Deficiencies in Safe Practices by Pilots Operating General Aviation Aircraft in Weather Conducive for Icing

Douglas Boyd Ph.D¹ and Thomas Guinn Ph.D¹

¹Embry Riddle Aeronautical University, 1 Aerospace Blvd, Daytona Beach, Florida 32114

ABSTRACT

Introduction: Flights of general aviation aircraft in icing conditions pose safety hazards especially since few airplanes are equipped with ice protection systems (FIKI). Herein, we sought to answer the following questions not previously addressed: (i) Has the general aviation icing-related accident rate declined over time? (ii) Which phase(s) of flight lead(s) to the highest fraction of fatal accidents? (iii) Do general aviation pilots adhere to safe practices when operating in forecasted icing?

Methods: Retrospectively, icing-related accidents were per the National Transportation Safety Board database. Prospectively, non-FIKI single-engine airplanes, operating in forecasted icing, were tracked (January–March 2023) using FlightAware®. Presumptive icing was determined with METARs/modelled Skew-T data. Statistical tests employed Poisson distributions/Pearson chi-square analyses.

Results: In a retrospective analysis, despite a nonstatistical \( p = 0.621 \) downward trend in icing-related accidents (2000–2019), over half of mishaps were fatal, a fraction unchanged \( p = 0.842 \) over the two decades. Loss-of-control represented the terminating event with the highest proportion of fatal outcomes (85%). Accidents involving takeoff-climb ice accretion were overrepresented for fatal outcomes (66%). In a prospective study arm, of 300 non-FIKI flights operating in forecasted icing and tracked in real time, 65% departed or descended/landed (44%) in presumptive icing.

Conclusions: A modest downward trend in icing-related accident rate and an undiminished high fraction of fatal mishaps rationalize focused training of pilots operating non-FIKI aircraft in areas prone to icing. Specifically, two novel observations warrant emphasis: (i) an approximately threefold higher icing-related fatal accident fraction compared with all general aviation accidents and (ii) the high proportion of lethal mishaps due to takeoff-climb ice accretion.

Keywords: general aviation, icing, accidents, weather, fatal mishaps

Introduction

General aviation is comprised of all civil aviation with the exclusion of air carriers (commonly known as airlines) and charters. General aviation flight safety pales in comparison with that of air carriers as evidenced by a greater than 60-fold higher accident (mishap) rate, a difference which is amplified if only fatal mishaps are considered (Boyd, 2017). A plethora
of reasons contribute to this disparity in safety including less restrictive operational regulations for general aviation compared to those of air carriers (in the USA, encapsulated in 14CFR 91 and 121 for general aviation and air carriers respectively). Another example is that air carriers have a mandatory minimum two-pilot aircrew (Electronic Code of Federal Regulation, 2015a, 2015b, 2017). Moreover, with respect to operating in hazardous weather such as icing, for example, aircraft utilized by air carriers are required to be equipped with certified ice protection systems (also known as flight-into-known-icing, FIKI) per 14CFR 121 (Electronic Code of Federal Regulation, 2017). By contrast few light aircraft, operating in accordance with general aviation regulations (14CFR 91) (Electronic Code of Federal Regulation, 2015a; Federal Aviation Administration, 2015), are FIKI-certificated (Federal Aviation Administration, 2021, 2023).

Operating in icing conditions can be particularly hazardous to flight safety especially for non-FIKI light aircraft for several reasons (Federal Aviation Administration, 2015). Firstly, ice or frost contamination of unprotected wings (and horizontal stabilizers) reduces lift with multiple related consequences. For example, the potential for an aerodynamic stall and an in-flight loss-of-control with a fatal outcome (National Transportation Safety Board [NTSB], 2016, 2018) is increased (Federal Aviation Administration, 2015). Also, the ability to climb and/or maintain sufficient altitude for obstacle/terrain clearance is compromised. Secondly, icing of an engine air intake (induction icing) or of a propeller may result in a loss of power, further compounding the degraded lift (Federal Aviation Administration, 2022). Thirdly, contamination of the pitot tube and static ports can lead to erroneous, or failed, air data (airspeed, vertical speed, altitude) critical for operating and escaping such adverse conditions (Federal Aviation Administration, 2015). Indeed, such weather conditions are considered so hazardous to the safe completion of a flight, that non-FIKI general aviation aircraft are prohibited from operating in known icing (Electronic Code of Federal Regulation, 2009).

Although the dangers of non-FIKI general aviation airplanes operating in icing conditions are well known, the authors are aware of only two research studies on icing-related general aviation accidents/incidents. In the first (Appiah-Kubi et al., 2013), researchers reported that ice accretion leading to accidents was most likely in the cruise (level flight) phase of flight. In a separate study (Knecht & Lenz, 2010), nonaviation forecasts used by the involved pilot(s) and decrease in forecast accuracy over time were identified as contributory factors to icing incidents. However, there are still considerable gaps in our knowledge of general aviation icing-related accidents. Notably, there have been no longitudinal studies to determine if the rate of such general aviation accidents has changed over time. This is an important question considering the advent of in-flight weather by way of mobile devices (https://en.wikipedia.org/wiki/iPad_(1st_generation)#:~:text=The%20device%20was%20announced%20and,3G%22%20variant%20on%20April%2030) and software (https://foreflight.com/about/foreflight/) in 2007–2010 plus scenario-based training in 2007 (Federal Aviation Administration, 2007). Furthermore, the aforementioned studies of general aviation icing-related incidents/accidents were limited in that they (i) failed to discriminate between FIKI- and non-FIKI-certificated aircraft, (ii) aggregated fatal and nonfatal accidents, and (iii) included operations conducted by air carriers, charters, and general aviation, all of which have their own prescribed regulations (Electronic Code of Federal Regulation, 2015a, 2017, 2020).

Consequently, the objectives of the current study were threefold. First, in a retrospective approach, we determined whether the rate of general aviation icing-related accidents (and fraction of mishaps with fatal outcomes) involving light aircraft (<12,501 lbs) operating in accordance with general aviation regulations (14CFR 91) (Electronic Code of Federal Regulation, 2015a) has declined over time. Second, the phase(s) of flight leading to the highest fraction of accidents with a fatal outcome was determined. Third, in a prospective arm of the study, the extent to which general aviation pilots adhere to/disregard safe practices (e.g., flying above/below a cloud layer presumptive for icing) when operating non-FIKI airplanes in forecasted conditions conducive to icing was ascertained.

Methods

Retrospective Study Arm: Identification of Icing Accidents

The NTSB aviation accident Microsoft Access® databases (March 2023 and 1982–2007 releases) (NTSB, 2021) were downloaded and the narrative cause queried for the term “icing” restricting the search to the 2000–2019 period and light (<12,501 lbs) airplanes operating under general aviation regulations (14CFR 91). We elected to use 2019 as the most recent year for analysis to exclude any confounding effects of the COVID-19 pandemic. Records in which accidents involved carburetor icing were excluded as this phenomenon can occur with ambient temperatures as high as 38°C (Federal Aviation Administration, 2016). Also deleted were mishaps in which the query for “icing” returned records in which this root was embedded in an unrelated term (e.g., “servicing,” “practicing,” “splicing”). Injury severity, the phase of flight for which ice accretion first occurred, instrument flight plan, and the terminal event prior to the accident were all per the NTSB database. Accident rates were determined using the equation below. Fleet times were from the general aviation annual survey (Federal Aviation Administration, 2021)
with data for 2011 derived by interpolating 2010 and 2012 fleet times.

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\text{Accident rate} = \frac{\text{Accident count (n)}}{\text{Annual fleet activity}} \times 10\text{ million}
\]

**Prospective Study Arm: Real-Time Tracking of Non-FIKI General Aviation Aircraft Operating in Geographical Areas for which Icing was Forecast**

Using the Aviation Weather Center Current/Forecast Icing Potential (CIP/FIP) product (https://aviationweather-cprk.ncep.noaa.gov/icing/fip), the contiguous USA was scanned daily (January 21–March 15, 2023) for geographical areas with forecast icing at 3,000 ft (mean sea level, MSL). This altitude was selected since non-turbacharged piston-engine aircraft, which represent by far the majority of the general aviation fleet (Federal Aviation Administration, 2021), perform optimally at altitudes lower than 6,000 ft MSL (Federal Aviation Administration, 2004).

Only areas of approximately >20,000 square statute miles with forecasted icing were pursued. Thereafter, the real-time flight tracking tool FlightAware® (FlightAware, 2023) was employed to track fixed-wing single-piston-engine aircraft operating under general aviation regulations (14CFR 91) within the aforementioned area(s). FlightAware® specifies the aircraft make/model and updates the location, altitude, and ground speed for each flight at intervals typically not exceeding a minute. The study was restricted to (i) non-FIKI airplanes operating at altitudes of 2,500–12,000 ft MSL at a maximum groundspeed of 200 kts and (ii) flights over a distance of no less than 50 nmi. Aircraft makes/models that were FIKI-certificated were identified by way of their initial or supplemental certification (Federal Aviation Administration, 2023) and excluded from the study. For each flight, FlightAware® text data were downloaded and imported into Microsoft® Excel as well as the corresponding flight path as a keyhole markup language (kml) file as described by us earlier (Boyd, 2022).

To identify conditions conducive to icing, Meteorological Aerodrome Reports (METARs) issued by airports equipped with Automated Surface Observation Systems (ASOS) (Committee on the Assessment of the National Weather Service’s Modernization Program, 2012; National Oceanic and Atmospheric Administration, 1998) and vertical soundings (Skew-T) derived from the 1-hour Rapid Refresh model (updated hourly) in effect at the time of airplane passage were used as described below. An example of these soundings is shown in Figure 1 (https://rucsoundings.noaa.gov/gwt/?data_source=Op40&latest=latest&airport=KHLN&en_hrs=19k).

Enroute ASOS-reporting aerodromes were identified using the FlightAware®-derived kml file imported into Google Earth Pro™ with an aeronautical chart overlay. Cloud ceilings (broken or overcast) and the corresponding base height (MSL) of the layer were determined from observational data (METARs). Temperatures, temperature–dewpoint difference (also known as dewpoint depression), and ceiling tops were per modelled Skew-T data for the corresponding METAR-reporting station at the time of station passage. Criteria for presumptive icing were (i) an observed ceiling (i.e., broken or overcast) layer with (ii) a modelled Skew-T-determined temperature range between 0 and −20°C (Federal Aviation Administration, 2015), and (iii) a dewpoint–temperature spread not exceeding 3°C (Figure 1). Due to altimetry inaccuracies associated with modelled Skew-T data, a 200 ft margin of error was included. It should be noted that enroute ASOS-reporting aerodromes were restricted to those <30 nmi distant from the flight path. If departure or arrival airports did not issue METARs, such data were obtained from the nearest weather-reporting aerodrome (up to 30 nmi distance).

**Statistical Tests**

A Poisson distribution (Dobson & Barnett, 2008) was used to determine if differences in fatal accident rates were statistically significant over time. The natural log of aviation fleet time was used to adjust for annual differences in general aviation fleet activity (i.e., used as an offset) in the Poisson statistical analysis. Differences in proportions were tested using two- or three-way contingency tables and Pearson chi-square exact test (2-sided) (Agresti, 2012; Field, 2009). Adjusted residuals (z-scores) were used to identify contributing cells. All statistical testing was performed using the SPSS v27 package (IBM®, Armonk, NY). A cutoff of \( p = 0.050 \) was used for statistical significance.

**Human Subjects Research**

The research performed herein did not constitute human subject research by virtue of all data being obtained from sources/databases in the public domain.

**Results**

**Temporal Change in Icing-Related Accident Rate and Injury Severity**

General aviation has witnessed fundamental changes in terms of technology (onboard weather) and advances in training methods (scenario-based training) over the last two decades (Federal Aviation Administration, 2007, 2020). Consequently, we first endeavored to determine if the icing-related accident rate has declined over this time period. For increased statistical power, accidents were binned into 5-year groups. Certainly, a downward trend was evident subsequent to the 2005–2009 period (Figure 2A) with a nearly 40% decrease for the most recent period
(2015–2019) compared to the initial period (2000–2004). However, this difference in icing-related accident rates did not reach statistical significance (Poisson distribution ($p = 0.057$) with the 95% confidence intervals crossing unity (odds ratio, 0.621; CI 95% 0.38,1.015)).

Although the Joseph T. Nall Reports (AOPA Air Safety Institute, 2019, 2021) categorize general aviation accidents on an annual basis, neither that study nor any that the authors are aware of has addressed the lethality of icing-related accidents over time. Over the two decades covered by the current investigation, more than half of icing-related accidents had a fatal outcome (Figure 2B). Importantly, no reduction in the proportion of fatal mishaps was evident over this period (Pearson chi-square $p = 0.842$). It is also noteworthy that the fraction of fatal icing-related accidents was elevated more than twofold over the fraction of mishaps unrelated to icing (horizontal line in Figure 2B).

These data would indicate that while a nonstatistical downward trend was apparent for the icing-related accident rate over the 2000–2019 period, the majority of such mishaps consistently had a fatal outcome.

**Terminal Events in Icing-Related Accidents**

The aforementioned high fraction of icing-related accidents with a fatal outcome begged the question as to the terminal event (defined operationally as that most proximate timewise to the accident) in these accidents. To address this question, icing accidents were categorized on the basis of injury severity (fatal vs. nonfatal) and terminal event (Table 1). The count of loss-of-control mishaps (defined as an accident in which the flight crew is unable to maintain control of the aircraft in flight resulting in an unrecoverable deviation from the intended flight path; International Air Transport Association, 2018) often due to structural contamination of the lifting surfaces (wings and horizontal stabilizers) was disproportionate ($p < 0.001$) for fatal mishaps (85% of such accidents). This was followed by the inability of the aircraft to maintain terrain clearance subsequent to icing contamination of lifting surfaces. Of all such icing-related accidents, 60% had a fatal outcome. Due to a small $n$, proportion testing could not be undertaken. In contrast, a disproportionate count of hard/forced landing icing-related accidents were nonfatal ($p < 0.001$), perhaps not too surprising as occupants are not subjected to extreme g-forces and blunt-force injuries as occurs in loss-of-control mishaps.

**Ice Accretion and Phase of Flight**

An earlier study (Appiah-Kubi et al., 2013) of aircraft accidents had documented cruise as the most frequent phase of flight for ice accretion. However, the phase of flight in which icing accretion is mostly likely to culminate in a fatal outcome has yet to be addressed. We next sought to answer this question. In considering accidents from the perspective of injury severity (fatal vs. nonfatal), the count of mishaps involving ice accretion during takeoff-climb was overrepresented (64% of accidents) for fatal outcomes (Figure 3). In fact, this disproportionate count of fatal accidents was comparable to that evident for cruise (66% of mishaps). In contrast, less than half of accidents with a lethal outcome were due to ice accretion in the descent-
landing phase. Taken together, these data suggest that a preponderance of lethal icing-related accidents is not limited to ice accretion in cruise but rather also includes icing build-up during takeoff-climb.

**Pilot Adherence/Nonadherence to Safety Practices when Operating Non-FIKI Airplanes in Conditions Conducive to Icing**

Considering the downward trend (which did not reach statistical significance) in the icing-related accident rate over the past two decades coupled with an unchanged fraction of fatal mishaps, we then undertook a prospective study to determine the extent to which aviators operating non-FIKI airplanes adhere to safe practices. Flights \( n = 300 \), unique aircraft registrations \( = 285 \) operating in forecasted icing conditions and under the auspices of general aviation regulations (14CFR 91) were tracked (January 21–March 15, 2023) in real time. Of these, half departed into conditions conducive to icing with a similar fraction (45%) completing the descent-landing phase in presumptive icing (Figure 4A). Conversely, for the cruise

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**Figure 2.** Longitudinal analysis of icing-related accident rate and fatal fraction. (A) Icing-related accident rate for general aviation, light aircraft over the specified periods. The denominator used was fleet times for fixed-wing aircraft for the corresponding times. A Poisson distribution was employed to determine if accident rates differed from those of the initial (referent) period (2000–2004). (B) The fraction of icing-related accidents with a fatal outcome is shown for the specified time frames. A Pearson chi-square test was employed to determine if proportions differed between the time periods. For comparison, the fraction of lethal accidents unrelated to icing across the 2000–2019 period is depicted as a horizontal line. \( n \), count of all (A) and fatal only (B) icing-related mishaps.
phase of flight the majority (73%) of non-FIKI aircraft operated clear of icing conditions.

Flights were then risk-assessed based on the duration of continual presumptive icing exposure per the count of consecutive weather stations/aerodromes over which such conditions existed at the time of aircraft transit (using the following arbitrary scale: 0–1, none–minimal; 2, very short; 3, short; 4, intermediate; 5, prolonged). Encouragingly, the vast majority (83%) of pilots operating non-FIKI aircraft in forecasted icing conditions adhered to safe practices as evidenced by a “none–minimal” icing exposure duration (Figure 4B). Put another way, such flights operated in conditions where no consecutive stations reported conditions conducive for icing. A small percentage (15%) of aviators operated with a very short–short continual exposure to icing per the number of consecutive stations (2–3) reporting such conditions. Moreover, only a small fraction (2%) of aviators elected to fly non-FIKI aircraft with a prolonged exposure (4–5 stations) to presumptive icing. Together these data would indicate that, by far, the majority of aviators operating non-FIKI airplanes elect to maintain a minimal exposure to such an adverse environment.

Lastly, considering that aircraft operating on an instrument flight plan (IFR) are assigned and must adhere to air traffic control-designated routes/vectors and specific alti-

<table>
<thead>
<tr>
<th>Terminal event</th>
<th>Fatal (n)</th>
<th>Fatal fraction</th>
<th>Nonfatal (n)</th>
<th>Nonfatal fraction</th>
<th>Totals (n)</th>
<th>p</th>
</tr>
</thead>
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<tr>
<td>Loss-of-control</td>
<td>62</td>
<td>0.85</td>
<td>11</td>
<td>0.15</td>
<td>73</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hard/forced landing</td>
<td>4</td>
<td>0.10</td>
<td>38</td>
<td>0.90</td>
<td>42</td>
<td>&lt;0.001</td>
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<tr>
<td>Inability to maintain terrain clearance</td>
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<td>0.60</td>
<td>2</td>
<td>0.40</td>
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<td>ND</td>
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<tr>
<td>Other</td>
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<td>0.67</td>
<td>4</td>
<td>0.33</td>
<td>12</td>
<td>ND</td>
</tr>
<tr>
<td>Unknown/ambiguous</td>
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<td>0.86</td>
<td>1</td>
<td>0.14</td>
<td>7</td>
<td>ND</td>
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<tr>
<td>Total</td>
<td>83</td>
<td>0.56</td>
<td>56</td>
<td></td>
<td>139</td>
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</tr>
</tbody>
</table>

Note. Icing-related accidents were categorized based on the terminal event and injury severity. A Pearson chi-square (2-sided) test and adjusted residuals were used to determine statistical differences in proportions. ND, not done as expected count <5. “Other” terminal event category included: frozen landing gear, failure to maintain glideslope or descent below minimum descent altitude, downdrafts exceeding climb capabilities.

Figure 3. Icing accretion phase for fatal icing-related accidents. Data shown are the fatal fraction of icing-related accidents (2000–2019) involving light aircraft for the indicated phase of flight. Phase of flight refers to when icing first occurred. n, fatal accident count.
tudes, we speculated that such flights would be more likely to encounter conditions favorable for icing than those not flying in accordance with an IFR flight plan. Accordingly, real-time flight data were analyzed to this end. In a three-way contingency table where IFR flight plan was the controlling variable, while a difference in proportionality was evident for the IFR operations \((p < 0.001)\), no such difference was evident for non-IFR flights \((p > 0.575)\). More specifically, encounters with presumptive icing were overrepresented for both the takeoff-climb \((p < 0.001)\) and descent-landing \((p = 0.005)\) phases for IFR flights (Figure 5). In contrast, for the enroute phase (cruise), little difference in the proportions of flights encountering conditions favorable for icing was evident between IFR and non-IFR flights.

Discussion

Herein, we have demonstrated a modest (albeit non-statistical) downward trend in the icing-related accident rate involving non-FIKI, light aircraft over the past two decades. Notwithstanding any minor reduction, the majority of icing-related mishaps had a fatal outcome with this proportion undiminished over the twenty-year study period. These findings are consistent with a prior study which had cited structural icing as the fifth-ranked weather factor linked to fatal weather-related general aviation accidents (Fultz & Ashley, 2016). Notwithstanding a relatively low count (lower than the cruise and descent-landing phases), a concerning finding of the current study was the previously unreported hazard of icing accretion during
takeoff-climb: the majority (64%) of such accidents had a fatal outcome.

Although the downward trend in icing-related accidents did not achieve statistical significance, it is still worth speculating as to candidate causes underlying such a trend. We strongly suspect that the advent of in-flight weather made available by way of tablets and mobile pilot apps were contributory. For example, one of the commonly used pilot apps (Foreflight®) providing in-flight weather was introduced in 2007 with the mobile tablet required for displaying such data (IPAD®) in 2010. Such technology affords the general aviation pilot the means of getting near real-time weather (temporal data latency) both pre-flight and enroute by way of satellite or ground-based links. Importantly, the introduction of this portable technology preceded the apparent reduction in icing-related accidents rate in 2010–2014. Another candidate reason for the downward trend in icing-related accident rates could reflect a shift in flight instruction methodologies (both ab initio and recurrent training) circa 2007 (Federal Aviation Administration, 2007). Thus, training has transitioned away from being purely maneuvers-based to scenario-based instruction, the latter focusing on managing real-world challenges. More specifically, scenario-based training uses a highly structured script of real-world experiences to meet flight training objectives in an operational environment (e.g., one prone to icing) with a focus on all aspects of the flight as it progresses including contingency planning to deal with an unexpected event (Federal Aviation Administration, 2007).

In prior research of icing-related mishaps, investigators sought to identify the phase of flight most frequently associated with icing, concluding that cruise was the most common flight segment for ice build-up (Appiah-Kubi et al., 2013). However, the authors failed to distinguish between fatal and nonfatal outcomes of these icing-related accidents. Herein, we addressed this shortcoming and demonstrated that ice accretion in the takeoff-climb phase of flight also culminated in a disproportionate count of fatal accidents to a level comparable with that of level flight (cruise). This novel finding is not particularly unexpected, however, for two reasons (Federal Aviation Administration, 2015). First, airplanes are vulnerable to ice accumulation during climb-out due to a lower speed. Second, the high angle of attack after departure exposes the underside of wings to icing conditions allowing ice to form farther aft than it would in cruising (Federal Aviation Administration, 2015).

What is unclear from our study are the reason(s) why aviators operate in weather conditions conducive to icing in non-FIKI aircraft. It may be that aviators consider relatively short exposures to icing to pose little threat to safety (Appiah-Kubi et al., 2013). Indeed, our findings that 83% of flights followed routes where no two (or more) consecutive aerodromes/weather stations had such overlying adverse conditions are consistent with this notion. Other studies have cited alternative arguments. In inter-
viewing pilots who had been involved in icing-related mishaps, investigators (Knecht & Lenz, 2010) reported a degraded accuracy of weather forecasts over time to be a contributing factor to the unintended icing encounter—thus, forecasted icing conditions at the destination airport were more likely to be inaccurate than at the departure aerodrome. However, since the capture period (2005–2006) of that study preceded the introduction of technology requisite for receiving in-flight near-real-time weather, such an argument would be less pertinent to the current findings. Another possibility is a deficit in pilot knowledge of conditions which may culminate in icing, e.g., temperature inversions (Federal Aviation Administration, 2015; National Aeronautics and Space Administration, 2016) or the false notion that freezing drizzle may imply warmer air above (National Aeronautics and Space Administration, 2016). A fourth possible reason is the poor interpretation of the displayed in-flight weather as has been reported elsewhere (Blickensderfer et al., 2020). The authors also entertain the notion that pilots may falsely assume that non-FIKI ice protection, especially for legacy aircraft, allows the aviator to operate in actual icing conditions which it does not. Indeed, current FIKI regulations only apply to aircraft certificated after 2000 (Federal Aviation Administration, 2015) thus requiring a supplemental type of certificate for legacy airplanes (those certificated prior to 2000). Finally, a variety of human factors, including fatigue and “get-home-it is,” have been advanced as putative contributory factors in icing-related accidents (Knecht & Lenz, 2010).

Our finding of the large count (n > 36) of aircraft not on an IFR flight plan but encountering conditions conducive to icing (per Figure 5) is disconcerting. The implication here is that such aircraft are operating in instrument meteorological conditions and thus in violation of visual flight rules (Federal Aviation Administration, 2018). Although we do not know whether such aviators were instrument-rated and presumably capable of flying in the absence of visual cues, nevertheless, electing to operate in such conditions adds an additional hazard (Benson, 1999; Partmet & Ercoline, 2008) to the safe completion of a flight.

Our study was not without limitations. In the context of the prospective arm in which aircraft operating in forecasted icing conditions were tracked in real time, these were as follows. First, some enroute weather stations were located up to 30 nmi off route and spacing intervals may not have been equidistant. Second, Skew-T data were modelled and altitudes defining presumptive icing were based on standard atmospheric pressure. Third, the icing area forecast (Current/Forecast Icing Potential, CIP/FIP; National Weather Service, 2023) employed to identify a geographical area to track general aviation aircraft in real time represented a short-term prognostication and may have varied with what the pilot received in a standard briefing up to six hours prior to his/her flight. In regard to the retrospective arm of the study, since only annual fleet times are available (Federal Aviation Administration, 2021), this value employed to calculate accident rates (see the equation in the Methods section) would have included fleet activity for months absent for icing conditions. This would have yielded an artificially low icing-related accident rate.

In conclusion, the modest downward trend in icing-related accident rate compounded by an undiminished high fraction of fatal mishaps argues for the need for additional training of general aviation pilots operating non-FIKI aircraft in geographical regions prone to icing. Importantly, the important finding, herein, that ice build-up during takeoff-climb contributes to a high proportion of lethal accidents deserves emphasis. That said, we recognize that the absolute count of fatal accidents in this phase of flight is modest. Future studies (pertinent in the current era of near-real-time weather data enroute) should endeavor to establish whether a failure to adhere to safe practices for operations in weather presumptive for icing is due to deficient subject matter (icing) knowledge, unrealistic expectations of non-FIKI deicing equipment (which should be used only as a means of exiting such conditions; Federal Aviation Administration, 2015), or inadequate weather interpretation (Blickensderfer et al., 2020) in addition to the recognized motivational factors (Bearman et al., 2009; Knecht & Lenz, 2010). A structured interview of pilots would be well suited for such an undertaking (Shappell et al., 2006).

References


