General Aviation Pilot Weather Knowledge

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Executive Summary

Weather-related accidents in general aviation (GA) continue to claim many lives every year (Aircraft Owners and Pilots Association, AOPA, 2001). However, what GA pilots are taught about weather during their earliest training is largely unknown. Likewise, it is unclear to what degree GA pilots have a solid base of weather knowledge that has relevance for real flight operations. The General Aviation Pilot Weather Knowledge and Training Study was proposed to provide information regarding these two areas. Thus, it was actually comprised of two separate studies: "The Weather Knowledge Challenge" and the "CFI Weather Training Survey." The Weather Knowledge Challenge was used to assess the knowledge that certificated U.S. pilots, at all training and experience levels, have regarding content in six weather categories: Causes of Weather and Weather Patterns, Weather Hazards, Weather Services, Weather Regulations, Weather Interpretation, and Weather-Related Decision Making. The CFI Training Survey collected information from certified flight instructors (CFIs) regarding the weather training they provide to primary student pilots.

The Weather Knowledge Challenge

Over one thousand pilots, who attended the EAA Airventure Fly-In at Oshkosh, Wisconsin in July 2000, completed a weather knowledge test, which had been designed to assess operational weather knowledge that should be mastered by, at a minimum, VFR-only pilots. The major findings of this study were that:

- In general, participants performed quite poorly on The Weather Knowledge Challenge. Many pilots apparently lack operationally relevant weather knowledge and/or have difficulty recalling what was once learned.

- The influence of gender, total hours of flight experience, and amount of flight experience within the preceding six months were each individually found to be significantly related to performance on the Weather Knowledge Challenge. However, all significant differences found related to gender and flight experience disappeared when evaluated in conjunction with participants' level of formal training (VFR-only, instrument-rated, CFI, ATP). Therefore, it appears that pilots generally require formal training to obtain weather knowledge and cannot be expected to acquire it on their own as they simply gain more flight experience.

- VFR-only pilots performed significantly worse than the other three groups did. Likewise, instrument-rated pilots performed significantly worse than CFIs and ATPs. The performance of CFIs and ATPs did not differ significantly from each other. However, all four groups, including CFIs and ATPs, performed poorly on The Weather Knowledge Challenge.

- Prior to completing the tests, pilots rated their mastery of weather-related decision making significantly higher than their mastery of content in the other five weather categories. However, their self-ratings for mastery of content in all six categories were in the Fair to Good range.

- After having completed the tests, the pilots rated their actual performance significantly lower than they had rated their mastery of weather category content prior to having taken the test. However, these subjective ratings of how they had performed were still generally better than their actual performance. Hence, many pilots do not have accurate perceptions regarding their levels of weather knowledge.

- Pilots tended to perform the best on items that were designed to be "pure" measures of knowledge of weather hazards and of weather-related decision making. Pilots tended to perform the worst on items that were designed to be pure measures of knowledge of weather interpretation and of weather services. Pilots at all levels of formal training, but particularly those who were certificated to fly only in visual meteorological conditions, generally had difficulty in integrating weather knowledge from several of the six different weather categories (e.g., weather hazards, weather services, weather interpretation, and weather-related decision making). All participants, but VFR-only pilots in particular, also had difficulty in demonstrating an understanding of the implications weather information has for real flight operations.

- Pilots at all levels of formal training had difficulty on items that required them to "decode" information in various weather products (e.g., METARs, TAFs, Winds Aloft Table, etc.) or to read various weather charts.

- All pilots, including many instructors, were unable to select correct answers for VFR weather regulations questions. Only 44.7% of all pilots were able to correctly identify Marginal VFR visibility and ceiling levels and 45.9% of all pilots actually incorrectly identified IFR visibility and ceiling levels as those that constitute Marginal VFR.

CFI Weather Training Survey

CFI participants were recruited through Part 141 schools and notices posted on the AvWeb/AvFlash, NAFI e-Mentor, AOPA, and TheCFI.com websites. Completed paper/pencil versions of the survey were returned by 177 CFIs and 233 CFIs completed the survey on-line. The surveys were designed to elicit information from active CFIs about the weather instruction they provide to primary student pilots (i.e., those students working toward a Private Pilot Certificate). The major findings of this study were that:

- CFIIs report placing greater emphasis on 17 of 34 different weather topics, grouped into six different weather categories, than CFIs do during the training of primary student pilots. However, CFIIs and CFIs do not differ in the amount of emphasis they report giving to Weather-Related Decision Making topics.

- Participants, who instruct under FAR Part 61 only, report placing significantly less emphasis on 27 of the 34 weather topics during training with primary students than their counterparts who teach also or only under FAR Part 141 and/or in academic settings.

- In terms of the reported emphasis given to teaching weather topics, CFIs who teach under both Part 141 and Part 61 bear greater resemblance to CFIs who teach only under Part 141 than to CFIs who teach only under Part 61.

- During instruction with primary student pilots, participants report that they place the least amount of relative emphasis on most topics related to the Basic Causes of Weather and to Weather Services. Participants indicated that they give the greatest emphasis to topics pertaining to Weather Regulations and to Weather-Related Decision Making.

- Although CFIs indicated that Weather-Related Decision Making was that category that held the greatest importance for training primary student pilots, in actuality it was found that they spend the greatest amount of time covering Weather Regulations topics. CFIs also appear to think that they emphasize Weather Hazards topics to a greater degree than they do in actual practice.

- All participants, regardless of their level of instructor rating or experience, or where/under which FAR Part they instruct, tend to spend around five to six hours during ground school and around five to six hours in-flight instructing their primary student pilots about weather. This appears to contradict the earlier finding of significant differences in the amount of emphasis reportedly given to individual weather topics due to type of instructor rating and where/under which FAR Part they instruct.

- Participants reported feeling very confident that they had mastered the content in the six different weather categories. However, participants rated the quality of instruction they provide in these same six categories significantly lower. Thus, the participants believe that they, themselves, understand weather material better than they are able to teach it to their students.

- An overwhelming majority of the participants advocate the practice of exposing primary student pilots to marginal weather conditions during training. Further analyses revealed that participants who instruct only under Part 61 were significantly stronger advocates of this practice than those who instruct also or only under Part 141 and/or Academia. No differences in this attitude were found between CFIs and CFIIs or between instructors with the lowest and highest amounts of experience.

- Four-fifths of the participants reported that they had actually flown with students into marginal conditions (around 2 times with each student). The most popular way to do this was for the instructor to file an IFR flight plan and fly in real IMC conditions with the student on-board. A very large number of instructors also reported that they make a point of flying in windy or turbulent conditions with their students.

- CFIIs were significantly more likely than CFIs to report having flown with students in marginal weather conditions. Likewise, instructors with the highest amounts of teaching experience were significantly more likely to report having done so than instructors with the lowest amounts of teaching experience. Instructors in the Part 61 Only group also appear to do this to a significantly greater degree than their colleagues instructing also or only under Part 141 and/or Academia.

- In summary, only a few differences were found between instructors related to their level of instructing experience (high or low). However, instructors who teach only under Part 61 appear to differ on several dimensions from those who instruct also or only under Part 141 and/or in academic institutions. Likewise, several differences were found between CFIs and CFIIs related to various facets of weather instruction with primary student pilots.

Conclusion

All participants, including flight instructors, appear to believe that they generally have a good understanding of weather and a broad base of aviation weather knowledge. However, none of the participants in this study, as a group, demonstrated a strong understanding of weather as it pertains to real flight operations. Pilots, CFIs, researchers, training material developers, and the FAA each have a role to play if we are to improve the state of pilot weather training, increase the level of pilot weather knowledge and understanding, and have a real and positive impact on general aviation safety related to weather.

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Final Report – First Part

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Introduction

It is well known that poor or hazardous weather conditions continue to play a central role in many general aviation (GA) incidents and accidents (Aircraft Owners and Pilots Association, AOPA, 1996; National Transportation Safety Board, NTSB, 1989). When these accidents occur, often the results are fatal. In 1999, 75% of all weather-related GA accidents resulted in fatalities (AOPA, 2001).

Under "Safer Skies – A Focused Agenda" the FAA identified "weather" as one of the primary safety issues needing to be addressed within General Aviation. A Joint Safety Analysis Team (JSAT) met several times to review a representative sample of GA accidents involving weather and identified seven root causes for these accidents, the first pertaining to pilots: "Inadequate initial and continuing pilot education and formal operational procedures for making weather decisions" (FAA, 1999, p. 12). Intervention strategies suggested by the JSAT to address this root cause related to improving initial and continuing education in order to increase GA pilot knowledge, skill and judgement in weather-related decision making (FAA, 1999).

To this end, the FAA Aviation Safety Program, as well as many other aviation organizations (e.g., AOPA) sponsor numerous safety workshops each year, many on weather-related topics. Two computer-based training (CBT) CD-ROMs have also been developed related to improving GA decision making. "Making Your Own Rules: Creating a Personal Minimums Checklist" (1999) is an effective CBT through which pilots are introduced to the idea of setting personal minimums for making a go/no-go decision. Some of the factors the CBT pilot users consider as they develop their own minimums checklists pertain to weather. In "Weather Wise" (1999), another FAA CBT, GA pilots sharpen their weather decision making skills as they learn to "read the weather out the cockpit window" and "recognize hazardous weather conditions." Although users, by virtue of having completed the CBTs, may gain some weather knowledge, both were designed with the expectation that pilot users would already have a good knowledge base regarding weather as their focus is on strengthening decision making skills.

Pilot decision making skills and strategies have also been the focus of much of the research related to GA weather-related accidents; the consensus in the aviation community is that many of these accidents stem from "pilot error" most notably, poor weather-related decision making (National Aviation Weather Program Council, 1997; Sand and Biter, 1997). Some researchers have examined the role that expertise has on aeronautical decision making more generally (Driskill, Weismuller, Quebe, Hand, & Hunter, 1998; Guilkey, Jensen, Caberto, & Fournier, 1995; Kochan, 1995) as well as in weather-related decision making, more specifically (Wiggins & O'Hare, 1995). Research has generally found differences in the quality of decisions made by novice pilots compared to those with greater expertise. As a result, some researchers have suggested teaching novices the decision making strategies employed by experts, thereby circumventing the time needed for a novice pilot to gain expertise (Orasanu, 1995). What is often overlooked, however, is that experts also typically have more knowledge than novice pilots do. Good decisions are not made in a vacuum but ensue from a solid knowledge base.

Researchers have also investigated other factors believed to pertain to GA weather-related accidents. Some have examined the amount of consideration or "worth" pilots give to different weather and terrain variables when planning cross-country flights in light aircraft (Driskill, et al.,1997; Driskill, Weismuller, Quebe, Hand, & Hunter, 1997; Martinussen, Hunter, & Wiggins, 1998). Others have focused upon the cognitive processes involved in making weather-related decisions (O'Hare & Smitheram, 1995) and pilot situational awareness of deteriorating weather conditions (Layton & McCoy, 1989; McCoy, Woleben, & Smith, 1994). Thus, although researchers have examined higher order cognitive processes and strategies to identify shortcomings in pilot weather-related decision making, none have examined pilots' weather knowledge bases, from which these decisions are derived, or the training the pilots' received whereby their knowledge bases were established.

Knowledge, Training the and Role of Certified Flight Instructors (CFIs)

Besco (1989) identified five factors commonly associated with pilot performance: knowledge, skills, attitudes, obstacles, and the systems environment. Although a deficiency in one alone is sufficient to lead to pilot error, they are inter-related and often co-occur in accidents in which "human error" is cited as a cause. Some skills can be learned by rote and performed without demonstrating real understanding and knowledge about the skill. For example, a student pilot can be taught to correctly apply right rudder pressure upon take-off to "keep the nose straight" without knowing or understanding concepts such as slipstream forces on the empennage, engine and propeller torque, gyroscopic precession, or propeller P-factor.

Some pilots may make weather-related decisions using a set of heuristics or "rules of thumb" which do not require that they have a thorough understanding of weather and the implications it has for flight. For example, VFR pilots flying in the Eugene, Oregon area might use the relationship of the cloud base to the tops of the Coburg Hills to determine whether or not to fly – "If the clouds hit the tops of the hills, I won't go flying." Heuristics like this one do not require large amounts of information or much processing by the pilot. Pilots who use such weather heuristics may fly quite safely as long as they follow them and do not venture out of the physical environment where they apply (R. Mauro, personal communication, August 21, 2002).

Critical thinking and decision making skills that are not based upon the use of heuristics or "rules of thumb" require that much more information be available to be processed. Information alone is not sufficient for good decision making to occur, though; in-depth knowledge and understanding of the information are crucial but often overlooked elements (Adams, 1997; Glaser, 1984).

Thus, pilots will often be unable to make good weather-related decisions if they lack a good fund of weather knowledge – to be distinguished from just having weather information (Sand & Biter, 1997). A pilot's weather knowledge base is typically established during his or her initial training and develops as he or she gains experience, obtains more advanced levels of pilot certification and ratings, learns from the experiences of others, and develops greater comprehension through continuing education materials and programs. However, if "weather" is neglected or given only cursory coverage during initial training, pilots will find it difficult to add to or shore up this weak and “crumbling” foundation later. Indeed, most student pilots look to their CFIs as their primary source of information when developing their knowledge bases and may lack the motivation or ability to obtain, understand, or integrate weather knowledge on their own.

To develop a better understanding of GA pilot decision making related to weather, we must first explore CFI weather training practices. Indeed, the kind, content, and quality of weather training has often been overlooked (Office of the Federal Coordinator for Meteorological Services and Supporting Research, OFCM, 2002). What and how do CFIs teach student pilots about weather? How much emphasis is given to different weather topics?   Do CFIs themselves have a thorough understanding of weather as it relates to aviation operations? What is the quality of the weather-related instruction CFIs give? As CFIs are the “foundation of the learning pyramid” (R. Baker, e-mail communication, February, 10, 2000) it is particularly important to assess deficiencies in their weather knowledge bases. If CFIs lack weather knowledge themselves, they will be unable to transmit information pertaining to weather correctly or at all to their students.

Little information has been available regarding private pilot and instructor knowledge about weather. Performance data from FAA written exam weather questions are not available separately from an applicant’s overall exam score. Likewise, no information has been available pertaining to CFI training practices regarding weather when instructing primary student pilots.

A clearer understanding of CFI training practices, pilot knowledge bases and deficiencies, and pilots’ abilities to apply weather knowledge will allow us to better evaluate errors in weather-related decision making and develop more effective training and intervention strategies.

The Current Study

The General Aviation Pilot Weather Knowledge and Training Study was comprised of two distinct parts: “The Weather Knowledge Challenge” and the “CFI Weather Training Survey.” The Weather Knowledge Challenge was used to assess the knowledge that certificated private pilots at all training and experience levels, including CFIs, have regarding content in six weather categories: Causes of Weather and Weather Patterns, Weather Hazards, Weather Services, Weather Regulations, Weather Interpretation, and Weather-Related Decision Making. Through the CFI Weather Training Survey, CFIs provided information regarding the weather training they provide to student pilots. The methodologies used, results and discussion of the findings for The Weather Knowledge Challenge and the CFI Weather Training Survey are presented separately below.

Method

Participants

Participants for this study were pilots attending the Experimental Aircraft Association (EAA) Airventure 2000 Fly-in at Oshkosh, Wisconsin. One thousand one hundred thirty-five (1,135) individuals completed a weather knowledge test. However, the tests were designed for private pilots who had completed their training, were certified to fly as pilots-in-command (PIC) in at least visual meteorological conditions (VMC), and who could be expected to be familiar with FAA weather regulations and services. Therefore, 72 student pilots, one individual with an Airplane and Powerplant certificate but no pilot certificate or rating, and 57 pilots who reported that they either lived or did most of their flying outside of the United States were eliminated from the dataset before analyses were performed.

Of the 1005 participants whose data were included in analyses, 89.8% were male ($n = 902$) and 10.0% ($n = 100$) were female (three participants did not indicate a gender). The participants ranged in age from 18 to 83 years old; the overall mean age was 47.68 years (48.15 years for males and 43.05 for females). The median age of the participants was 48 years (48 years for males and 44 years for females).

Participants were asked to report the total number of flight hours they had logged as well as the number of flight hours logged during the previous six months. The mean number of total flight hours logged was 2140.11 hours (2244.94 for males and 1243.77 for females) with a median of 650 hours (700 for males and 405 for females). The total number of flight hours for all participants (as well as those for male participants) ranged from a low of 20 (logged by a pilot who had a lighter-than-air certificate) to 33,000 hours. The total number of flight hours for female participants ranged from 75 to 15,000 hours.

Both males and females reported a low of zero hours flown in the previous six months; males reported a high of 1004 hours compared to a high of 500 hours for females. The overall mean number of hours flown by all participants in the preceding six months was 75.99 hours (median = 40 hours): the mean for males was 75 hours (median = 40 hours) and the mean for females was 86.12 (median = 30 hours).

Although the male and female pilots did not differ significantly from each other in terms of amounts of recent flight experience (i.e., hours logged in the preceding six months) they did differ significantly in the amount of overall flight experience (t (184) = 3.71, $p < .001$). As indicated above, male pilots in this sample had logged substantially more hours than the female pilots. Males were distributed fairly equally across four different experience level groupings (as determined by using quartile splits of the total numbers of flight hours logged): 23.6% were in the lowest level of experience group, 26.0% were in the next highest level, 25.5% were represented in the third highest level, and 24.9% had obtained enough flight experience to place them in the highest experience level. Females on the other hand were disproportionately represented in the lowest level of overall flight experience (39.0%) and far fewer were in the highest level of flight experience (13.0%); twenty-three percent (23.0%) and 25.0% had obtained the amount of flight experience to place them in the second and third highest experience levels, respectively.

The participant pilot statistics pertaining to certificates and ratings earned are compared with the overall U.S. pilot population, as estimated by the FAA, in Table 1, which can be found in Appendix D.

Measures

An aviation meteorologist drafted approximately 48 multiple-choice questions. Each question was intended to be as pure a measure as possible of content in one of six different weather categories: Basic Causes of Weather, Weather Hazards, Weather Services, Weather Regulations, Weather Interpretation, and Weather-Related Decision Making. The aviation meteorologist also developed three other questions that were designed to assess knowledge from more than one category. These questions required pilots to integrate information and knowledge across these weather categories to ascertain the correct answer.

All questions were specifically designed to be operationally relevant. Questions were intended to measure weather knowledge that would be necessary for VFR-only pilots, flying single-engine land aircraft, to plan flights and fly safely. Care was taken to try to avoid questions that required the recall of rotely memorized weather facts that were not pertinent to real-world general aviation flight operations.

Because of the limited time between the awarding of the grant and data collection at Oshkosh, it was not possible to pretest the questions with pilots in any formal way or to conduct any types of statistical analyses to determine the extent to which the questions loaded on factors deemed to be related to the weather categories. Instead, four CFIIs, who were also experienced aviation psychology researchers, reviewed each of the questions and made suggestions for revisions. Based upon their review, only the strongest 30 questions (five in each of the six weather categories) and the three "integration" questions were retained for final use. Finally, a FAA Flight Service Station weather analyst, who was also a CFII, reviewed the final set of 33 questions and made suggestions for further minor revisions.

Three different test forms were developed and the three integration questions appeared on each. The remaining 30 test questions, which were designed to be more "pure" measures of a single weather category, were divided among the three test forms so that each form included at least one question, and usually two, assessing each weather category. Thus, each of the three test forms contained 13 weather knowledge questions – three of which appeared on each test form and 10 that were unique to that form.

The first section on each of the test forms asked the pilots to provide demographic and background data pertaining to pilot certifications and ratings earned, average number of hours flown annually, and related information. Pilots were also asked to rate the confidence they had in their level of mastery of content in the six different weather categories being assessed.

The second section contained the 13 weather questions with the three integration questions appearing last. A final question asked participants to rate how well they thought they had done on the test. Thus, pilots rated their perceived mastery of weather content prior to having taken the test and also indicated how well they believed they had performed following completion of the test. Finally, pilots were invited to write down any comments they wished to make regarding the test, the study, or weather and pilot training in general. The three test forms can be found in Appendixes A, B, and C.

Three different test forms were developed to keep them as short as possible so that participants would be able to complete the test in 10-15 minutes. Given that the tests were to be completed during the Oshkosh Airventure, it was assumed that the pilots would be less likely to participate if the test required more than a few minutes to complete. However, even with only 13 weather questions, the research assistants who collected the data reported that most participants took at least 20 minutes to complete the tests and several worked on it for a great deal more time (up to 45 minutes for one participant). It appears that, in general, the participants approached the task seriously and gave their best efforts.

Procedure

Data collection occurred Wednesday, July 26, 2000, through Sunday, July 30, 2000, as these were the days in which attendance at Airventure was expected to be the greatest. Through the assistance of Dr. David Hunter and Mr. Roger Baker (FAA, Office of Aviation Medicine) arrangements were made for a table in the display area of the Oshkosh FAA Building to be used for data collection. A sign advertising "The Weather Knowledge Challenge" was posted on a large display board, which was graciously provided by the FAA, behind the table. This sign indicated that the FAA was funding "The Weather Knowledge Challenge." Other signs that described the raffle prizes, which were used as incentives (described below), were also posted throughout the FAA Building. Six undergraduate students who were matriculating in the Aviation Studies program at the Catonsville Community College in Maryland assisted in the collection of data.

As pilots passed the table they were asked if they would like to complete a weather knowledge test. They were told that it would take approximately 15 minutes and that their responses would be kept confidential. Pilots were also told that all participants were eligible to win a raffle drawing of a hand-held GPS and gift certificates toward the purchase of pilot supplies. Eligible participants (i.e., certificated pilots who were not affiliated with the FAA or the researchers conducting the study) were given a description of the study that included informed consent and researcher contact information. They were also randomly given one of the three test forms and a raffle ticket to complete.

A $100 gift certificate for the purchase of pilot supplies was raffled off each of the five days of data collection, with a posting of the winners' names each day. The raffle drawing of one, Garmin 195, hand-held GPS was held just after 5:00 p.m. on Sunday, July 30th. For each drawing an employee of the local FAA FSDO was asked to blindly select from the completed raffle tickets to identify all winners. Participants did not need to be present at the time of the drawings in order to win nor participate in the raffle drawings in order to complete a test measure.

Because the measures were numbered, it was possible to provide follow-up information to each of the participants about how well they answered the weather knowledge questions. Participants who were interested in obtaining such information were instructed to self-address a mailing label. They were sent results of their performance after the data were analyzed – a few weeks after the completion of data collection.

Results

Randomization Check and Equivalency of Participant Groups by Test Form

As mentioned earlier, prior to the completion of any analyses, data from student pilots, non-U.S. pilots, and one participant who did not hold a pilot certificate were eliminated from the final dataset. Analyses were then conducted to determine the degree to which the groups of pilots who took the three test forms (A, B, and C) were different from each other. There were no significant differences in the number of pilots who completed test form A (n = 320) test form B (n = 346) and test form C (n = 339; X^2 (2) = 1.08, p = .58).

Analyses of pilot demographics revealed two characteristics where significant differences by test form existed: female pilots (X^2 (2) = 10.16, p < .01; n = 100) and pilots with rotorcraft ratings (X^2 (2) = 7.40, p < .05; n = 40). A third of the female pilots who participated in the study (n = 34) completed form B, as would be expected. However, over twice as many completed form A (n = 46) as completed form C (n = 20). Likewise, as would be expected, one third of the participants with rotorcraft ratings (n =14) completed form B. However, a full half with this rating (n = 20) completed form C whereas only six (n = 6) completed form A.

No significant differences were found between the participants due to test form completed related to the numbers who selected correct answers on the three weather knowledge integration questions (question 11: X^2 (2) = 2.07; p = .36; question 12: X^2 (2) = 1.63, p = .44; question 13: X^2 (2) = 1.25, p = .54). Likewise, no significant differences related to the test form completed were found regarding the ratings participants gave of their mastery of weather content in six different areas – recall that participants made these ratings prior to having completed the test questions.

As indicated earlier, participants were also asked to evaluate their performance on the test after having completed the weather questions using a 5-point Likert scale (1 = Very Poor, 5 = Superior). Differences in these ratings between the participants who completed forms A and B approached, but did not reach, statistical significance (t (652) = 1.76, p = .080) as did those between the participants who completed forms A and C (t (648) = 1.94, p = .053). In both instances, the participants who completed form A rated their performance on the Weather Knowledge Challenge (M = 3.43, SD = .75) higher than those who completed form B (M = 3.33, SD = .74) or form C (M = 3.31, SD = .78).

Performance on the Weather Knowledge Challenge

Preliminary analyses of the performance of participants on the weather knowledge questions were conducted. Through these analyses it was determined that one question (A4) was sufficiently confusing and poorly written to warrant dropping it from the test prior to running further analyses. Additionally, after further review and critique by several pilots and CFIIs, it was determined that four questions (B9, C9, C10, A/B/C12) each had two answers which could be considered to be correct. All analyses reported below reflect such a change in scoring for these questions.

Amount of experience and level of formal training (as determined by certifications and ratings earned) were expected to play an important role in any test performance differences found among the participants. A review of the distribution of participants' logged flight hours (both overall and within the preceding six months) indicated that quartile splits would be appropriate ways of dividing the participants into groups on these variables.

Pilots were also divided into four discrete groups by their levels of formal training. VFR pilots were those recreational, private and commercial pilots who did not have an instrument or instructor rating or an Airline Transport Pilot (ATP) certificate. Instrument Pilots were those who had an instrument rating but not an instructor rating or ATP certificate. Instructors included those participants who held a CFI, CFII, and/or a MEI, but who did not also have an ATP certificate. ATP pilots were those participants who held an ATP certificate regardless of any other certificate or rating they might have also held. No data were gathered regarding whether a pilot's instrument or instructor rating was current or whether a pilot with an ATP certificate was actually employed as an airline transport pilot.

Participants' mean numbers of weather knowledge questions correct are presented in Table 2, which can be found in Appendix D. Overall, the 1005 participants achieved a mean score of 8.54 correct out of 13 questions ($\underline{SD} = 2.07$). Thus, with 66% correct, as a group, the participants earned a "grade" of D on this test. The performance of the participants did not differ significantly across the three different test forms (forms A, B, C) – each group performed solidly in the D range with 65% or 66% correct answers.

Gender differences. Male participants achieved 66% correct ($\underline{M} = 8.60$, $\underline{SD} = 2.05$) compared to female participants who achieved 62% correct ($\underline{M} = 8.06$, $\underline{SD} = 2.24$; see Table 2). Although this difference in performance is statistically significant ($\underline{t}$ (1000) = 2.46, $\underline{p} < .05$), this finding disappeared when considered in conjunction with level of formal training (see below). Thus, gender does not explain differences in performance on The Weather Knowledge Challenge.

Differences related to amounts of flight experience. Correct scores on the weather tests were significantly correlated with both total flight experience ($\underline{r} = .17$, $\underline{p} < .001$) and recent flight experience ($\underline{r} = .27$, $\underline{p} < .001$). Recent flight experience was significantly correlated with test performance for both VFR-only pilots ($\underline{r} = .20$, $\underline{p} < .001$) and for flight instructors ($\underline{r} = .23$, $\underline{p} < .01$) but not for instrument-rated pilots ($\underline{r} = .04$, $\underline{p} = .49$) or pilots who held an ATP certificate ($\underline{r} = .06$, $\underline{p} = .56$). However, none of these relationships were particularly strong.

Performance on the knowledge questions improved with increasing amounts of flight experience (total flight hours logged: $\underline{F}$ (3, 1000) = 21.52, $\underline{p} < .001$; hours logged in the preceding six months: $\underline{F}$ (3, 998) = 37.35, $\underline{p} < .001$). However, even those pilots with the most experience did not perform particularly well (see Table 2 in Appendix D). Participants in the group with the greatest total number of flight hours achieved a mean correct score of 9.32 ($\underline{SD} = 1.95$), which is equivalent to 72% correct. Participants who had logged the most flight time within the preceding six months earned the slightly higher score of 73% correct (M = 9.51, SD = 1.99).

Although differences in performance related to total amount of flight experience and recent flight experience are statistically significant, these findings also disappeared when considered in conjunction with level of formal training (see below). Therefore, flight experience alone does not explain differences in performance on The Weather Knowledge Challenge.

Differences due to level of formal training. With increasing amounts of formal training performance improved significantly on the weather knowledge questions (F (3, 1001) = 57.43, p < .001)). Again, however, even those pilots with the most training did not perform particularly well (see Table 2). ATP participants scored the best of the four pilot groups with 75% correct (M = 9.70, SD = 1.69). Readers are reminded that all questions were intended to measure weather knowledge that should be mastered by even VFR-only private pilots who fly in the United States.

Joint effects of training, experience, and gender. Three-way ANOVAs were performed to examine the main and interaction effects of level of formal training, amount of flight experience (total and recent), and gender. As can be seen in Tables 3a and 3b (found in Appendix D) only a main effect for level of training was found to be statistically significant (F (3, 975) = 9.10, p < .001, when total hours of experience were considered; F (3, 969) = 8.86, p < .001, when recent hours of experience were considered). Tukey post hoc analyses revealed that VFR-only pilots (M = 7.70, SD = 1.99) scored significantly lower (p < .001) than instrument rated pilots (M = 8.93, SD = 1.90), flight instructors (M = 9.50, SD = 1.88), or pilots with ATP certificates (M = 9.70, SD = 1.69). Similarly, instrument-rated pilots scored significantly lower than flight instructors (p < .05), and participants holding ATP certificates (p < .01). Flight instructors and participants holding ATP certificates did not perform significantly differently from each other. Therefore, although earlier analyses indicated significant performance differences related to gender and to amounts of total and recent flight experience, these findings can be explained by differences in levels of formal training.

Actual Test Performance and Self-Ratings

As discussed earlier, after completing the 13 weather questions, pilots were asked to rate how well they believed they had performed on the test using a 5-point Likert Scale (1 = Very Poor, 5 = Superior). Actual performance scores correlated significantly with pilot's self-ratings (r = .367, p < .001). Additionally, pilots' mean self-ratings of performance corresponded to the relative magnitudes of their actual test performance mean scores. The three pilots who gave their performance a "Superior" rating achieved a mean score of 10.00 (SD = 1.0). Eighty-three (83) pilots believed they had performed "Above Average" and they achieved a mean score of 9.98 (SD = 1.71). Most pilots (n = 546) believed their performance had been "Average" and they earned a mean score of 8.91 (SD = 1.95). "Below Average" was the rating that 280 pilots selected to describe their performance; they obtained a mean score of 7.86 (SD = 1.88) on the test. The group that selected "Very Poor" (n = 79) obtained a mean test score of 7.00 (SD = 2.19).

Although the relative magnitude of the pilots' actual test performance matched the self-ratings in order from highest to lowest, the text anchors used for the self-rating scale did not correspond well to the pilots' actual performance. Those who rated their performance as "Superior" only obtained 77% correct. Similarly, those who described their performance as "Average" provided 69% correct answers.

Interestingly, in each of the 5 rating groups, including the "Very Poor" group, there was at least one participant who achieved a perfect score (13 correct answers) except for in the group who rated their performance to be "Superior." In fact, 11.4% (n = 9) of the pilots who rated their performance as "Very Poor" provided 10 or more correct answers (earning a "grade" of C or better). In the "Below Average" self-rated group, 16.8% (n = 47) provided 10 or more correct answers. Conversely, in the group who rated their performance to be "Above Average" 42.2% (n = 35) earned a score equivalent to a D or an F. Hence, many participants in this study lacked an accurate perception of how they had really performed.

Recall that prior to completing the weather test questions, participants were also invited to rate their perceived level of mastery of content in six different weather categories using a 5-point Likert scale (1 = Very Poor, 5 = Excellent). In order from lowest to highest, all the mean mastery self-ratings fell in the Fair to Good range: Weather Interpretation (M = 3.28, SD = .84), Weather Services (M = 3.36, SD = .85), Basic Causes of Weather (M = 3.40, SD = .71), Weather Regulations (M = 3.55, SD = .81), Weather Hazards (M = 3.63, SD = .74), Weather-Related Decision Making (M = 3.90, SD = .73). Planned comparisons revealed that participants rated their mastery of Weather-Related Decision Making significantly higher than their mastery of content in each of the other five weather categories (Huynh-Feldt F (4.6, 4421.1) = 138.92, p < .001).

Pilots' ratings of their mastery of weather category content, made prior to taking the test, were also compared with their performance ratings, made after taking the test. All pilots rated their mastery of the content in each of the six weather categories significantly higher than they ended up rating their actual performance on the test (planned comparisons: Huynh-Feldt F (5.5, 5280.5) = 400.08, p < .001). Likewise, planned comparisons (with Huynh-Feldt corrections) revealed that pilots at four levels of training each rated their mastery of all categories of weather material significantly higher than they ended up rating their actual performance on The Weather Knowledge Challenge (VFR-only: F (5.5, 2350.1) = 204.84, p < .001; Instrument-rated: F (5.5, 1626.9) = 108.53, p < .001; Flight Instructors: F (5.6, 738.2) = 46.70, p < .001; ATP: F (5.5, 530.8) = 54.00, p < .001).

Knowledge of Weather Category Content

In addition to the overall performance of pilots on The Weather Knowledge Challenge, their performance on questions within each of the six weather categories was of interest in this study. The mean proportion of correct responses made by the participants to questions within each of the six weather categories are presented in Table 4, which can be found in Appendix D. A review of these proportions reveals that pilots generally performed best on questions related to Weather Hazards and Weather-Related Decision Making and tended to perform the most poorly on questions related to Weather Interpretation and Weather Services. Performance on questions related to Basic Causes of Weather and Weather Regulations fell in between.

Patterns of results found earlier were replicated in the findings here: pilots tended to perform better in each category as they increased in level of formal training, and overall, pilots tended to perform fairly poorly. Even in the Weather-Related Decision Making category (which was generally the second highest category in terms of proportion of correct answers), the proportion correct was in the .70's for most groupings of pilots.

A review of frequency analyses where participants responded to two questions in a weather category indicates that the proportions correct within each category roughly resemble normal distributions of answers. In other words, most participants gave one correct answer with fewer numbers giving no or two correct answers. Thus, the proportions presented in Table 4 likely represent the performance of one population of pilots and are not an aggregation of correct scores across two different populations of pilots – ones who were very knowledgeable about weather and ones who knew nothing about weather.

Analyses of Individual Weather Questions

Because 30 of the 33 weather questions, assessing knowledge in one of six different weather categories, were distributed across three different test forms, it was not possible to run more sophisticated analyses typically used in conducting item analyses (e.g., factor analysis). However, an evaluation of each item (test question), based upon the performance of the participants and various groupings of participants is possible. The most simplistic of these evaluations is a review of the number of times the various answer choices were selected by the participants for each question. These data are presented in Table 5, found in Appendix D.

Table 6, also in Appendix D, presents the percent of correct answer choices for each weather item by the participant's level of formal training: VFR-only, instrument-rated, flight instructor, or ATP. Table 7 presents the percent of correct answer choices for each question by the geographic regions where pilots reported they flew the most (see Appendix D).

A review of these findings, particularly those presented in Tables 5 and 6, reveal some interesting trends. First, as has been noted in the results of earlier analyses, as the level of formal training increased, participants generally selected a greater percent of correct answers for most items. Thus, generally, instrument-rated pilots tended to select the correct answer more often than VFR-only pilots, instructors tended to select the correct answer more often than instrument-rated pilots, and so on. Although this pattern was seen for many questions, there were some notable exceptions where participants holding an ATP certificate actually selected the correct answer significantly less often than instructors or even, at times, less often than instrument-rated pilots. These exceptions are described in more detail later.

As a group, VFR-only pilots differed significantly from the other three groups of pilots in their knowledge of weather facts and services that can have real implications for safe flight. For example, only 54.1% of VFR-only pilots were able to correctly predict that fog was likely to form given a series of METAR reports (question C8). Likewise, only 53.5% of the VFR-only pilots selected the correct answer regarding what would happen to an aircraft's airspeed when flying through a microburst near the ground (question C3). Almost a quarter (23.2%) of the VFR-only pilots did not know the correct radio frequency for Flight Watch (EFAS) (question

B4). Interestingly, in this instance their performance was not significantly different from flight instructors, slightly over 10% of whom did not know the Flight Watch frequency.

A third and very robust observation is that pilots of all levels of formal training have difficulty deciphering, reading, and understanding the coded information that is presented to them in METARs, TAFs, and other weather charts and tables. Question C7 presented participants with a TAF for Dallas/Fort Worth International Airport (DFW) and asked them to use it to determine the earliest time they would expect thunderstorms to reach DFW; only 31.9% of all participants selected the correct answer and only 42.1% of the participants with ATP certificates (who performed the best of the four pilot groups) selected the correct answer. Similarly, over 25% of all participants were unable to interpolate winds aloft at 8,000 ft. using the winds aloft table presented in question A8. Only 64.1% of the VFR-only pilots selected the correct answer for this question.

To see if difficulty in deciphering and reading information in METARs, TAFs and other weather charts and tables could be responsible for the participants' poor performance on The Weather Knowledge Challenge, all questions requiring such ability were eliminated from the tests and the overall percent correct was again computed. Eliminating these questions did not improve pilot performance across the three test forms; 65.3% of the remaining questions were answered correctly compared to 65.8% correct answers when these questions were retained (t (1002) = 1.44, p = 1.50.

Pilots performed quite poorly even on questions that did not require the pilots to read and use weather charts and tables but simply assessed their general knowledge about such materials. For example, only 41.6% of all pilots and 58.8% of ATP certificate holders (the highest scoring subgroup) knew that the coverage area of a TAF was within 5 nautical miles of the issuing airport (question B5). Similarly, only 43.4% of all pilots knew that wind information included in METARs is presented in true, rather than magnetic, headings (question A5). Just 38.7% of VFR-only pilots, 41.5% of instrument-rated pilots, 62.0% of instructors, and 41.2% of ATP participants selected the correct answer to this question.

A fourth observation was that all pilots, even many instructors, were unable to select the correct answers related to VFR weather regulations. Two questions (A7 and B6) presented participants with scenarios and asked them, given the situations described, the cloud clearance and visibility requirements for VFR flight. Fewer than half of all participants selected the correct answers to each of these questions. Interestingly, although the questions are very similar, 79.2 % of the flight instructors completing test form B selected the correct answer to question B6 but only 50.0% of the instructors completing test form A selected the correct answer to question A7 – why is unclear.

One of the most surprising findings was that only 44.7% of all pilots were able to correctly identify Marginal VFR visibility and ceiling levels (question A6). Shockingly, 45.9 % of all pilots selected the incorrect answer choice that actually presented IFR visibility and ceiling levels. Of the four pilot groups based upon levels of formal training, the instructors performed the best on this question but still a full 26.0% selected the wrong answer. At 44.1% correct, the ATP pilots did little better on this question than the VFR-only pilots with 32.4% correct. One might argue that airline transport pilots (if they are actually employed as such) might be excused for not being familiar with Marginal VFR ceilings and visibilities as they likely always fly under instrument flight rules (IFR). Although this argument might have some merit, it is equally true that all pilots attending the Oshkosh Fly-In, where these data were collected, tend to fly as general aviation pilots under Part 91 regulations and, hence, are very likely to fly under VFR rather than, or in addition to, under IFR.

A final observation evident in a review of the answers selected for each item supports findings reported earlier: pilots have difficulty using weather trends and current weather information to predict how future flight conditions might be affected. This was true even for Weather Interpretation questions that did not require pilots to read, decipher, and use METARs, TAFs, and weather charts and tables (see for example question B8).

Participants' Comments

Several themes were apparent in the types of comments that pilots spontaneously wrote following the completion of the test. One theme related to a desire to obtain more weather training or a felt need to study weather information:

> "I need to hit the books again." "Going home to brush up on wx." "I think this is a great tool to alert pilots to how much they don't know about wx, especially if they don't fly in it often." "I'll be reading the weather book again!" "Need to review weather reading charts." "I need to get a book on weather and learn to read weather systems better. Difficult to learn on own. A program would make it easier." "I think that more current and user friendly training materials would be helpful to train pilots to interpret the weather." "This is an area that is over-looked in Part 61 training programs."

Another theme evident in the participant comments pertained to frustration with current weather products and the ways in which they present weather information:

> "Make plain language weather reports!!!" "The FAA must improve and simplify the process for pilots to obtain weather information. Problem – too many weather charts and too much interpretation required – use plain English. Need consolidated wx charts – 2 types: current wx and forecast…" "We need to get away from putting weather information in code and start using English…" "With the ability of modern digital communications – I don't understand why FAA continues to use the arcane coded TAF's and METAR's."

Some participants expressed concerns about specific questions on The Weather Knowledge Challenge but a number generally thought that the test was a good one:

> "This is great – questions were very challenging. This is the way we need to teach weather!" "Excellent – good review." "Tough test!" "Thank you for the opportunity to take this test. It is a service and an eye opener." "I am an ATC center operator. These are good questions. I did not know several!" "Excellent Exam…" "Very good situation oriented questions!"

All comments made by participants whose data were included in analyses are presented in Appendix E.

Discussion

One of the most potentially important findings of this study is that, overall, pilots' weather knowledge, as measured by The Weather Knowledge Challenge, is quite poor. This finding only has importance, however, if this measure has both content and construct validity, is reliable, and assesses weather content that has a high degree of operational relevance. These issues, as they relate to both The Weather Knowledge Challenge and to current FAA Private Pilot Written Exam weather questions, are explored further below.

It was not surprising to discover that as pilots' level of formal training increased their knowledge about weather increased. What was not expected was the finding that level of formal training alone rather than an increase in flight experience, or a combination of the two, accounted for this increase in weather knowledge. This supports the notion that, generally, pilots require formal training related to weather and cannot be expected to "pick this information up on their own" as they simply gain more flight experience. This has significant implications for how we approach pilot training and places even greater importance on weather being taught in a comprehensive and thorough manner at all levels of flight training.

Similarly, weather information, particularly its application to real flight situations, should also be systematically integrated into both the ground and in-flight portions of biennial flight reviews. Participants in this study overestimated what they knew about weather until they were asked to "prove it." After having taken the tests, pilots, although a great deal more humble, still tended to overestimate the quality of their performance. In biennial flight reviews and more formal training, pilots can receive feedback that should help to ensure that their self-perceptions are more in line with the reality of what they really know about weather. Pilots who are complacent about weather issues or think that they know more about weather than they do are probably more likely to encounter weather-related difficulties in flight (NTSB, 1974).

Pilots tended to do relatively well on questions that assessed, in isolation, knowledge of weather hazards or weather-related decision making. Interestingly, pilots tended to have more difficulty with questions related to weather interpretation – a necessary ability if one is to make sound weather-related decisions. However, an examination of the structure of the decision making and weather interpretation questions included in this measure helps to explain these findings.

Several of the weather interpretation questions required that pilots be able to decipher, read, and use information presented in various weather products (e.g., TAFs, etc.); pilots' difficulty in deciphering or reading the information in the charts and tables may account for some of the depression of the scores on the weather interpretation questions. Additionally, the "pure" decision making questions did not require the participants to interpret weather information since they were designed to purely assess decision making. However, the three integration questions, which appeared on each test form, did require that the pilots have a store of basic weather knowledge, have familiarity with various weather products, be able to interpret weather information that was presented to them, and to make sound weather-related decisions. Generally, pilots did quite poorly when required to do all these things. These findings indicate that, generally, pilots have some difficulty using weather trends and current weather information to predict how future flight conditions might be affected. It is possible, however, that pilots' difficulty in reading and using various weather products can, again, at least partly explain the poor performance on the test questions that required an integration of weather knowledge.

It was disturbing to find that a large number of participants (even flight instructors) could not accurately identify marginal VFR ceiling and visibility conditions and even confused them with those that constitute instrument meteorological conditions (IMC). "Marginal VFR" is term that is often used by Flight Service Station (FSS) weather analysts during their briefings and one with which all GA pilots should be familiar. Although many other factors are surely involved when pilots fly under VFR into IMC, it is likely that a lack of knowledge about what constitutes VMC, Marginal VMC and IMC (both on paper and "out the cockpit window") also contributes.

All pilots, including many flight instructors, performed poorly on questions related to cloud clearance and visibility requirements in various types of airspace, at various altitudes, and at different times of day – so called "VFR Weather Minimums." Many pilots may find these minimums to be unnecessarily confusing and arbitrary. Because the differences between them are not explained or made clear pilots are forced to memorize them by rote. Any facts that are memorized by rote are, as such, not linked to other pertinent information and are not deeply processed. Therefore, they are particularly vulnerable to being forgotten, as is supported by the findings in this study.

<u>The Weather Knowledge Challenge and FAA Private Pilot Written Exam Weather Questions</u>
Although every possible effort was made to ensure that all questions included on The Weather Knowledge Challenge were clear, unambiguous, and operationally relevant, in hindsight it is not hard to see that some questions could have been improved. This is particularly so for those questions deemed to have two correct answers and the question that was dropped prior to conducting analyses (A4). Thus, a certain degree of measurement error related to question construction exists in The Weather Knowledge Challenge, as it does for most tests.

Additionally, no one form of the test, nor even all three test forms taken together, assess the weather content domain adequately. Therefore, it is unfair to say unequivocally that pilots have a deficiency in their knowledge of weather regulations, for example, if they happened to miss the one or two weather regulation questions that appeared on their form of the test. The general state of pilots' knowledge about weather may not be quite as dismal as might be presumed from an examination of their performance on The Weather Knowledge Challenge.

This problem – a lack of content validity – is one also shared by the FAA Private Pilot Written Examination (Hunt, 1991). Relatively few weather questions appear on any Private Pilot Written Examination and it is actually possible for a private pilot candidate to miss every single one of them and still achieve a passing score on the overall exam. Additionally, the entire data set of possible weather questions, from which the few that actually appear on any one Private Pilot Written Examination are selected, is comprised of questions from a relatively narrow range of topics from only four weather categories. Of the 140 weather questions that an airplane pilot applicant might currently see on the written test (http://av-info.faa.gov/data/airmanknowledge/par.txt), 32 questions (23%) pertain to basic causes of weather and weather patterns, 29 (21%) relate to various weather hazards, 17 (12%) involve a knowledge of weather regulations, 62 (44%) pertain to various weather services and products (e.g., Area Forecasts, etc.); none at all pertain to weather-related decision making.

No questions on the Private Pilot Written Examination require that an applicant be able to interpret weather information and demonstrate an understanding of the implications that information has for a flight that is imminent or in-progress. However, 39 of the 62 weather services questions (63%) require the test taker to decode the abbreviations used in various weather products (e.g., TAFs, METARs, FAs, PIREPs, etc.) or read a weather chart. One "Weather Interpretation" question included in the Weather Knowledge Challenge (question C7) involved the same type of task ("Using the [following] TAF for DFW, what is the earliest that you would expect thunderstorms to reach DFW?"). An argument can easily be made that this type of activity does not really measure a pilot's ability to actually <u>interpret</u> weather information – which should include understanding the implications that information has for flight – merely his or her ability to decode the cipher.

In addition to content validity, the construct validity of both The Weather Knowledge Challenge and the FAA Private Pilot Written Examination weather questions is of concern. There is no doubt that both assess aspects of weather knowledge – what aspects of weather, however, is the issue. As mentioned before, The Weather Knowledge Challenge Questions were intended to measure knowledge that has operational relevance for VFR pilots. However, a great many of the FAA Private Pilot Written Examination questions assess weather knowledge that has little bearing on real world flight operations (http://av-info.info.faa.gov/data/airmanknowledge/par.txt). Some examples of these questions include:

304. Every physical process of weather is accompanied by, or is the result of a
    A. heat exchange
    B. pressure differential
    C. movement of air

321. What are the processes by which moisture is added to unsaturated air?
    A. Heating and condensation
    B. Evaporation and sublimation
    C. Supersaturation and evaporation

365. What types of fog depend upon wind in order to exist?
    A. Radiation fog and ice fog
    B. Advection fog and upslope fog
    C. Steam fog and ground fog

Many pilots are loath to study and make the effort to acquire weather knowledge if they cannot see the relevance the information has for what they really want to do: fly airplanes (Besco, 1989). Likewise, if pilots are unable to see the relevance weather knowledge has for flight operations, they will be less likely to be able to remember it. In addition to psychometric issues mentioned earlier, it is likely that the poor performance of pilots on The Weather Knowledge Challenge can also be attributed to a combination of memory problems, due to disuse of information (Besco, 1989), as well as to a true lack of knowledge about weather.

That all pilots, particularly those who were only qualified to fly under VFR, had great difficulty in determining the implications weather information had for flight across different several questions is truly a troubling finding.

Final Report
Conclusions

Although Certified Flight Instructors, as a group, believe that they have a solid mastery of weather information that is important for safe flight operations, the findings in this study do not generally support this contention. However, none of the pilots in this study, even those with the greatest amounts of experience or training, demonstrated a strong mastery of the weather material. Although they certainly have a role, CFIs alone should not bear the blame for the state of impoverished weather knowledge demonstrated by the participants in this study. Pilots, themselves, must take responsibility to learn about weather during training. They must work with their CFIs to actually learn the material – not just what they will need to know to pass the written test. CFIs should not leave it up to the student to acquire all weather information on their own, nor should students leave it up to the CFIs to "spoon-feed" them everything about the weather that they will need to know. Certificated pilots must make a concerted effort to refresh their weather knowledge regularly; making sure that weather is taught comprehensively at all levels of instruction and during recurrent training would help. This is especially important given that pilots do not seem to gain operationally relevant weather knowledge in a systematic way through experience alone – formal training is necessary for this to occur.

Strangely, very few differences are reported to exist between CFIs related to the amounts of experience they have in instructing. However, instructors with higher levels of instructor ratings (i.e., CFII) and those who are required to teach in more structured ways (i.e., under Part 141 or in academia) do appear to differ from their colleagues in the weather instruction they provide. Further exploration is needed to determine if these reported differences do indeed exist and, if so, how they might relate to instruction quality and student learning.

CFIs acknowledge that the quality of the weather instruction they provide is not at the same level as their own knowledge of the information. CFIs may need better support, materials, and methods to use to assist them in improving the weather training they give to their students (OFCM, 2002). There is much that the FAA could also do to assist. Weather questions on the FAA Private Pilot Written Examination could tap into a broader range of weather topics, particularly weather-related decision making, and could focus better on weather knowledge and skills that are operationally relevant. In particular, questions are needed that require applicants to integrate their weather knowledge across several different areas, interpret the information they are given, and demonstrate an understanding of the implications that information has for real flight operations. Various weather services and products could be made more "user friendly" (Joint Action Group for Aviation Weather, 1999) by doing away with unneeded abbreviations. Likewise, unnecessary redundancies between the various products could be eliminated. Weather regulations that are inconsistent without reason could also be changed; inconsistencies that are necessary could be supported with those rationales to improve pilot comprehension and retention.

All members of the aviation community bear responsibility for improving the state of pilot weather training and increasing the level of pilot weather knowledge and understanding. Only if we each do so can we improve the state of general aviation safety related to weather.

References

Adams, R. J. (1997). The 3 U's of decision making – what is understood, what is unknown and what is unconscious. In R. S. Jensen (Ed.), Proceedings of the Ninth International Symposium on Aviation Psychology (pp. 703-708). Columbus, OH: The Ohio State University.

Aircraft Owners and Pilots Association (1996). Safety Review, General Aviation Weather Accidents: An Analysis and Preventive Strategies. Frederick, MD: AOPA Air Safety Foundation.

Aircraft Owners and Pilots Association (2000). 2000 Nall Report: Accident Trends and Factors for 1999. Frederick, MD: AOPA Air Safety Foundation.

Besco, R. O. (1989). Analyzing knowledge deficiencies in pilot performance. In R. S. Jensen (Ed.), Proceedings of the Fifth International Symposium on Aviation Psychology (pp. 61-86). Columbus, OH: The Ohio State University.

Burian, B. K. (1999). Student Pilot Training About Weather. Unpublished manuscript.

Driskill, W. E., Weismuller, J. J., Quebe, J., Hand, D. K., Dittmar, M. J., & Hunter, D. R. (1997). The use of weather information in aeronautical decision making. (Technical Report DOT/FAA/AM-97/3). Washington, D.C.: Federal Aviation Administration.

Driskill, W. E., Weismuller, J. J., Quebe, J., Hand, D. K., & Hunter, D. R. (1997). The use of weather information in aeronautical decision making: II. (Technical Report DOT/FAA/AM-97/23). Washington, D.C.: Federal Aviation Administration.

Driskill, W. E., Weismuller, J. J., Quebe, J., Hand, D. K., & Hunter, D. R. (1998). Evaluating the Decision-Making Skills of General Aviation Pilots. (Technical Report DOT/FAA/AM-98/7). Washington, D.C.: Federal Aviation Administration.

Federal Aviation Administration (1999). Safer Skies: A Focused Safety Agenda, General Aviation Weather Joint Safety Analysis Team Final Report. http://rms.faa.gov/eroom/HF/General Aviation/Library/Weather JSAT Report.doc.

Glaser, R. (1984). Education and thinking: The role of knowledge. American Psychologist, 39, 93-104.

Guilkey, J. E., Jensen, R. S., Caberto, S. C., & Fournier, D. L. (1995). Piloting expertise intervention strategies for aeronautical decision making. In R. S. Jensen (Ed.), Proceedings of the Eighth International Symposium on Aviation Psychology (pp. 804-808). Columbus, OH: The Ohio State University.

Hunt, G. J. F. (1991). Getting test items to measure knowledge at the level of complexity which licensing authorities desire: Another dimension to test validity. In R. S. Jensen (Ed.), Proceedings of the Sixth International Symposium on Aviation Psychology (pp. 1169-1177). Columbus, OH: The Ohio State University.

Joint Action Group for Aviation Weather (1999). National Aviation Weather Initiatives. (FCM-P34-1999). Washington, DC: National Aviation Program Council

Kochan, J. A. (1995). Aeronautical decision making: The expertise method. In R. S. Jensen (Ed.), Proceedings of the Eighth International Symposium on Aviation Psychology (pp. 801-803). Columbus, OH: The Ohio State University.

Layton, C. F., & McCoy, E. (1989). General aviation pilot perceptions of deteriorating weather conditions. In R. S. Jensen (Ed.), Proceedings of the Fifth International Symposium on Aviation Psychology (pp. 377-383). Columbus, OH: The Ohio State University.

Making your own rules: Creating a personal minimums checklist [Computer Software]. (1999). Aviation Safety Program, Pilot Mastery Series. Washington, D.C.: Federal Aviation Administration.

Martinussen, M., Hunter, D. R., & Wiggins, M. (1998). The use of weather information by Norwegian, American, and Australian pilots. Paper presented at The 23rd Conference of the European Association for Aviation Psychology, Vienna, Austria.

McCoy, C. E., Woleben, J. K., & Smith, P. J. (1994). Individual differences in weather situation awareness and assessment. In R. D. Gilson, D. J. Garland, & J. M. Koonce (Eds.), Situational Awareness in Complex Systems. Daytona Beach, FL: Embry-Riddle Aeronautical University.

National Aviation Weather Program Council (NAWPC) (1997). National Aviation Weather Program: Strategic Plan. (FCM-P32-1997). Washington, DC: NAWPC.

National Transportation Safety Board (NTSB) (1974). Special Study of Fatal, Weather-Involved, General Aviation Accidents. (NTSB/AAS-74-2). Springfield, VA: National Technical Information Service.

National Transportation Safety Board (NTSB) (1989). Safety Report – General Aviation Accidents Involving Visual Flight Rules into Instrument Meteorological Conditions (NTSB/SR-89/01). Springfield, VA: National Technical Information Service.

Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) (2002). Aviation Weather Training: A Report on Training for Emerging and Recently Implemented Aviation Weather Programs. (FCM-R16-2002). Washington, DC: OFCM.

O'Hare, D., & Smitheram, T. (1995). "Pressing on" into deteriorating conditions: An application of behavioral decision theory to pilot decision making. The International Journal of Aviation Psychology, 5, 351-370.

Orasanu, J. (1995). Training for aviation decision making: The naturalistic decision making perspective. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting. Santa Monica, CA: Human Factors and Ergonomics Society (pp. 1258-1262).

Sand, W. R., & Biter, C. J. (1997). Weather-related aircraft accidents, new sensors, and pilot's (sic) weather understanding. (AIAA 97-0411). Paper presented at the 35th Aerospace Sciences Meeting & Exhibit, Reno, Nevada.

Weather Wise [Computer Software] (1999). Aviation Safety Program. Washington, D.C.: Federal Aviation Administration.

Wiggins, M. W., & O'Hare, D. (1995). Expertise in aeronautical weather-related decision-making: A cross-sectional analysis of general aviation pilots. Journal of Experimental Psychology: Applied, 1, 305-320.

General aviation. Content. Avionics Designed with Tomorrow in Mind.Â Our products are designed for pilots by pilots. Plus, theyâ€™re ready and approved for installation today in hundreds of makes and models of aircraft, including helicopters, by the FAA, Europeâ€™s EASA, Canadaâ€™s TCCA and Brazilâ€™s ANAC authorities. Garmin Avionics. Onboard with the future of flight.Â Aircraft vertical speed range: -20,00 to +20,000 fpm to +20,000 fpm. Aircraft airspeed range: 0 - 300 kts IAS.Â Supplying graphical and textual weather information to the panel-mount GTN 750Xi/650Xi series and GTN 650/750 series avionics, as well as the G500/G600, G500 TXi/G600 TXi multifunction displays, the GDL 69 helps pilots make timelier and more strategic weather avoidance decisions. General aviation pilot weather knowledge and training: Final report (Unpublished project report for FAA Grant #00-G-020). San Jose, CA: San Jose State University and NASA Ames. Weather technology in the cockpit (WTIC) Project B: Unexpected transition from VFR to IMC.Â (2016). AC-006B aviation weather. Washington, DC: Author. Retrieved from https:// www.faa.gov/documentLibrary/media/Advisory_Circular/AC_00-6B.pdf. Recreational pilot and private pilot knowledge test guide (FAA-G-8082-17). Jan 2016. Federal Aviation Administration. (2017). Recreational pilot and private pilot knowledge test guide (FAA-G-8082-17). General Aviation Pilotsâ€™ Aviation Weather Knowledge: Research Results and Implications for Training and Assessment General Aviation Pilotsâ€™ Aviation Weather. Warm-Up â€“ 4/18 â€“ 10 minutes Utilizing your notes and past knowledge answer the following questions: Name the four type of weather observations. What are. Turbulence-Related Products Robert Sharman NCAR/RAP. The general information for Training Purposes and the Standard Operating Procedure (SOP) contained herein satisfy Regulatory Authoritiesâ€™ Air Safety Department (ASD) requirements for Low Visibility and All Weather Operations. Low Visibility Procedures come into effect when the Reported Visibility is less than 400m for take-off or below 800m (RVR 550m) for approach and landing. Chapter 13: Aviation Weather Services (PDF, 13 MB). Chapter 14: Airport Operations (PDF, 31.9 MB). Chapter 15: Airspace (PDF, 12.7 MB).Â U.S. Department of Transportation Federal Aviation Administration 800 Independence Avenue, SW Washington, DC 20591 (866) tell-FAA ((866) 835-5322). Web Policies. Web Policies & Notices.Â Contact FAA. Office of Inspector General (OIG) Hotline. Freedom of Information Act (FOIA).