issue as well.

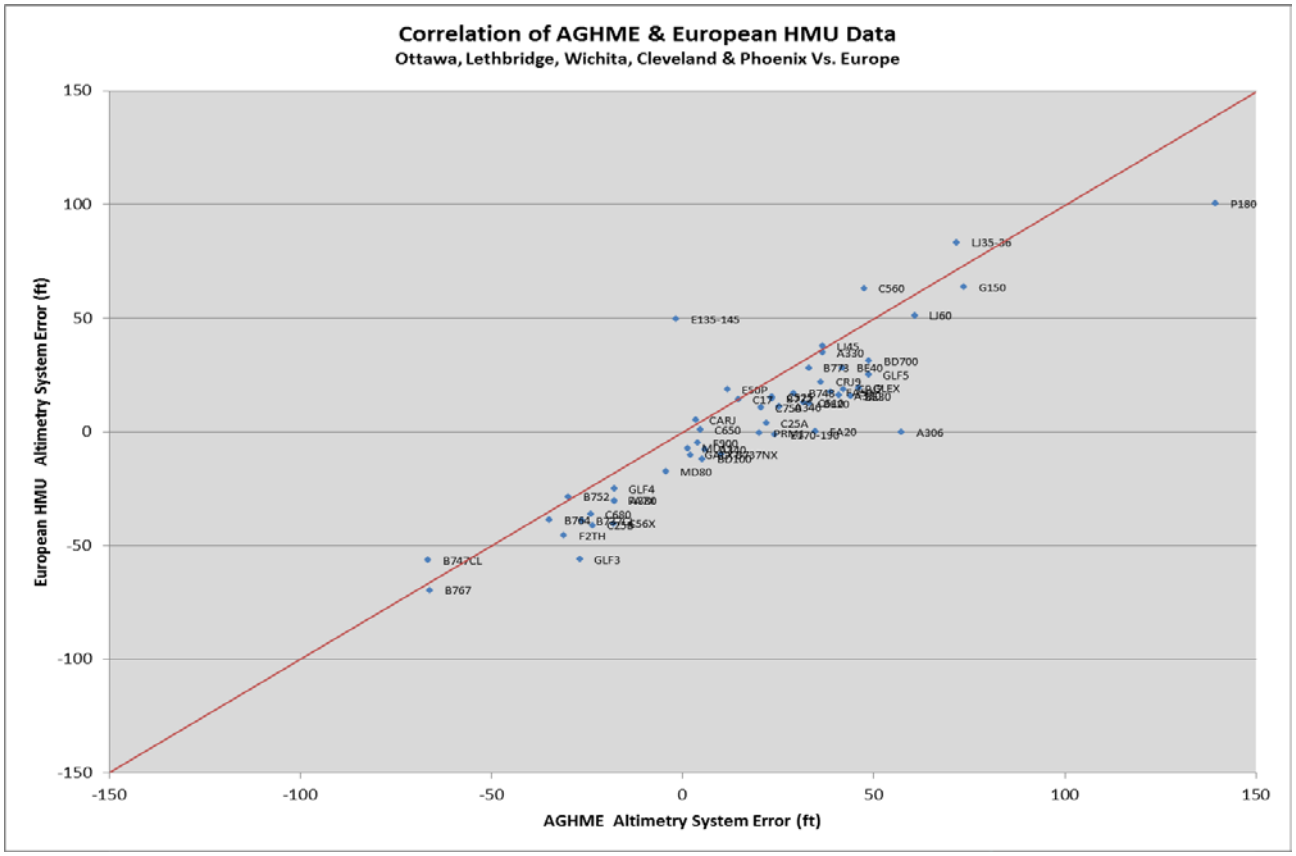

Figure 1. Comparison of ASE by Aircraft Monitoring Group Obtained from the AGHME and EuroControl HMUs

2.8 The following figures contain similar plots of average ASE estimates by aircraft monitoring group. Each figure contains the average ASE estimates obtained from the AGHME system on the horizontal axis. Figure 2 contains the average ASE estimates from JASMA HMU, shown on the vertical axis. Figure 3 contains the average ASE estimates from ADS-B data, shown on the vertical axis. Figure 4 contains the average ASE estimates from the GMS's EGMU data, shown on the vertical axis. Figure 5 contains the average ASE estimates from the AAMA ADS-B system on the horizontal axis and the AGHME system on the vertical axis.

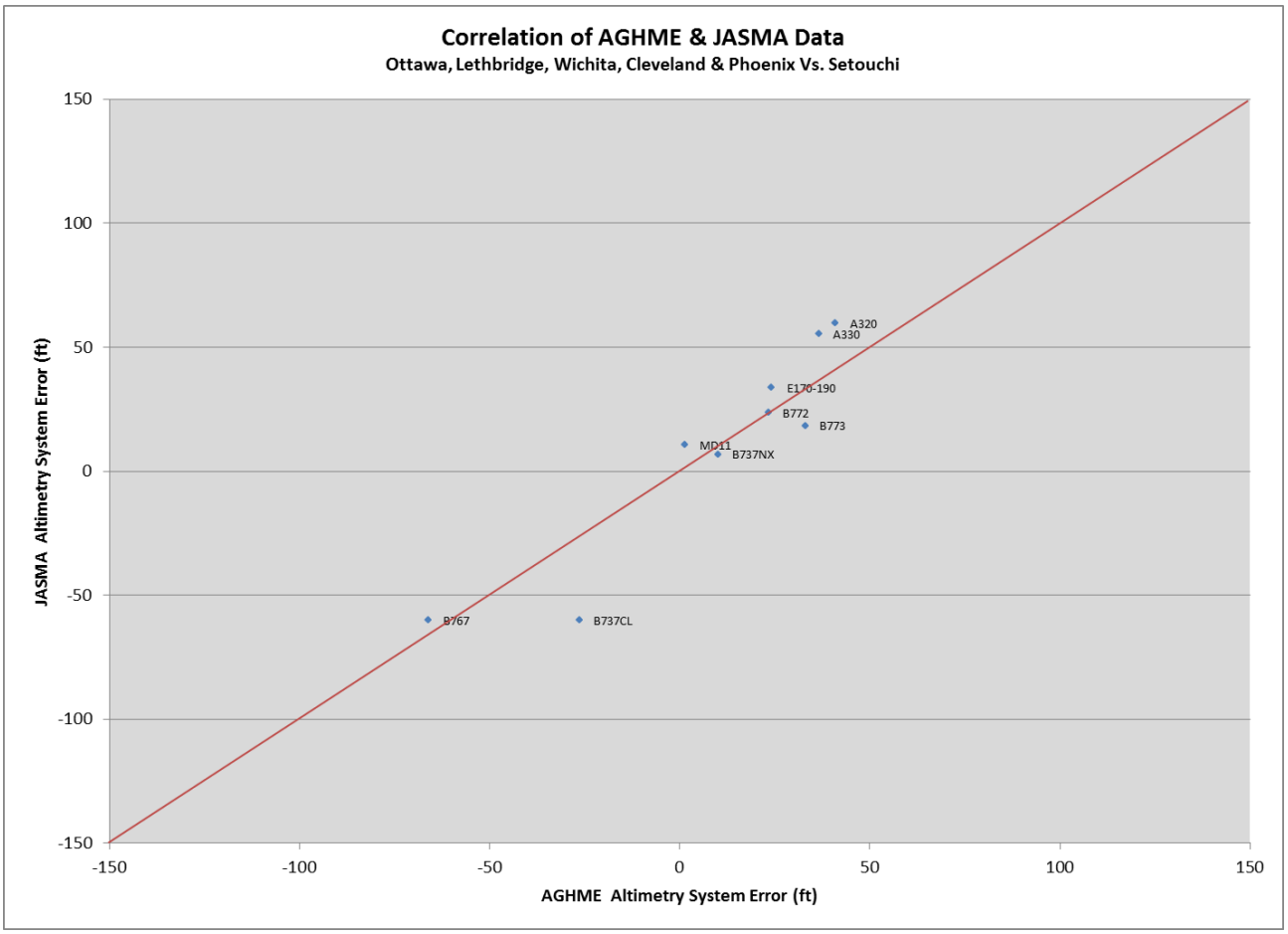

Figure 2. Comparison of ASE by Aircraft Monitoring Group Obtained from the AGHME and JASMA HMU

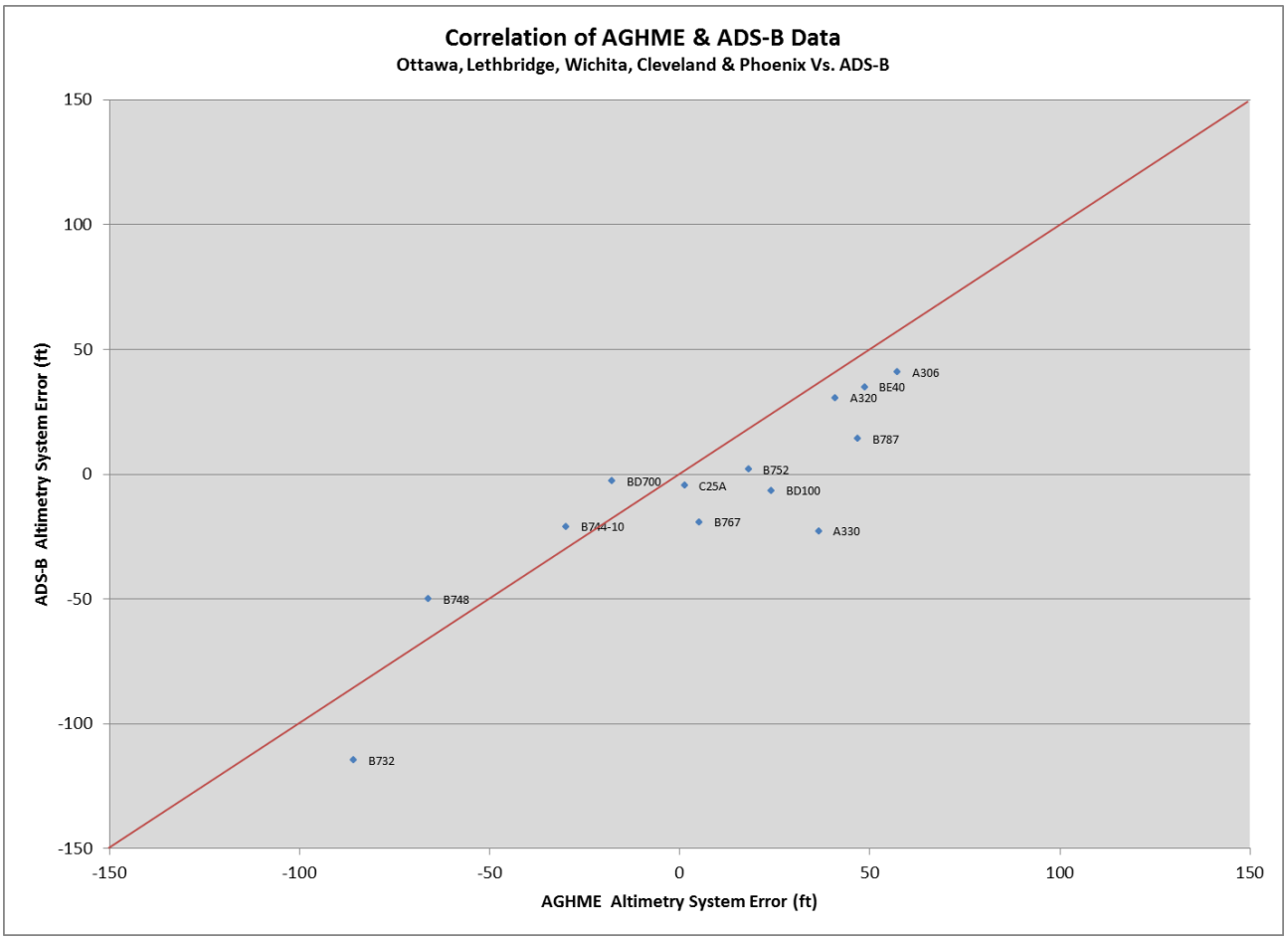

Figure 3. Comparison of ASE by Aircraft Monitoring Group Obtained from the AGHME and ADS-B Data

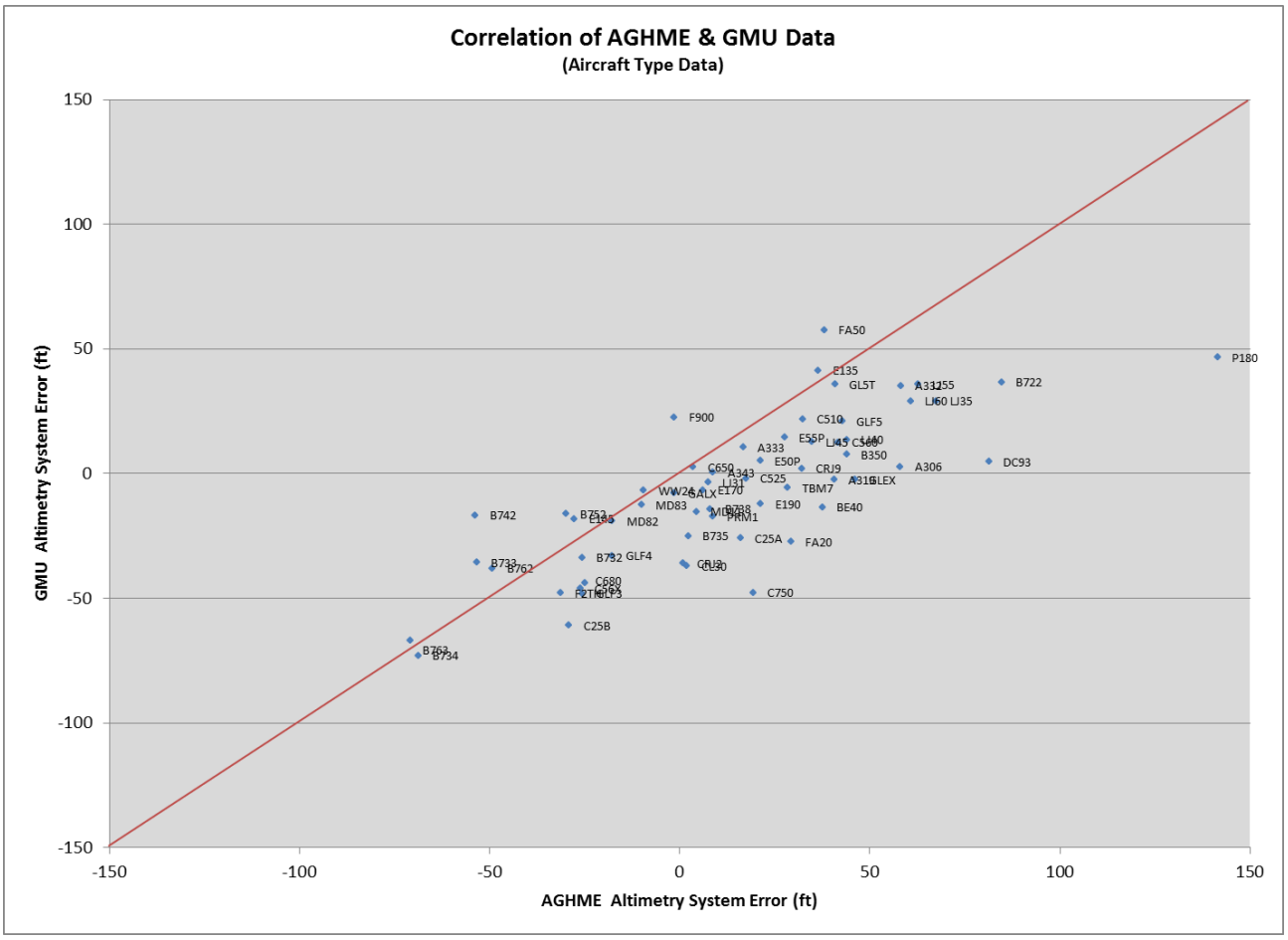

Figure 4. Comparison of ASE by Aircraft Monitoring Group Obtained from the AGHME and GMS (EGMU) Data

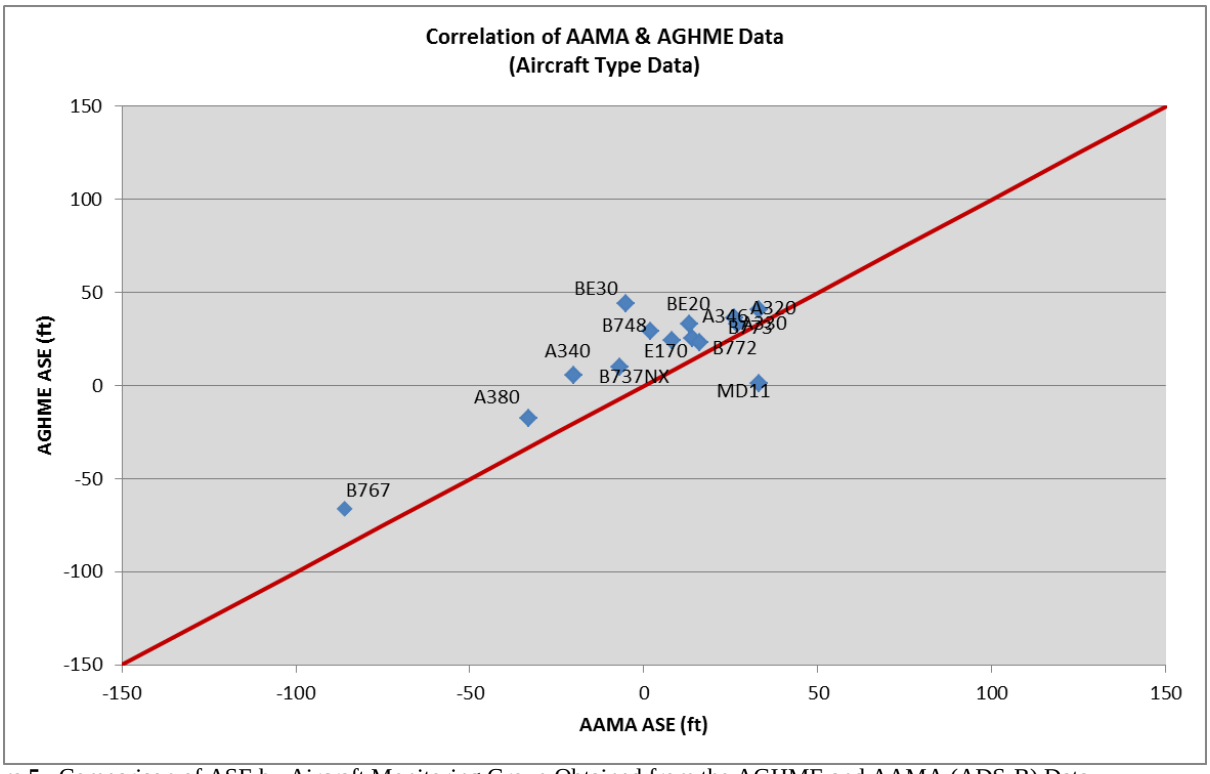

Figure 5. Comparison of ASE by Aircraft Monitoring Group Obtained from the AGHME and AAMA (ADS-B) Data

2.9 These comparisons are performed to assure that any conclusions drawn from estimates obtained from the AGHME system would be consistent with conclusions made using other methods of ASE measurement, thus confirming the design of the independent monitoring systems. These comparisons provide an example of how monitoring systems can be compared between regions. In addition, these validation exercises may reveal important height-keeping performance characteristics related to aircraft monitoring group ASE performance not previously noticed.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note and review the contents of this working paper;

b) agree that comparisons of these types be performed for all monitoring systems to assure consistent results can be expected, and

c) agree that the RMAs within the Asia Pacific Region continue to compare ASE means, and provide updates to the RASMAG meeting.

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