

3A.3 WEATHER AND COLLABORATIVE DECISION MAKING IN THE AVIATION COMMUNITY: TWO “TACTICAL” CASE STUDY EXAMPLES

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1. INTRODUCTION

Collaborative Decision Making (CDM) is a key concept of the Federal Aviation Administration's (FAA) Next Generation Air Transportation System (NextGen), which is intended to fully upgrade the current air traffic control system from an aging, ground-based radar system, to a satellite-based, “aircraft-centric” system based on Global Positioning System technology. CDM, in conjunction with NextGen programs such as Automatic Dependent Surveillance-Broadcast, the National Airspace System (NAS) Voice Switch, System Wide Information Management, Common Support Services-Weather (formerly known as NextGen Network Enabled Weather, NNEW), and others will be implemented to increase the capacity of the NAS to its projected one billion passengers to be flown by 2021 (FAA, 2011). NextGen will be needed to account for this growth in order to decrease the work load on air traffic controllers (ATC), allowing more aircraft to operate closer together, in safer conditions.

CDM has been in use for nearly 20 years. The current implementation of CDM is defined by FAA (2011) as “... a joint government/industry initiative aimed at improving air traffic management through increased information exchange among the various parties in the aviation community. The CDM program is made up of representatives from government, general aviation, airlines, private industry and academia who are working together to create technological and procedural solutions to traffic flow problems that face the NAS.”

CDM evolved from a series of experiments known as the FAA/Airline Data Exchange (FADE; FAA, 2011). The FADE experiments were designed to evaluate whether having the major airlines send updated schedule information to ATC could reduce delays, and if so, to what extent. The FADE experiments were very successful, and led to follow-on investigations that showed a delay reduction of 10-35% could be achieved when CDM practices were applied. By the summer of 1995, the CDM Program had officially formed, comprised of both government and industry participants. Within 2 years the AOCnet, developed by the Communications Working Group, directly connected eight Airline Operations Control Centers (AOCCs) to the Air Traffic Control System

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Command Center (ATCSCC), allowing real-time data exchange (FAA, 2011).

As the CDM concept evolved, the FAA further defined the roles and responsibilities of both Air Traffic Control-Traffic Flow Management (ATC-TFM) and AOCCs. From 1998 to 2000, the Enhanced Ground Delay Program (GDP-E) began prototype operations, first at San Francisco (SFO) and Newark (EWR) International Airports, then expanded to a dozen larger airports, and eventually to all CONUS airports. When GDP-E Prototype Operations ended its testing period and became fully operational, Flight Schedule Monitors (FSMs) were ordered for all Air Route Traffic Control Centers (ARTCCs) and major Terminal Radar Approach Controls (TRACONS) to create and run Ground Delay Programs (GDPs) and Ground Stops. By 2001, 36 airlines, 46 FAA facilities, and 7 Nav Canada facilities were using FSMs. Web-based post operation evaluation tools were introduced along with NAS playbook routes, FSM version 7.9, and state-of-the-art computers and communication equipment to enhance the efficiency of CDM (FAA, 2011).

Today the FAA has divided CDM into nine sub-teams. These sub-teams are headed by field experts, who provide in-depth research and opportunity development in their specific area, which then is presented to the FAA for further development (FAA, 2011). Table 1 contains a list of each Sub-team.

Table 1. CDM Sub-teams.

| |
|---|
| Flow Evaluation Team |
| Future Concepts of Traffic Flow Management Team |
| Enhanced Ground Delay Program Team |
| CDM Training Team |
| Midwest Capacity Focus Team |
| E- Special Traffic Management Program Team |
| Weather Evaluation Team |
| Surface CDM Systems Team |
| Fuel Team |

1.1 Weather and CDM – Current Focus

To address the aviation community's growing need for integrated data exchange, the Weather Evaluation Team (WET), consisting of U.S. and Canadian government and industry representatives, has been collaborating on several research projects. The primary focus of the team's efforts to this point has been on integrating the potential impacts of convective weather on the NAS for decision-making on the strategic time scale, which is defined as

beyond 2 hours into the future. In April 2012, the Extended Convective Forecast Product (ECFP), an extended version of the current Collaborative Convective Forecast Product (CCFP), became operational. The ECFP provides a quick-look forecast of the greatest possibility of convective weather and a planning tool that allows for 1-3 day in-advance planning for convective weather (Aviation Weather Center [AWC], 2012a).

While primarily focused on convective weather, additional WET collaboration has led to advances in addressing other types of aviation-impacting weather. The Aviation Winter Weather Dashboard (AWWD) flags a 30% or greater probability of impending winter weather (snowfall, freezing rain, and visibility) that could negatively impact operations at 29 major terminals across the U.S. (AWC, 2012b). This product currently updates four times a day. Another example of weather and CDM is a project known as Operational Bridging (OB). Designed to be an event-driven forecast created through collaboration between meteorologists and ATM, a successful dry run for OB took place this past summer. OB will expedite the transition between probabilistic forecasts and near-deterministic forecasts and will produce an Aviation Weather Statement (AWS) that will most likely replace the current CCFP in the future. The AWS will be technically prepared, widely distributed, and user friendly, all in line with NextGen requirements (AWC, 2012c).

1.2 Weather and CDM in NextGen

In NextGen, the CDM concept will be expanded to include sharing of multiple types of information between all the users currently operating in the NAS. By including relevant meteorological information, weather and CDM could be a method for NAS users to share information on current and forecast weather conditions to increase shared situational awareness. The concept of a “common weather picture” has been mentioned as a NextGen enabler by Souders et al. (2009) and others, and would certainly go a long way towards improving weather and CDM.

The challenge will be to define exactly what constitutes a *common* weather picture to different users in the NAS, and for *which temporal and spatial scales*. While the WET projects described above hold great promise for strategic planners in the NAS, our literature review and interviews with individuals on the CDM Working Group and WET revealed that there has been precious little research on weather and CDM at *tactical* time and spatial scales, which generally extend from pre-flight planning to the enroute phase of an individual flight. We found this to be the case whether one considers the general aviation (GA) community or commercial airline industry.

1.3 Study Approach

Our research approach was to examine the state of today’s weather/CDM environment at the “low-end” of GA and in the commercial airline environment by use of two illustrative case studies. For the GA case, we chose a weather-related fatal accident from 2007 to investigate the weather/CDM environment as it existed in that accident. For the commercial case, we chose to study the Continental Connection Flight 3407 (Colgan Air) accident from February 2009.

In both cases, we examined the meteorological conditions observed during the period of the flight. We also looked at the situational awareness of the pilots with respect to the current weather by studying the extent of information sharing between NAS users. In both cases, the pilot filed an Instrument Flight Rules flight plan, got a preflight weather briefing, and spoke to ATC enroute. So there was collaboration between the pilot and several entities in the NAS both before and during the flight. Tactical CDM (defined here as decision-making in the timeframe of 0-2 hours) occurred between the pilot and NAS users in both cases—but the result was still a fatal (and likely avoidable) accident. Another important part of this study involved examining the extent to which real-time data-linked weather information could have helped or hindered the decision-making process of the pilots in each case.

2. CASE 1 – TRAPPE, MD, 4 APRIL 2007

According to the National Transportation Safety Board (NTSB) accident report for this case (#NYC07FA091, hereafter referred to as NTSB, 2008), the left wing of a Piper PA-30 Comanche separated from the aircraft during flight after exiting hazardous weather (embedded thunderstorms) on the morning of 4 April 2007 and impacted the ground over Trappe, MD (located on the Delmarva Peninsula), killing the pilot and two passengers. The pilot was a 62-year-old male with over 4,000 hours, 12 of them within 90 days of the accident. He held a Private pilot certificate with rating for single engine and multiengine aircraft, as well as instrument. The pilot had logged 167 hours of actual instrument time with 1.5 hours in the 90 days prior to the crash (NTSB, 2008).

Recovery of flight-path information from the FlightAware.com web site indicated that the aircraft departed from Westchester County Airport, New York (KHPN) at 1151 UTC, headed west and then turned to the south where it flew over New York City and Long Island before making a turn to the southwest and roughly followed the New Jersey coast before making another turn to the southwest to cross into Delaware (see Figure 1). Tabular flight data from FlightAware showed that the pilot maintained a fairly steady flight altitude of about 6,000 feet until 1321 UTC, after which time there was no further tracking

data. After this point we began using information provided by NTSB (2008), which covered the period from 1324 UTC (the first time the pilot made contact with Patuxent River, MD ATC), to 1337 UTC, when contact was lost.



Figure 1. Trappe, Maryland case flight path (white line) recovered from the FlightAware.com web site (<http://flightaware.com/live/flight/N555EM>). Note that regional weather radar data on this graphic was valid at the time of departure.

2.1 General Meteorological Conditions

Figure 2 displays the meteorological conditions over the Mid-Atlantic States at 1200 and 1400 UTC (panels 'a' and 'b', respectively). Comparison of these charts shows that the sea-level pressure fell rapidly over the Delmarva Peninsula and New Jersey during this period, and a surface low formed just south of the crash location at 1400 UTC. An interesting aspect of this case is the formation of thunderstorms north of the warm front in the shallow cold air over Delmarva during the morning hours. Elementary meteorological instruction normally describes the favored location for thunderstorms to be in the warm sector of an extratropical cyclone, and the favored time for development to be in the mid to late afternoon. Despite the unusual circumstances for convective weather formation in this case, the Aviation Weather Center (AWC) had correctly issued Convective SIGMETs 34E and 38E for this location during the time of the flight.

Figure 3 displays an analysis of atmospheric stability for 1200 UTC. The significance of this analysis is that the surface-based Lifted Index values of +12 to +20 overlaid the areas of Convective SIGMETs 34E and 38E. To the weather 'novice' this situation would appear to be a contradiction because Lifted Indices above about +2 indicate stable air. In fact, the 1400 UTC surface observations at Easton and Dover indicated thunderstorms with surface temperatures and dew points in the mid to upper 40s Fahrenheit, well below typical "textbook" surface temperatures associated with thunderstorms. However, analysis of the atmosphere *above the*

surface showed that stability conditions were much more favorable for convective weather (indicated by the red boxed Lifted Index values in the figure). Our analysis of the situation revealed that this was a case of *elevated convection*. Elevated convection is a topic that may be touched upon briefly in undergraduate meteorology courses, but is not normally covered in significant detail. Most elementary texts show stable conditions north of a warm front, even though this is not always the case. In fact, a climatological study of elevated convection by Colman (1990) showed that one of the *preferred locations* for elevated convection is to the north and northwest of the surface low, which was precisely where they were observed at 1400 UTC (Figure 2b). Analysis of atmospheric soundings for northern Virginia and southern Maryland (not shown) revealed that the base of this elevated convection was about 5,000 feet, meaning that the pilot essentially flew his aircraft directly into the area of these elevated thunderstorm bases.

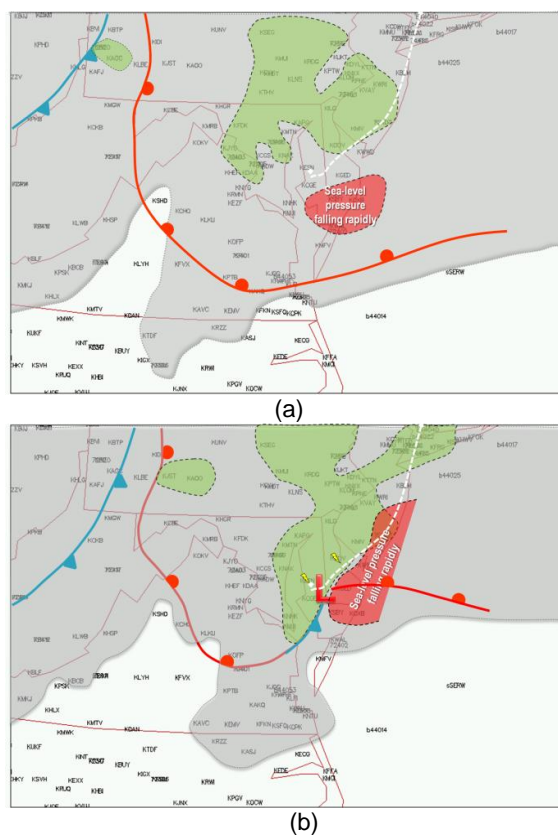


Figure 2. Surface weather analyses for (a) 1200 UTC and (b) 1400 UTC. Conventional frontal symbols are used, with grey and green shading indicating areas of cloud ceilings and precipitation, respectively. Rapidly falling sea-level pressure areas are shown by red shading, and lightning symbols denote the locations of thunderstorms over Easton, MD and Dover, DE at 1400 UTC. The flight path is shown by the white dashed line with the arrow indicating the crash location.

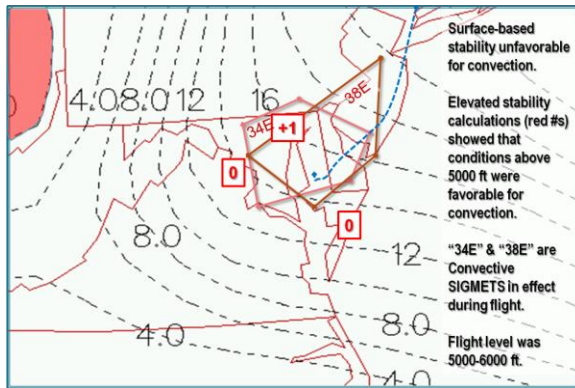


Figure 3. Atmospheric stability analysis for 1200 UTC. Dashed lines indicate surface-based Lifted Index values, with red shading showing the location of areas favorable for surface-based thunderstorm formation over eastern Ohio. Elevated Lifted Index values between 0 and +1 for three locations in Virginia and Maryland are shown by the small red boxes, and indicate conditions favorable for elevated thunderstorms, consistent with the locations of Convective SIGMETs 34E and 38E, shown by the dark red boxes. The flight path is shown by the blue dashed line, with crash location indicated by the arrow. Lifted Index analysis is courtesy of the Plymouth State University Weather Center.

2.2 Weather and CDM Analysis

We divided the weather/CDM analysis of this case into three parts: 1) description of the preflight briefings from New York Automated Flight Service Station (AFSS); 2) description of the pilot's communications with Patuxent River ATC during the last 13 minutes of the flight; and 3) analysis of the weather/CDM environments during the preflight and in-flight phases.¹

Preflight Weather/CDM. The pilot contacted New York AFSS twice: the day before the flight and on the morning of the flight. In the first briefing, the AFSS specialist indicated that the weather was not going to be good, with Instrument Flight Rule (IFR) conditions and marginal Visual Flight Rule conditions at the departure location. The specialist also indicated that thunderstorms and turbulence were expected for the route with a stationary front in the area up to the destination airport. Our review of the transcript for the first weather briefing (the timeframe for strategic CDM according to our definition) showed that the pilot made very few comments during the briefing beyond acknowledging the specialist. The pilot did not indicate he was worried about the marginal forecast, and concluded the conversation.

¹ Note that additional information about this case was obtained from the NTSB through a request for the complete docket pertaining to the accident.

The pilot filed an IFR flight plan on the day of the flight, contacted New York AFSS for an updated briefing, and was advised of numerous hazards along the flight path, including embedded thunderstorms, low-level wind shear, turbulence, hail, and gusty winds (NTSB, 2008). The NTSB transcript of the preflight briefing on the 4th showed that the first Convective SIGMET had been issued and was briefed to the pilot, but the coordinates were simply read from the text-based product, so unless the pilot had hand-plotted them or had good geographical knowledge of the region, he may not have known he was going to fly into the SIGMET area.

Our review of the second briefing transcript from the day of the flight (by our definition, in the tactical CDM timeframe) suggests that this briefing may have been even less productive than the first one. The briefing was very long with the AFSS specialist relaying a large amount of information, including departure-point weather, destination weather, enroute weather, and all the products available to the specialist within and around these areas. The specialist also included information on weather conditions outside of the pilot's flight path, such as Providence, RI and eastern Pennsylvania (NTSB, 2008). On a few occasions the AFSS specialist seemed to queue the pilot into a detail he had missed, but for the most part the pilot appeared frustrated with the briefing. After about twelve minutes of briefing, the pilot cut off the AFSS specialist, announced he had already filed a flight plan, and concluded the conversation. During the conversation there was not much collaboration, and the transcript suggests that the AFSS specialist was frequently ignoring or talking over the pilot. For example, at one point the pilot asked "where KFYJ was" in regards to information the specialist had just given on it, and the specialist failed to understand what the pilot was asking for, prompting the pilot to say "where ever the hell that is" after receiving the conditions at KFYJ. When referring to radar images, the pilot often responded with "yeah I'm looking at that," indicating he was likely viewing a radar display during the briefing.

Flight-path information during the last 13 minutes of flight. At 1324:29 UTC, the pilot made first contact with Patuxent River ATC to report his flight level and was given the local altimeter setting. At 1329:08 UTC, the pilot contacted the controller to inform him that he was "going to have to deviate a little bit left here" to avoid a thunderstorm to the aircraft's southwest across the current flight path. The controller cleared the maneuver and told him to report when he was able to resume his flight path direct to Richmond, VA.

The controller asked if the pilot had "weather radar" on board, to which the pilot responded that "We have metrad on board" and upon further inquiry he told the controller that it updated about every five minutes (NTSB, 2008). From 1330 to 1331 UTC, the pilot and controller discussed the directions and distances of

the embedded thunderstorms from the aircraft's flight path, and the pilot consistently responded that he was "*seeing the same thing*" on his onboard display as Patuxent River ATC was seeing on theirs. During the next four minutes, the aircraft turned to fly between two thunderstorms on a south-southwest heading before turning to the southwest to proceed direct to Richmond, VA. At 1335:19 UTC, the pilot informed ATC that he was proceeding direct to Richmond. The controller and pilot then discussed radio issues that sometimes occur when lightning is in the vicinity. The pilot remarked that there was "*a lot of lightning*" and was hearing a squelch, but also stated, "*believe it or not, the turbulence here is light.*"

The next exchange between them (1335:55–1336:07 UTC) concerned the winds, when the pilot remarked "*It's thirty thirty...we've got thirty knots at the base.*" The controller offered to direct him to 4,000 feet, but the pilot declined, stating that it was not going to help. Between 1336:51 and 1337:04 UTC, the pilot contacted Patuxent River ATC to report "*we just, uh... we got a problem. Looks like we just lost... We lost attitude.*" At this point the controller informed him that he was now heading *northbound* (see flight path in Figure 2), but did not receive a response from the pilot. This was the last transmission from the aircraft, which continued proceeding towards the north at approximately 5,100-5,700 feet altitude before turning eastbound between 1337:16 and 1337:21 UTC. The controller continually attempted to contact the pilot while observing the aircraft make this gradual right turn. The last known position of the aircraft was over Trappe, MD at 1337:26 UTC at 5,100 feet, after which time the plane was presumed to have broken up and crashed at 1337:40 UTC (NTSB, 2008).

Assessment of Weather/CDM. There was essentially no collaboration between the pilot and the AFSS specialist regarding unfavorable weather and options such as postponing the departure. In our opinion, the extent of collaboration on weather information in this case is a typical example of how weather/CDM occurs in today's low-end GA environment. This assertion is backed up by other studies (e.g., Shappell et al. 2010), which show an underutilization of AFSS and a great deal of "self-briefing" from Internet-based sources.

During the in-flight phase, the weather/CDM interaction appeared to be more productive than the preflight AFSS weather briefings. Once the pilot contacted the controller and informed him that he would need to deviate around the storms, the controller initiated weather/CDM by asking if the pilot had weather radar on board. At this point they began sharing their observations of the distance and direction of the thunderstorms from the flight path, essentially "comparing notes" regarding location and intensity of weather as seen on their two radar displays. Although we were unable to confirm whether

the pilot and Patuxent River ATC had similar or different radars, we know from the transcript that they were both in agreement on the position of the hazardous weather and what action to take (NTSB, 2008). Despite the unfortunate outcome, we assert that the weather/CDM occurring in this phase of the flight was "productive," because once the pilot was in the area of embedded thunderstorms, the objective was to get him safely out of harm's way. The collaboration between the pilot and ATC in this phase of the flight was remarkably similar to that documented by Shappell et al. (2010) in their study of 24 GA pilot weather encounters, especially in the descriptions of how the pilots got into trouble and the nature of the weather assists provided by ATC. The transcripts of those encounters were not much different from this one, with the one huge exception being the outcome.

2. CASE 2 – COLGAN AIR FLIGHT 3407, 13 FEBRUARY 2009

On 12 February 2009, at 2217 EST (0317 UTC), a Colgan Air, Inc. Bombardier DHC-8-400, operating as Continental Airlines Flight 3407, lost control while on approach to Buffalo-Niagara International Airport (KBUF) in Buffalo, NY, and crashed into a residential zone, killing both pilots, two flight crew members, and 45 passengers. There were no survivors on board and an additional person was killed on the ground, resulting in a total of 50 fatalities. Due to flight-crew training issues, the pilots failed to recognize the configuration the aircraft was in during preparations for landing while on autopilot, which led to the loss of control from which the pilots failed to recover (NTSB, 2010).

The NTSB report, using performance data retrieved from the flight data recorders and an icing simulation, determined that aircraft performance degradation due to icing was minimal. Their conclusion was that the ultimate loss of control and subsequent crash of the aircraft was attributed to the flight crew's incorrect response to a stall warning during approach. The aircraft had been configured for icing conditions, which increases the stall speed of the aircraft's warning systems, but the first officer failed to input this configuration when receiving approach and landing reference speeds from Colgan through the Aircraft Communications Addressing and Reporting System. As the aircraft reached the reference speed for approach, which was slower than the stall speed warning in icing configuration, the autopilot disconnected and indicated the aircraft was in an aerodynamic stall when it actually was not. The captain then applied heavy nose-up attitude control input, which induced a stall from which the flight crew never recovered. The flight crew's response to the stall warning was found to be a result of fatigue, poor cockpit procedures, poor training, and lack of experience (NTSB, 2010).

3.1 General Meteorological Conditions

On the night of the accident, a cold front extended from the northern Great Lakes into eastern Quebec, and was producing snow and widespread cloud cover across the northeast U.S. The synoptic situation at 0300 UTC on 13 February is summarized in the surface analysis from the Hydrometeorological Prediction Center shown in Figure 4.

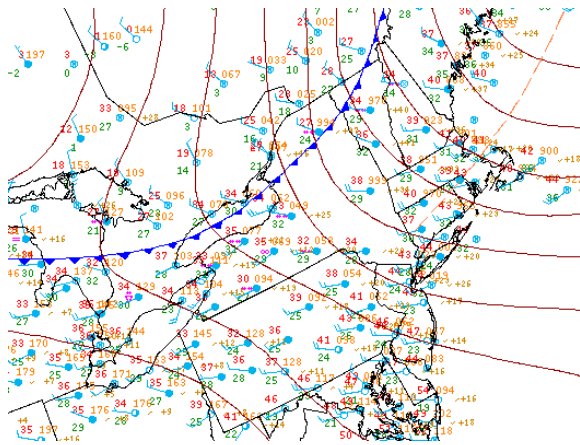
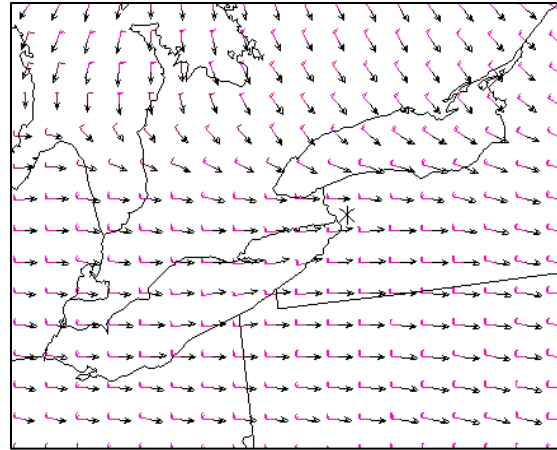
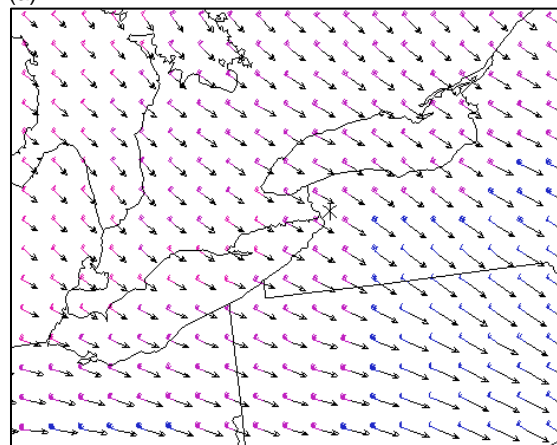


Figure 4. Surface analysis from 0300 UTC, 13 February 2009 (courtesy of HPC archive).

An analysis of the low- to mid-level winds was conducted using archived data from the National Oceanic and Atmospheric Administration's Air Resources Laboratory (ARL) ETA Data Assimilation System 40-km gridded data product (NOAA ARL, 2011). Figures 5a and 5b display the winds from the surface and 750 hPa, respectively, and show that the surface winds were westerly at 10-15 kt and became northwesterly at 15-20 kt at 750hPa. The flow trajectory across Lake Erie, which was not frozen, would likely have been responsible for the production of lake-effect snow.



(a)



(b)

Figure 5. Panel (a): ARL 10-meter above ground level (AGL) winds valid at 0300 UTC 13 February 2009 showing westerly surface winds. Panel (b): 750 hPa winds valid at 0300 UTC 13 February 2009. At this level the winds are roughly perpendicular to Lake Erie, which is a classic set up for producing lake-effect snow. The location of Buffalo is indicated by the asterisk symbol on the charts.

To confirm the presence of lake-effect snow (meteorological reports (METARs) had already confirmed it was snowing), we retrieved archived radar data from the National Climatic Data Center NEXRAD Inventory for Buffalo. The composite reflectivity from the radar at the time of the accident is shown below in Figure 6. Precipitation bands coming off Lake Erie can be seen south of Buffalo with light precipitation across the rest of the area.

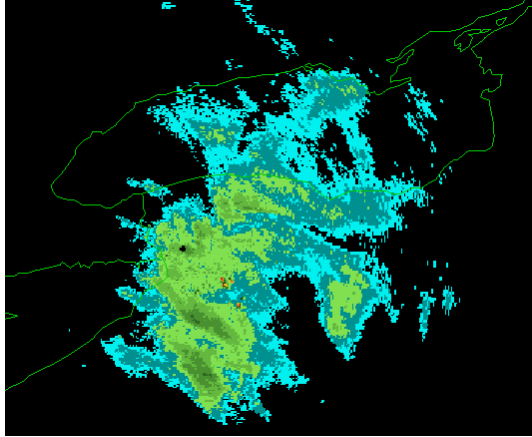


Figure 6. Composite reflectivity image from Buffalo, NY NEXRAD for 0319 UTC, 13 February 2009.

In addition to the lake-effect snow showers, these conditions were also generating light to moderate rime icing, according to the few pilot reports (PIREPs) that were available. The 0000 UTC KBUF sounding, shown in Figure 7, indicated favorable conditions for icing from just above the surface to about 13,500 feet above mean sea level (MSL). This layer had small temperature-dew point depressions and temperatures between 0°C and -20°C.

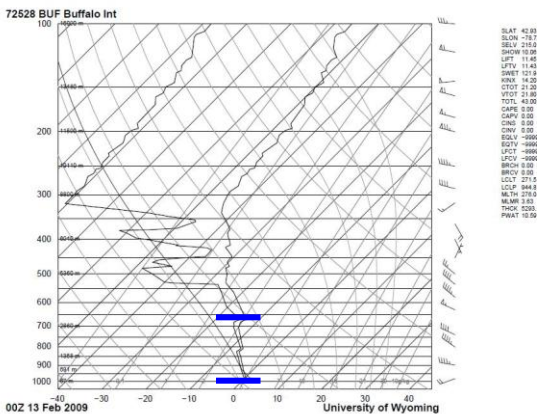


Figure 7. Skew-T Log-P analysis from KBUF from 0000 UTC 13 February 2009. The layer of small dew point depressions with temperatures between 0°C and -20°C is bounded by the solid blue lines. (Courtesy of the University of Wyoming)

A detailed discussion of the meteorological conditions associated with this accident, including the results of some preliminary mesoscale model simulations of the case, can be found in Mosher et al. (2010).

The most pertinent forecast products for this case were the Airmen's Meteorological Information (AIRMETs) for icing issued by the AWC. The NTSB report did not indicate whether Colgan Air, Inc., provided any supplementary, third party, or private sector forecast products. There were four AIRMETs

issued for the northeast U.S. during the time of the flight: two were active before the flight departed and the other two were issued during the flight, after the first two expired. Both sets of AIRMETs showed similar conditions with only slight changes to the coverage area. In both sets, AIRMET 1 indicated occasional moderate icing below 18,000 feet and AIRMET 2 indicated moderate rime icing below 8,000 feet, from 2045 UTC on 12 February, continuing to 0400 UTC on the 13th.

3.2 Weather and CDM Analysis

As in the Trappe, MD accident case, we divided the weather/CDM analysis of this case into three parts: 1) description of the preflight briefings from Colgan's Airline Operations Center; 2) description of the flight crew's communications with ATC during the flight; and 3) analysis of the weather/CDM environment during the preflight and in-flight phases.

Preflight Weather/CDM. The NTSB accident report found that the weather information provided to the flight crew *did not* include the first two AIRMETs that were issued for the northeast U.S. (NTSB, 2010). However, the flight weather document *did* include two PIREPs indicating light to moderate rime icing, which was representative of the environment, but three Center Weather Advisories (CWA) and Temperatures and Winds Aloft forecasts provided to the pilots for the Buffalo area were not valid at the time of the flight (NTSB, 2010).

In-flight Weather/CDM. While the NTSB report did not cite icing as the primary cause of the accident, it certainly was a contributing factor, and begs the question of whether improved situational awareness of the weather conditions in the area could have resulted in a different outcome. In this context, we now focus on the extent to which weather and CDM was occurring among users in the NAS during the time period of Flight 3407. Particular attention will be paid to the information exchanges among the flight crew, other pilots, ATM, and dispatchers, while highlighting the types of weather information that were available.

As reported earlier, the Colgan Air dispatchers provided outdated weather information and omitted pertinent weather information to the flight crew. The dispatchers neglected to inform the pilots of the two current AIRMETs over the flight path. At best we can suggest that situational awareness of the icing hazard was limited during the pre-flight phase, according to the information we have from the NTSB report.

The first author attempted to determine whether there was a lot of "chatter" in the region about the weather conditions during the time of Flight 3407. According to a conversation that the first author had with an air traffic manager familiar with the region and the accident, because the conditions in the area were

considered “normal” for that time of year by those who were operating in that region, many pilots did not report and share the exact conditions they were experiencing. Of the icing PIREPs that were sent into the reporting system, most indicated light to moderate rime icing. It should also be mentioned that submitting PIREPs is a tedious manual process, so the number of actual reports is far less than what might actually be occurring in a sector of airspace.

While the 0000 UTC KBUF sounding was nearly 3 hours old by the time of the accident, the radar and METARs still indicated conditions favorable for icing. As the maximum cruising altitude of Flight 3407 was 16,000 feet, it entered the icing environment within minutes of beginning its descent, according to the tracking data from FlightAware.com. Immediately after the accident, KBUF ATC asked pilots if they had experienced icing in the same vicinity as the crash location. A Delta Air Lines pilot informed ATC that ice had accumulated between 6,500 and 3,500 feet, and a US Airways pilot reported $\frac{1}{4}$ - $\frac{1}{2}$ inches of ice accumulation between 5,000 and 2,300 feet. According to the NTSB transcript, on nine separate occasions during the flight, the captain, first officer, or ATC mentioned the weather (two of these statements referred to the ice protection test having been completed). The captain and first officer of Flight 3407 both acknowledged that ice was present during their flight, but at no time did either of them expound on the current weather conditions. At 2140 EST the New York Center controller asked another aircraft whether they were experiencing icing and the aircraft responded with “light to moderate rime,” but the captain of Flight 3407 never paused or deviated from an anecdote he was telling the first officer. At 2210 EST, $6\frac{1}{2}$ minutes before the crash, the first officer inquired about ice on the windshield, as summarized by the transmission below (NTSB, 2010):

“22:10:22 EST First Officer: is that ice on our windshield?”

22:10:25 EST Captain: got it on my side, you don't have yours?”

22:10:32 EST First Officer: oh yeah oh it's lots of ice.

22:10:47 EST Captain: oh yeah that's the most I've seen - most I've seen on the leading in a long time. In a while I should say.”

The conversation then went into how the captain experienced icing on his first day with Colgan Air, and he began discussing his hiring process with Colgan Air. At 2212 EST, the first officer stated “I've never seen icing conditions. I've never deiced... I've never experienced any of that... I'd have like seen this much ice and thought oh my gosh we are going to crash.” At this point the captain admitted he felt the same way in his first winter in the Northeast, but offered no advice on how to handle the situation.

Assessment of Weather/CDM. Based on the analysis above, it is nearly impossible to determine whether

enhanced weather situational awareness would have led to a different outcome. However, it is safe to say that effective tactical weather/CDM is virtually impossible when pertinent data is missing or outdated. The foundation of a safe and successful flight begins before the aircraft leaves the ground with a well-informed flight crew.

4. CONCLUSIONS

4.1 Summary of Findings

Our investigation into Weather and CDM at the tactical level of decision-making revealed that there is virtually no difference between today's operating environment and that of 30 or 40 years ago. Our case-study analyses of the Trappe, MD fatal GA weather-related accident and the Colgan Air accident confirmed that observation, as the standard preflight weather briefings were essentially a one-way transmission of text-based weather information over the phone, with little to no interaction. In the Trappe, MD case, pilot-ATC collaboration only occurred when the pilot encountered embedded thunderstorms over the Delmarva Peninsula. Despite an apparently “successful” navigation around the storm cells, the pilot lost attitude and likely subsequently encountered conditions that caused the left wing to separate from the aircraft, causing a fatal accident. While the presence of data-linked weather radar in the cockpit helped him navigate the convective cells, its presence in the cockpit may have given him confidence to fly there when he should not have. The use of weather-in-the-cockpit products for tactical decision-making is strongly discouraged in FAA publications such as AC 00-63 (FAA, 2004).

An additional piece of data not presented earlier may help explain why the pilot in the Trappe, MD case proceeded to fly, even though the conditions were less-than-ideal. In an interview following the crash, the pilot's wife and daughter stated that he “had navigated airplanes through rough weather before, and had successfully made at least two emergency crash landings.” (Fernandez, 2007). In the Shappell et al. (2010) study of GA pilot weather encounters, the research team identified four “human-factor causes” for GA pilots flying into hazardous weather: 1) Motivation (also known as “get-home-itis”); 2) Lack of complete weather information; 3) Conflicting weather information; and 4) Lack of appreciation/understanding of the weather. Our analysis of this case most closely aligned with Factor #4. Regarding Factor #4, Shappell et al. wrote, “Some pilots may not understand the implications of the weather, or if they do, they may not appreciate the threat to flight safety that adverse weather poses. In effect, these pilots lacked a practical strategy for managing the weather hazard they faced.” We would argue that the pilot in this case did not appreciate the seriousness of the embedded thunderstorms over the route of flight, and the fact that he had successfully

navigated through adverse weather in the past could have given him a sense of confidence that did not match his experience in instrument meteorological conditions.

The Colgan Air case was not chosen because better situational awareness of the weather would have changed the outcome (though we can speculate on this point), but rather because it was a well-documented case where pilots were conducting routine operations in post-frontal lake-effect snow conditions considered “normal” for the area (western New York state) and time of year (February).

In the Colgan Air accident, we know that weather was a contributing, but not a causal factor. By studying this accident from a weather and CDM perspective, we can glean clues about situational awareness and what assumptions about “normal operating conditions” can lead to. First, the dispatchers failed to communicate all of the pertinent weather information to the flight crew. According to the NTSB (2010), this was caused by problems with Colgan’s weather contractor subsystem. Second, ATC, operating under “typical winter conditions,” only inquired once about the current icing conditions. Third, the captain and first officer never took it upon themselves to ask ATC about conditions, and when ATC made their general inquiry, the captain did not acknowledge the question. Most significantly, at no point did the captain or first officer ever expound upon the current weather conditions they observed; instead they simply went back to their previous conversation.

In this case, as in the Trappe, MD accident, two human-factors causes may have contributed to the end result: 1) Lack of complete weather information (in this case due to problems with the preflight weather briefing), and 2) Lack of appreciation and understanding of the weather.

4.2 Improving Weather Situational Awareness in the NAS

While some communication and data exchange about weather conditions may seem irrelevant and redundant to some NAS users, it is significant for maintaining shared situational awareness among *all* NAS users. As we approach the NextGen era, it is important to examine not only the technological possibilities for weather and CDM, but the “cultural” considerations as well. One way to accomplish this is to examine the concept of a “common weather picture” for different NAS users. This is a non-trivial exercise because different NAS users have different roles that require different views. For example, a Tower ATC is primarily concerned with the weather that is currently surrounding the airport. Although a Tower ATC should be aware of large-scale, synoptic weather features for planning purposes, their responsibilities are directed more at the present than the future. Flight dispatchers working at an airline

operations center are responsible for monitoring current and future weather features and deciding what information will be most pertinent for their flight crews. Pilots are concerned with the weather from the location they depart, the en route conditions at cruising altitude, and conditions upon descent, maneuver, and landing at their destination. Aircrews in particular are greatly dependent on others for their weather information, namely the dispatcher’s preflight brief, ATC, and any limited weather equipment in the cockpit (most likely a real-time data link to weather products, or perhaps onboard radar). It is safe to say that with a few minor exceptions, weather and CDM in today’s tactical environment is still largely dependent on voice communications and paper products which are not updated frequently.

From an aircrew perspective, weather technology in the cockpit (WTIC) has made real-time information available during the in-flight phase, and has tremendous potential for increasing situational awareness during flight. However, many private pilots either cannot afford the required equipment and service, or do not have the proper training on how to use the products in-flight. Additionally, commercial carriers have been slow to adopt WTIC due to equipage and training costs, and other considerations. Today, most commercial carriers still rely on traditional methods such as paper products and telephonic briefings from their airline operations centers to get weather information during pre-flight planning. In flight, the vast majority of weather information is passed via voice communications, which are inefficient, time-consuming, and subject to translation errors. Despite these limitations, WTIC would appear to have the potential to revolutionize the common weather picture, users’ situational awareness, and CDM in the NAS. However, there are many unanswered questions in terms of technological development, testing, user education and training, and technology integration—and WTIC just pertains to the aircrew users—how can the same type of weather picture be provided to dispatchers, ATC, and others in the NAS?

As part of the Colgan study, we developed a Google Earth-based Geographic Information System display of the environmental conditions and flight information covering the temporal and spatial scales of the accident using archived data from regional weather radars, satellite imagery, PIREPs, and AIRMETs, overlaid along the path of Flight 3407. The development of this tool is shown in Figure 8, and is used as an example of the type of weather/CDM product that could display a common weather picture for NAS users using currently available technology.

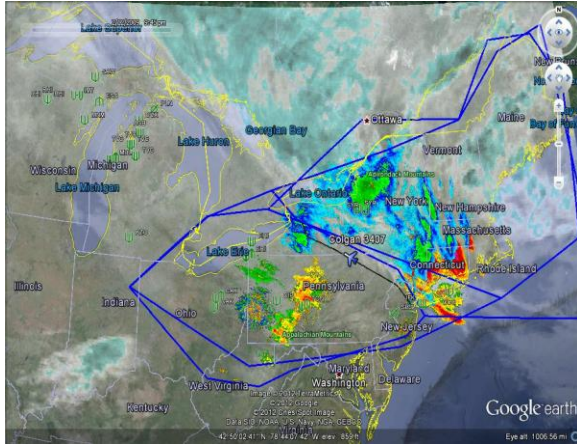


Figure 8. Composite situational awareness product with NEXRAD and Terminal Doppler Weather Radar data, satellite data, AIRMETs (blue outlines), icing PIREPs using conventional notation, Flight 3407's path (black line), and the aircraft's current position (airplane graphic). The overlapping AIRMETs indicate a new AIRMET has been issued and the older one is about to expire.

By developing a "proof of concept" tool that integrates available meteorological and flight data, and graphically displays it in a single animation, vast amounts of information can be communicated effectively to a large number of users simultaneously. Each weather data type can be "toggled" on and off, since these are layers built upon one another. We believe that such a comprehensive product could potentially improve an aircrew's situational awareness of the weather conditions that are being observed during the timeframe of a flight, and that this type of product could also be potentially useful to other NAS users such as ATC and airline operations centers.

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