# INFLUENCE OF GRAPHICAL METARS ON PILOTS' WEATHER JUDGMENT

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VFR flight into IMC conditions accounts for over 10% of general aviation fatalities each year. Recent research suggests that pilots may not properly assess weather conditions. New graphical weather information systems (GWISs) may positively or negatively influence pilot weather-related judgments. Since GWIS information is not always current it may not be veridical. In the current investigation twenty-four GA pilots made visibility and ceiling estimates of simulated weather conditions either with or without a GWIS display. Pilots generally overestimated weather conditions and their judgments were influenced by the GWIS. The results revealed an interaction between ceiling and visibility that suggests a new model for understanding VFR flight into IMC. The current results suggest an important area for future research into understanding pilots' decisions to continue into deteriorating weather conditions. Results are discussed in terms of advancing aviation decision making models for understanding VFR into IMC flight, and the design of GWIS symbology to foster accurate assessments.

## INTRODUCTION

Weather-related accidents are a persistent threat to General Aviation (GA) safety. Although weather was a factor in less than 4% of the total GA accidents in 2002, these same accidents represented 13% of the total fatal accidents during that year (AOPA, 2003). Pilots flying under visual flight rules (VFR) into instrument meteorological conditions (IMC) accounted for 90% of these fatal weather accidents (Aircraft Owners and Pilot Association Air Safety Foundation, 2002). Analysis of these accidents from 1990 – 1997 revealed a fatality rate of 80% (Goh & Wiegmann, 2001a).

Several hypotheses exist for why pilots continue flight under VFR into IMC. Survey data suggests that GA pilots tend to be overconfident in their own abilities and do not fully appreciate the risk associated with weather (Wilson & Fallshore, 2001). Other evidence suggests that how pilots frame their decision, (i.e., either as losses or gains) has an impact on their decisions to continue a flight (O'Hare & Smitheram, 1995). Pilots who frame their decision in terms of losses, such as time and money, are more likely to continue or "press on" into instrument conditions.

More recent evidence suggests that pilots continue into IMC because they do not fully realize conditions have deteriorated (Goh & Wiegmann, 2001b; Wiegmann, Goh, & O'Hare, 2002). Goh and Wiegmann (2001b) found that a VFR-rated pilot's ability to estimate visibility was the best predictor of the decision to continue in a simulated flight task. Pilots who accurately assessed the visibility as IMC opted to divert, where as the pilots who continued overestimated the visibility. These pilots were presumed to lack the experience necessary to distinguish between instrument and visual conditions (Goh & Wiegmann, 2001b). It has been demonstrated that pilots grouped by cross-country hours for experience (i.e., > 1000 cross country hours = expert) actually use different weather cues when making their judgments (Wiggins & O'Hare, 2003).

Graphical weather information systems (GWIS) now available to GA pilots offer graphical data linked weather information in flight. If pilots have difficulty in accurately judging weather conditions then additional weather information may be beneficial. A number of studies have found that a GWIS can influence pilots' weather decision making (Beringer & Ball, 2003; Chamberlain & Latorella, 2001). However this previous research focused on pilots' use of graphical precipitation data (i.e., NEXRAD) for avoiding convective activity. It is not clear how graphical METARs, symbols depicting ceiling and visibility as observed from the ground, will influence pilots' judgment of weather conditions. Because this information can be up to 1 hour old it may not always be veridical.

The present study examines the impact of graphical METARs on pilots' judgment of ceiling and visibility.

## METHOD

### Participants

Participants were 24 general aviation pilots from 19 to 76 years of age (M = 40.8). Total flight times ranged from 154 – 975 hours (M = 402). Each instrument pilot was matched with a non-instrument-rated pilot on cross-country hours, such that there were no significant differences in the means of these two groups (M = 192 hrs non-instrument and 128 hrs instrument). Pilots were recruited, scheduled and compensated through a contract with Lockheed-Martin.

### Equipment/Apparatus

The sessions were conducted in an experimental chamber room at NASA Langley Research Center. Two PC computers, connected through a local area network presented experimental conditions. One computer drove the out-the-window (OTW) depiction. The OTW was projected onto a 34.75 inch x 26 inch screen. The OTW video clips were created using Microsoft Flight Simulator 2004 and enhanced with satellite imagery from MegaScenery, a commercially available add-on for Flight Simulator. The scenery depicted the same location and altitude in Eastern Long Island, NY. The terrain contained features such as a road and an airport that pilots could use to aid in distance judgment. The OTW depictions were video clips 5 seconds in duration. A second computer displayed the primary flight instruments for a C172 i.e., altimeter, airspeed indicator, compass, and attitude direction indicator. This information never changed; the aircraft heading was always 90 degrees, at 2400 ft and traveling 120 knots. The second display also contained the GWIS which showed graphical METARs and station identifiers and aircraft position. The METAR information conveyed the ceiling and visibility levels (one of 4 categories: LIFR, IFR, MVFR and VFR) by color-coding and associated legend. Pilots were reminded that METAR information could be up to one hour old and how they used the METAR information was entirely at their discretion.

### Procedure

Pilots received training to decode graphical METAR information and on the approximate distances of objects in the terrain. Distance information was provided because pilots flying in familiar airspace typically use distances to known landmarks to help with their visibility estimates. After the training and a short practice session, the subject pilot completed two experimental blocks. In each trial the pilot viewed the OTW depiction and then estimated the ceiling (in feet) and visibility (in statue miles). The OTW video looped until the pilot completed the judgments.

There were a total of 6 different OTW depictions used in the current experiment. These were created from a combination of 2 ceilings (i.e., 900 and 2900 ft) and 3 visibilities (i.e., 2, 3, and 5 miles). These different OTW depictions were combined with 6 different graphical METAR consistencies (see Table 1). The METAR manipulations were such that information was either in the same category as the OTW or one category better or worse. There were 36 conditions that were replicated twice for a total of 72 trials. The order of presentation of the trials was randomized within each replication or block.

**TABLE 1:** Graphical METAR Consistency Manipulation

| METAR Condition | Relation to Out-the-Window | |
|---|---|---|
| | Ceiling | Visibility |
| No METAR (N) | NA | NA |
| METAR Accurate (A) | Same | Same |
| Ceiling Better (C-B) | Better | Same |
| Ceiling Worse (C-W) | Worse | Same |
| Visibility Better (V-B) | Same | Better |
| Visibility Worse (V-W) | Same | Worse |

## RESULTS

The data were analyzed using a Ceiling (2) x Visibility (3) x METAR (6) repeated measures Analysis of Variance (ANOVA), with separate ANOVAs for ceiling estimation error (CEE) and visibility estimation error (VEE). Error values were defined by subtracting pilots' estimates from the actual conditions. Therefore error values could be either negative (an underestimate) or positive (an overestimate). All significant effects were further analyzed with Tukey HSD *post hoc* tests.

### Ceiling Estimation Error

There was a significant main effect of METAR condition on CEE, $F(5,115) = 2.568$, $p < .05$, $\eta^2 = .100$. The CEE data for the METAR conditions is presented in Figure 1. The only significant difference was between the ceiling better (C-B) condition and ceiling worse (C-W) condition with the later having a smaller error.

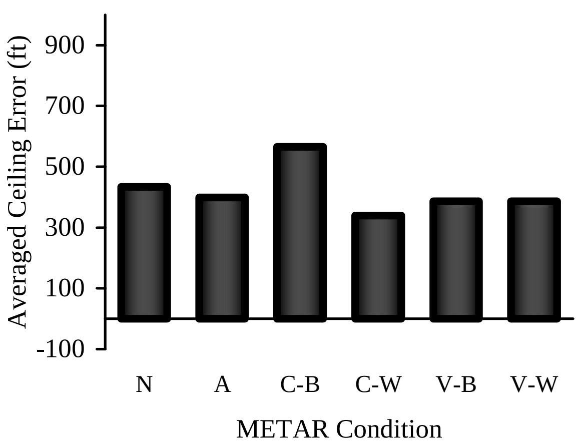


*Figure 1.* The main effect of METAR condition on ceiling estimation error.

A significant interaction of ceiling and visibility on CEE was found, $F(2,46) = 5.534$, $p < .05$, $\eta^2 = .194$. Tests of simple main effects of visibility were performed at each ceiling. Within the 900 ft ceiling conditions the 3 mile visibility condition had a significantly lower ceiling error compared to the 5 mile visibility. At the 900 ft ceiling the 2 mile visibility condition was not significantly different from the other two visibilities.

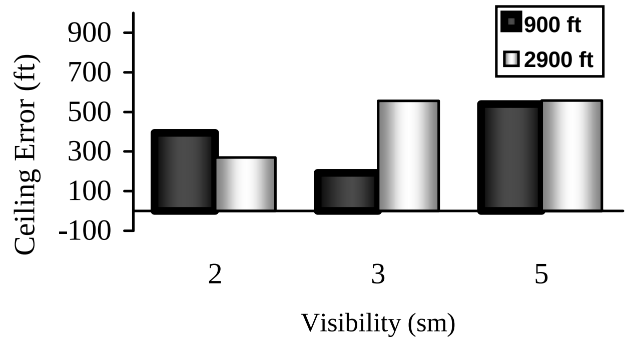


*Figure 2.* The interaction of ceiling and visibility on CEE.

### Visibility Estimation Error

There was a significant main effect of METAR condition on VEE, $F(5,115) = 6.363$, $p < .05$, $\eta^2 = .217$. The VEE data for the METAR conditions is presented in Figure 3. The visibility better (V-B) condition had a significantly larger error compared to all of the other conditions except the ceiling worse (C-W) condition. No other differences between METAR groups existed. There were no significant differences between visibilities at the 2900 ft ceiling.

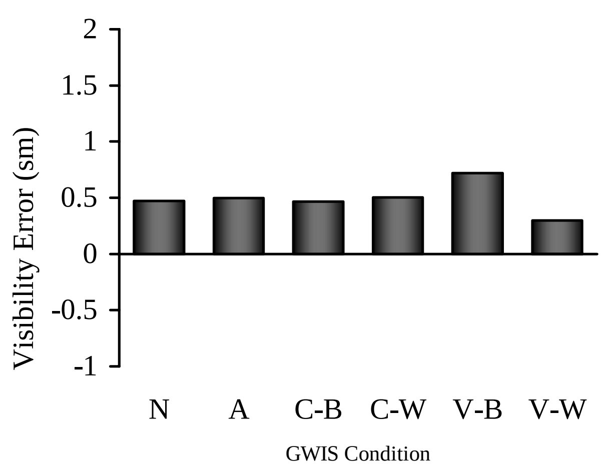


*Figure 3.* The main effect of METAR condition on visibility estimation error.

There was a significant interaction of ceiling and visibility on the VEE, $F(2,46) = 62.884$, $p < .05$,

$\eta^2 = .732$. Tests of simple main effects of ceiling were performed at each visibility. Pilots' averaged estimates of visibility were lower at the 900 ft ceiling compared to the 2900 ft ceiling at every visibility level.

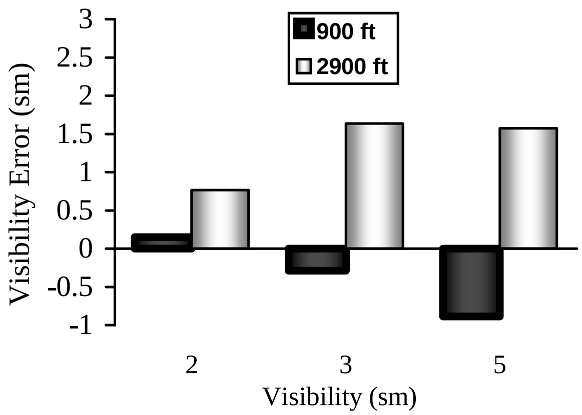


*Figure 4.* The interaction of ceiling and visibility on visibility estimation error.

## DISCUSSION

The graphical METARs did impact pilots' weather judgments. When information was either better or worse than the OTW representation pilots shifted their judgment in the corresponding direction. It is important to note that regardless of the condition, on average, pilots overestimated the weather conditions. That is, on average, they consistently rated that conditions were better than those that were actually presented. The graphical weather display may have the potential to either exacerbate or alleviate this problem of overestimation. Although it is important to note that even when GWIS information was displayed as worse than the OTW conditions the pilots still tended to overestimate the weather conditions. When the GWIS presented indications consistent with the OTW pilots' weather judgment did not improve.

The present study represents only a limited use of graphical weather information. Pilots were constrained to a single METAR within 1 mile of the aircrafts position. One of the purported benefits of a GWIS is that it helps pilots build a better picture of the larger weather patterns in the area (Lind, Dershowitz, & Bussolari, 1994). Additionally in normal use pilots would have access to the textual METAR report that would also provide numerical information for ceiling and visibility and a timestamp for this data. Finally, in reality, pilots have exposure to expectations from preflight and the dynamics of weather through the course of a flight to gain insight into the validity of perceptions and displayed information. The study lays substantial foundation and justification for further examining effects of GWIS information in richer context.

This study identified some interesting interactions between pilots' ability to estimate ceilings and their ability to estimate visibility. Specifically, there was evidence that suggests that it is harder to accurately estimate ceilings when visibility is lower; and, also more difficult to accurately assess visibility when ceilings are lower. More importantly, on average, pilots overestimate visibility when ceilings are higher, and overestimate ceilings when visibility is better. The interaction of ceiling and visibility suggests pilots may be inappropriately assessing weather conditions. Pilots are trained to base their assessment of IMC upon the worst ceiling or visibility condition. That is, if the visibility is IMC but the ceilings are VMC a pilot should still recognize that conditions are IMC. The interaction observed in this investigation may better model how pilots actually assess weather and may account in part for their decisions to continue into IMC.

Although not fully discussed within the present paper due to space limitations, analyses of pilot ratings revealed no effect of rating on pilots' ability to estimate weather. The number of cross-country hours was also not correlated with pilot's estimation abilities. However, it should be noted that in order to match the instrument and non-instrument pilots on cross-country hours, only relatively low hour instrument pilots participated in the study. Thus the difference in terms of total flight hours between the two groups was minimal. The lack of correlation between flight hours and ability to estimate weather may simply be due to a restriction of range. On the basis of cross country hour cutoffs used previously (Wiggins & O'Hare, 2003), all of the pilots used in the present experiment were novices.

Current GWIS systems vary in the presentation of categorical METAR information, some showing categorical coding for ceiling and visibility separately, and others providing a single indicator of the worse of the two dimensions. Results from this initial study indicate that presenting a single overall station category based upon the worst factor may mitigate the effects of pilots' tendencies to commingle these estimates. The display could allow access to specific ceiling and visibilities but only graphically present a single dimension. This might help to reduce the tendency for pilots to let VFR conditions in one dimension to improperly influence their estimation of the other. Further research should examine the impact of single category graphical METARs and examine the influence of data age on pilots' use of METAR information.

## ACKNOWLEDGEMENTS

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