CORRESPONDENCE

Comments on “Characterization of Aircraft Icing Environments with Supercooled Large Drops for Application to Commercial Aircraft Certification”

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1. Background

The 1994 Roselawn, Indiana, accident was a watershed event for the in-flight icing community. Cober and Isaac (2012, hereinafter CI12) presented a climatological description of drop sizes in freezing drizzle and freezing rain in the Great Lakes region and eastern Canada. These data were collected during six field projects and are expected to form the basis for certifying commercial aircraft for flight in supercooled large droplet (SLD) conditions. The Roselawn accident was caused by SLD.1 The Federal Aviation Administration (FAA) has published a Notice of Proposed Rulemaking (docket number FAA-2010–0636) and is in the process of issuing new certification regulations for engines [Code of Federal Regulations, title 14, part 33 (14 CFR 33, appendix D—Ice crystals)] and for “Transport Category Airplanes” (14 CFR 25, appendix O—SLD).

During a flight over the Sierra Nevada on 26 February 1982, the University of Wyoming (UW) King Air B200 (WKA) encountered an in-flight icing condition that was more severe by an order of magnitude than those conditions for which the aircraft was certified under FAA Federal Aviation Regulations (FAR) Part 25, appendix C. This was a watershed event for the UW scientists. They used the case-study approach to investigate this rare and dangerous icing condition by focusing on both the icing condition and the response of the aircraft to that icing condition. The articles by Cooper et al. (1984) and Sand et al. (1984) concluded that the rapid loss in performance was not related to median volume diameter (MVD); rather the rapid loss in performance was related to “drizzle drops” in the size range of 40–300 μm.

Ashenden and Marwitz (1997, 1998, hereinafter AM97 and AM98, respectively) presented a more detailed analysis of in-flight icing encounters by the WKA. AM98 included five flights on which encounters with supercooled drizzle drops (SCDD)2 resulted in performance degradations that were severe enough to force descent within 5 min. These five cases are referred to here as severe SCDD (SSCDD) encounters. The icing environment for these SSCDD cases is shown in Table 1. The measured high drag rates and increased stall speeds in these rare icing conditions were attributed to the rapid development of small, rough ice elements in the 5%–15% of chord on the negative pressure or “lift” side of an airfoil. These roughness elements are a few millimeters in height and are in the shape of saber teeth. When the WKA was flown in clear air or in clouds that contained ice crystals following an SSCDD encounter, the performance recovery rate was equal to the performance degradation rate.

1 The phrase “supercooled large droplets” was coined by J. Dow et al. (2008, personal communication) during the Roselawn accident investigation. The phrase was intended to refer to drops outside the appendix-C droplet distribution sizes. CI12 have arbitrarily redefined SLD to be drop spectra with Dmax > 100 μm.

2 The phrase “supercooled drizzle drops” was defined by Bershinskiy et al. (1995) and Marwitz et al. (1997) to be drops in the diameter range from 40 to 400 μm. On the basis of more detailed analysis of the WKA data, AM98 slightly revised the definition of SCDD to be in the diameter range from 30 to 400 μm. AM98 refer to the LWC in SCDD sizes as freezing drizzle (ZL).
2. Specific deficiencies in CI12

There are two specific deficiencies in CI12. The first one is that icing environments presented by CI12 are based on MVD. The existing data indicate that MVD is not correlated with performance degradation (Cooper et al. 1984; Sand et al. 1984; AM98). CI12 present no data or references that indicate that maximum diameter (Dmax) is related to performance degradation. Therefore, it is not clear that the partitioning parameters used by CI12—namely, MVD and Dmax—are related to performance degradation.

The second deficiency is that the data presented by CI12 do not represent SSCDD environments in terms of LWC or drop size distributions. The mean total LWC (TWC; =0.49 g m$^{-3}$) and mean temperature (–7.7°C) from Table 1 are plotted on Fig. 1. The mean TWC for these five cases exceeds the 99% LWC envelopes for freezing drizzle (CI12’s Fig. 9). The mean value of the 80% mass diameter (80VD; 79 μm) with the end points spanning the mean value of the percent of water mass in SCDD sizes (ZL/TWC = 67%) from Table 1 is plotted in Fig. 2. The drop size distributions for SSCDD are between the drop size distributions for freezing-drizzle environments for MVD > 40 μm and MVD < 40 μm. Therefore, the climatological values of drop sizes provided by CI12 do not represent the SSCDD icing environment.

3. Summary

Why the dramatically different result between CI12 and the UW work? I submit that an explanation was provided by Dow (1996) when he defined SLD to be icing conditions in freezing rain, freezing drizzle, and SCDD. CI12 focused on freezing rain and freezing drizzle, whereas the UW scientists focused on SCDD. The WKA data indicate that cloud droplets, freezing rain, and most freezing drizzle are not, in general, a severe hazard. There is, however, a particular form of freezing drizzle that results in rapid performance degradation that is sufficient to force descent within 5 min: severe SCDD.

<table>
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<th>Table 1. Icing environment for SSCDD.</th>
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<td>TWC (g m$^{-3}$)</td>
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FIG. 1. Freezing-drizzle environments in terms of LWC and temperature. This figure is similar to Fig. 9 in CI12. The mean temperature (–7.7°C) and mean TWC for SSCDD conditions (0.49 g m$^{-3}$) have been added (open diamond).

FIG. 2. Drop cumulative mass distributions for freezing drizzle. This figure is similar to Fig. 3 in CI12. A line has been added through the mean value of 80VD (79 μm) with the end points spanning the mean value of the percent of total water mass in SCDD sizes (67%).
REFERENCES