Factors Affecting Air Traffic Controller's Weather Dissemination to Pilots

Ali Alshaqah

Chen Ling

Emma Pierson

Shengyoung Wang

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Ali Alshaqah, Chen Ling, Emma Pierson, Shengyoung Wang
The University of Akron
Akron, Ohio

As the number of flights in the United States continues to rise steadily, an equally amplified need for reliability and safety has come to the forefront of aviation research. One of the most alarming trends is the number of general aviation (GA) accidents during severe weather events that occur yearly, with fatalities occurring in more than half of these cases. This study focuses on identifying factors influencing weather dissemination of Air Traffic Controllers (ATC) to GA pilots. Ten factors affecting controllers' performance during severe weather events were identified through an in-depth literature review including controller mental workload, situation awareness, weather information format and accuracy, weather information needs, weather tool limitations, inaccurate assumption and bias, controller training and expereince, regulatory factor, supervisory factors, and pilot-controller relationship. Recommendation can be developed to address each factors so that aviation safety could be enhanced in severe weather situations.

The dynamic nature of the aviation environment is aggravated by adverse weather conditions which may change rapidly. These weather conditions generally require continuous evaluation and interpretation of weather information by both controllers and pilots to ensure a safe flight. The uncertain weather situation also requires a series of pre-flight and/or in-flight decisions to avoid accidents. The information incorporated to make these decisions is complex and is obtained from a range of sources. Therefore, the Federal Aviation Administration (FAA) considers the highest-priority weather functions to be those that detect phenomena posing a potential hazard to aviation. Indeed, controllers play a crucial role in providing tactical weather assistance through the dissemination of timely, accurate weather information. Inefficient weather-related decision-making of the flight crew during severe weather conditions, in which controllers can have a significant impact on the outcome, has been cited as a significant causal factor in general aviation (GA) accidents (Madhavan et al., 2006). Through numerous studies of literature based on weather-related accidents and incidents reports from the National Transportation Safety Board (NTSB), ten factors have been identified as recurring themes. These factors help set the stage for future in-depth research and analysis into mitigation strategies, interventions, and techniques that can improve methods by which air traffic controllers are trained to use weather-related information to aid pilots, especially GA pilots, in safely reaching their destinations.

1. Mental Workload

Air traffic controllers' tasks are cognitively complex in nature, and the mental workload is a dominant safety-related consideration in the air traffic controller domain. Throughout the literature, significant relationships between extremes of workload (under load, high workload, and overload) and a decline in controller performance, such as an increase in operational errors, have been consistently reported (Cox-Fuenzalida, 2007). A high workload may be experienced

when air trafific controller disseminate weather information during severe weather situations, as additional weather related decisions making are needed and more pilots request diversions or assistance. Once the workload is driven over the "red line," performance can start to deteriorate, and errors can begin to appear when time stress is excessive (Wickens, 2017, NRC, 1997) Another issue is the transitions between workload extremes, which have been reported to be negatively associated with controller performance. Cox-Fuenzalida (2007) investigated the effect of workload transition in association with performance, and the results showed a significant decrement in performance after a transition in both high-to-low and low-to-high experimental conditions. Although the study was not specific to the air traffic controller domain, the results suggest that caution need to be exercised as many situations involving severe weather conditions may be associated with workload transitions from low to high or from high to low.

2. Situation Awareness

Weather situation awareness in the ATC domain is a combined perception of time, current weather location, airspace volume, weather movements in the near future, sector traffic flow, and the available control options(Ahlstrom et al., 2003). A high weather awareness would imply that the controller is able to form a coherent future "mental weather picture" and manage the air traffic accordingly. This means that the controller would know where the severe weather areas will be and how to adjust the traffic flow accordingly. It also implies that the controller could adjust their tactical strategies for more efficient traffic flow, vector planning, and better assistance to the pilot (Ahlstrom et al., 2003). In the current national airspace (NAS), controllers maintain their situation awareness by monitoring the aircraft using advanced display system integrated with decision support tools that show different levels of precipitation on the Standard Terminal Automation Replacement System (STARS), or the ARTS Color Display, or by receiving a weather briefing from their supervisor. In addition to this information, controllers get reports from pilots of hazardous weather conditions they encounter during flight. Therefore any deficiencies of the aviation weather system from collecting, communication, interpreting weather information would result in a controller's loss of situation awareness.

3. Weather Information Format and Forecast Accuracy

Weather-related accidents can usually be attributed to a lack of valid weather information during flight. Aviation weather information in aural format is difficult to integrate with spatial flight information and recall for reference. Indeed, the controller’s lack of knowledge of complex aviation weather conditions often necessitates reference to various weather resources to develop a comprehensive understanding of meteorological conditions (Latorella et.al., 2002). When the weather resources for controllers are limited, controllers might have a lesser understanding of the available weather information, hindering flight safety (King et al., 2016). After National Research Council committee (NRC, 1995) identified some operational shortcomings pertaining to aviation weather dissemination, FAA conducted many studies to resolve these shortcomings, e.g. improving the weather forecast accuracy and quality to enhance the controller’s ability to provide a timely, accurate, consistent and adequate information. Some of these issues have been addressed while others need further research to identify where the exact gaps are in the controller-pilot system. Although significant efforts have been underway to provide more accurate forecasts, weather forecast always comes with a degree of an uncertainty. When controllers provide weather information to pilots, it must be accurate. According to FAA Order

JO7110.65, controllers are to provide complete weather information based on all weather sources and this information should be consistent and accurate, considering the radar delay. Therefore, controllers may be hesitant to provide any weather information that is "incomplete, inconsistent, and outdated." If an accident is caused by ATC providing inaccurate information, it might lead to government liability (Bartsch, 1996).

4. Controller Information Needs for Integrated Weather Information

A poor understanding and under-defining of controller's weather information needs, including the actual weather information necessary to maintain the controller's situation awareness still exists. Research is still lacking in the exploration and specification of the weather information needs for controllers (Ahlstrom et al., 2003). FAA has outlined the concepts of operations for the weather in the NAS domain as well as the weather information needed by NAS decision-makers to mitigate the effects of weather on flight safety. However, according to Ahlstrom et al. (2013), the validation requirements on practical use were not established although a summary of conceptual weather information needs and a strategy to mitigate the deficiencies were presented. Therefore, to improve weather information display tailoring to the weather needs of different types of controllers and to understand the associated impact on operational services, more in-depth research is still needed, including a plan for integrating multiple sources of weather information onto user displays (Ahlstrom et al., 2003).

5. Training and Experience

Insufficient training and low experience levels in aviation weather scenarios could adversely affect air traffic control performance. Ruitenberg (1997) emphasized on the periodical recurrent training-schemes, which providing training when new technology is introduced to facilities, also providing training on any new pertinent knowledge or skills to controllers. Investigations in some aviation accident revealed a lack of training of air traffic controllers on how to retrieve both required and additional useful weather information from a regular channel, when such information is not instantly and directly available at their workstations (NTSB, 2015). Past reserach also identified that some controllers have limited aviation weather knowledge, and there is a lack of standardized procedures or protocols in training programs on mitigating weather-related incidents (King et al. 2016). To address this issue, recurrent training focusing on weather and scenario-based weather training could enhance controller's weather readiness.

6. Inaccurate Assumptions and Biases

Several inacurate assumption or bias may hinder controller from effectively disseminating weather information to pilots. Controllors may assume GA pilots are able to avoid bad weather visually, however pilots may be operating in IMC and cannot see anything beyond the aircraft's windshield. Moreover, there is a common thought in the ATC community that the pilot has a better perspective on what lies ahead because they have airborne weather radar. Cockpit weather radar systems are not better than NEXRAD or any other controller weather detection systems- they are just different (Werth, 2014). Another bias was identified by NRC committee as it gathered information from various FAA organizations and individuals. Because of ATC's heavy focus on aircraft control and collision avoidance, ATC community seem to have developed a general bias against increasing their involvement with weather-related issues (NRC,

1995). During severe weather, controllers may be so busy working with aircraft that they have little time to explore the weather. For this reason, and because some controllers view weather information as advisory service, they may not be aware of current and forecast weather conditions in their sector (NRC, 1995). The third bias is related to the controller's use of probabilistic weather information. Although NextGen provides better weather forecast accuracy and integrating the probabilistic weather information to the DST system, the NAS users still show insufficient understanding of the probabilistic weather information in the decision-making process (Abelman et.al., 2014).

7. Limitations in Weather Tools

ATC facilities utilize both ASR system which displays precipitation in 4levels and Weather and Radar Processor (WARP) which reports precipitation in 3 levels to provide weather information to controllers. These systems have their limitations in showing weather information. Unlike approach controllers who use ASR (which is nearly real-time), ARTCC or Center controllers use WARP which cannot provide warnings about precipitation until it reaches the "moderate" threshold because WARP does not display light intensity of precipitation (FAA Order JO7110.65, section 2-6-4 weather and chaff services). At this threshold, the weather situation can already be hazardous for unprepared pilots or light aircraft. Moreover, the data which appears on the controller's scope is typically six minutes old, since WARP collects and integrates data from one or more remote NEXRAD sites (FAA, 2016). In convective conditions where the severe weather activity builds rapidly, the time lag can render WARP information obsolete before it ever hits the screen. Understanding the limitations of aviation weather detection systems that NAS operators typically utilize, and developing a comprehensive understanding of how these systems can complement each other have a profound impact on safety (Werth, 2014).

8. Organizational, Regulations and Procedure Factors

Controllers should provide operational significant weather information to pilots before, and during flight, who then utilize this information to decide when and where to fly (FAA, 2017). NTSB (2014) suggest that controllers must have unconstrained access to critical information on essential weather information, such as real-time lightning data. Controllers must also be trained and equipped to disseminate this critical information expeditiously. Further, FAA must have the infrastructure and protocols in place to ensure vital information such as pilot reports (PIREP's), is conveyed in the NAS system (NTSB, 2014)frequently. However, controllers' first priority is to separate aircraft and issue safety alerts. Rational prioritizing should be used of all other provisions of FAA order based on requirements of the situation at hand. According to FAA Order JO7110.65, controllers should "select the most appropriate course of action in convective weather scenarios." The rule also instructs that "additional services, such as traffic advisories and safety alerts, can be offered to aircraft flying in uncontrolled airspace but only on a workload permitting basis". Therefore, it is up to the controller's discretion to decide whether to disseminate weather information to pilots based on the workload. Additionally, when various weather information sources exist, causing it difficult for controllers to decide how weather could impact their tasks, controllers may shift their decision-making process to be based

on personal knowledge and experience rather than making sound decisions that are rule-based to assist in time-critical weather encounters (Lindholm, 1999).

9. Supervisory and Management Factors

Organizational and supervisory factors have a profound influence on restricting unsafe acts committed by controllers, including decision errors, skill-based errors, perceptual errors and violations (Pounds et al., 2000). Also, supervisory activities and practices such as enhancing operational effectiveness, managing resources, enhancing interpersonal skills, and monitoring controllers performance were reported as important to safety (Connor et al., 2001). Moreover, a sufficient number of trained supervisors/controllers also is considered as an essential factor. Therefore, clear guidance provided by trained supervisors and facility manager on how to disseminate weather information as well as a safety culture in the facility on weather-related issues will help controllers achieve safer and better performance.

10. Controller-Pilot Relationship

ATC and pilot work is interdependent of each other and their work depends on each other to be successful, and they need to trust each other (Owen, 1998). Successful joint practices for both parties enabled by smooth communication is needed to support such a highly inter-dependent system. Any miscommunication may endanger system safety and efficiency. Controller and pilot tasks have different objectives, controller ensure safe and expeditious traffic flow of an air space, while pilot ensures safe and expeditious traffic for their specific airplane. Constrained by their own work rules, there could be miscommunication and breakdown in coordination at the border of their individual activities. Both pilots and ATC might have inadequate understanding of one another's weather resources, capabilities, and the supportive working strategies necessary to avoid contingency flight situations. However, the controller-pilot relationship could be so tenuous or challenging that it is referred to as an "awkward alliance" , and similar tension may be due to pilots perception of the ATC role as "traffic cop" (Besco, 1997). Therefore, pilots may be hesitant to use ATC as a weather resource.

Conclusion

The need for improved weather dissemination is intended to reduce GA accidents. Overall better weather-related decisions for ATCs could also help reduce unnecessary diversion of aircraft and achieve better planning and more efficient routing. High-quality aviation weather service and weather information (e.g., weather observations, forecasts) must be provided, and controllers must be adequately trained in properly disseminating weather information to ensure consistent and safe air operations. Recommendation can be developed to address the identified factors so that aviation safety could be enhanced in severe weather situations.

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