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A REFINEMENT OF THUNDERSTORM CLIMATOLOGY  
FOR THE TERMINAL RADAR CONTROL AIRSPACE\*†

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## 1. INTRODUCTION

Convective storms pose a significant threat to aviation safety, and often result in substantial flight delays for the commercial aviation industry. The overall impact of these storms is typically based on thunderstorm climatologies and are often one of the factors used in decisions by the US government regarding the operational benefits and allocation of its weather surveillance resources. These climatologies are based on the average number of days that a thunderstorm is observed at a particular airport. Due to the nature of the criteria used to identify a thunderstorm, the climatological statistics often do not accurately represent the number of thunderstorms that impact an airport's operations. The present study utilizes data from the Dallas Ft. Worth International Airport (DFW) and the Orlando International Airport (MCO) to identify deficiencies in the climatological data as it applies to aviation applications. A spatially representative climatology is presented as a more accurate climatology for use in evaluating the impact of convection on an airport's operations. This type of climatological estimate of thunderstorm frequency significantly increases the estimated number of thunderstorms impacting an airport and their associated costs.

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\* This work was sponsored by the Federal Aviation Administration. The views expressed are those of the author and do not reflect the official policy or position of the U.S. Government.

†Opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the United States Air Force.

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## 2. CURRENT THUNDERSTORM CLIMATOLOGIES

The assessment of the benefits of US government's aviation weather surveillance resources such as the Weather Surveillance Radar (WSR-88D), Terminal Doppler Weather Radar (TDWR), Integrated Terminal Weather System (ITWS), and the Airport Surveillance Radar (ASR) 9 Weather Systems Processor (WSP) are based in part on the 'thunderstorm day' climatology. A 'thunderstorm day' is defined as "a local calendar day on which thunder is heard,... regardless of the actual number of thunderstorms" (WMO, 1953). This criteria results in a good estimate of the number of days a year in which a location could expect to experience a thunderstorm, however, it does not have the temporal resolution which is preferable when trying to determine the amount of time in which one could expect thunderstorm conditions to impact airport operations. Benefits assessments often provide results in terms of yearly hours of delay. One of

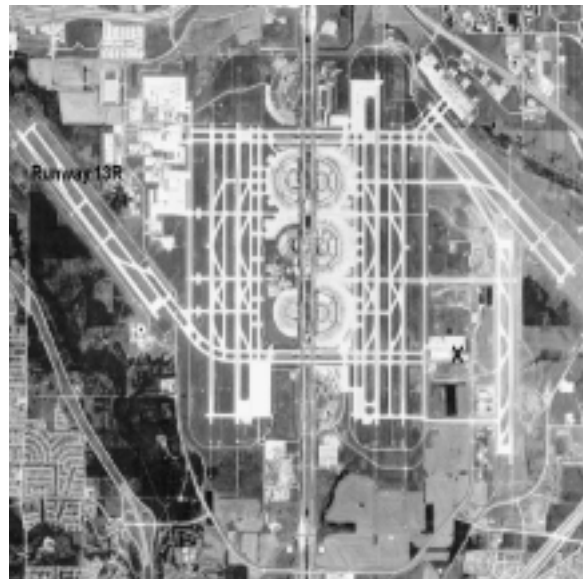


Figure 1. Dallas Ft. Worth International Airport. The X denotes the location where weather observations are taken, and runway 13R is at the top left side of the picture.

the unknowns is the average amount of time that a particular location might experience thunderstorm conditions (Rhoda and Weber, 1996). Since climatological data of this type are not available, this factor is based on information from air traffic controllers and empirically derived from the ‘thunderstorm day’ climatological averages.

The spatial resolution of the ‘thunderstorm day’ climatological record is also deficient when used for aviation applications. A thunderstorm is observed at a station when either “a: thunder is heard, b: or overhead lightning or hail is observed, and the local noise level is such as might prevent hearing thunder” (FMH No. 1, 1988). This strict criteria for identifying a thunderstorm in conjunction with the aerial extent over which airport operations are susceptible to thunderstorm induced delays, imply that the use of the ‘thunderstorm day’ might underestimate the true frequency in which thunderstorms impact an airport. This point is illustrated in figure 1 which depicts the DFW airport and the location where the weather observations are taken. A thunderstorm over the 3 mile final approach arena of runway 13R would be approximately 7 miles from the weather observation location, identified by the X in figure 1. Due to the size of this airport, it is possible for a thunderstorm to impact an arrival arena yet still not meet the criteria for a thunderstorm observation to be made.

Thunderstorms can impact airport operations not only when the storm is over the airport itself, but anytime there is a storm inside the Terminal Radar Approach Control (TRACON) airspace. Air traffic volume is typically the greatest within the TRACON airspace, and thunderstorms within this area disrupt normal air traffic routes. Thunderstorms over Arrival Transition Areas (ATA) and Departure Transition Areas (DTA) can result in a significant impact on air traffic flow since aircraft move from the TRACON to the en-route airspace through these regions. The TRACON airspace including the ATA and DTA’s typically encompass an area within a 50 nautical mile (nm) radius of the airport. This problem requires a spatially representative estimate of thunderstorm frequency instead of the point measurements which are currently used. Applying the ‘thunderstorm day’ climatology to this problem significantly underestimates the impact of thunderstorms in the TRACON.

To accurately assess the impact of thunderstorms on airport operations, both the temporal and spatial deficiencies in the climatology should be addressed. The present study focuses on the spatial deficiencies of the climatological data set and demonstrates the use of a spatially representative thunderstorm occurrence climatology over the currently available point measurement, the ‘thunderstorm day’.

| Site | Observed storms | Storms inside 10 nm | Storms inside 50 nm |
|------|-----------------|---------------------|---------------------|
| DFW  | 69              | 114                 | 171                 |
| MCO  | 107             | 185                 | 215                 |

**Table 1.** Total number of observed storms ‘thunderstorm days’, storms within 10 nm of each of the airports, and storms within 50 nm of each of the airports.

### 3. SPATIALLY REPRESENTATIVE THUNDERSTORM CLIMATOLOGY

The spatially representative thunderstorm frequency estimates were derived from data from two of the ITWS prototype field sites, DFW from May 17, 1995 to September 30, 1996, and MCO from June 1, 1995 to September 9 1995, and March 1 1996 to September 30 1996. Radar data from the respective airports ASR9 radars, as displayed on the air traffic planners ITWS situation displays, were reviewed to generate the spatially representative climatological statistics. Thunderstorms with a National Weather Service (NWS) Video Integrated Processing (VIP) level of three or greater were considered strong enough to impact airport and TRACON operations. This threshold was chosen based on a widely quoted air traffic controller’s rule-of-thumb, in which pilots begin to ask for deviations around convective storms of level three or greater. This rule-of-thumb is further supported by statistical evaluations of Rhoda and Pawlak, 1998. Two separate spatially representative climatological statistics were generated by tabulating the number of storms in which VIP level three or greater convection occurred within a 10 nm and 50 nm radius of the airport. The 10 nm radius corresponds to the area in which convection has a substantial impact on airport operations and 50 nm is the approximate size of the TRACON.

During the period used for this analysis, DFW had 69 and MCO had 107 official ‘thunderstorm days’. The ITWS field sites were operating at this time on nearly every day in which VIP level three or greater weather occurred within the TRACON. There were, however, several instances in which storms occurred late at night or in the early morning hours when the ITWS system was not operational. This resulted in six days in DFW and four days in MCO in which there were thunderstorm observations and ITWS was not operational. Although there were several occurrences in which this was the case, overall, the ITWS data set accurately represents the frequency of thunderstorms at the two airports. A 98% correlation in DFW and 99% correlation in MCO

between the 10 nm spatially representative data set and the official ‘thunderstorm day’ data set, confirm that the ITWS data is a good representation of thunderstorm climatology over this period. These results are derived from the climatological statistics shown in Table 1. This table contains the official ‘thunderstorm day’ climatology in addition to the spatially representative climatologies for both DFW and MCO.

The climatological statistics from Table 1 were used to develop correction factors. In general, the correction factors for the 10 nm spatially representative thunderstorm climatology were fairly consistent between DFW and MCO. Within 10 nm of the airport there were 1.65 times more storms in DFW and 1.73 times more storms in MCO in the spatially representative climatology than in the official ‘thunderstorm day’ climatology. The correction factors were less consistent between the two sites for the 50 nm spatially representative climatology. There were 2.48 times as many storms in DFW and 2.01 times as many storms in MCO within the TRACON than were observed at each of the airports. The discrepancy between the sites is most likely due to the fact that DFW data set has more line storms which may enter the edge of the TRACON, while the MCO data set captures more airmass type thunderstorms. Airmass thunderstorms are typically more evenly distributed throughout the TRACON, increasing the likelihood that when airmass storms occur a thunderstorm will be observed at the airport, resulting in a lower correction factor.

The correction factors based on a spatially representative thunderstorm frequency are applicable to longer term thunderstorm climatologies. Table 2 displays the long term climatological averages and the adjusted numbers of thunderstorms which could be expected to occur within 10 and 50 nm of both DFW and MCO. In the Dallas-Ft. Worth area an average of 37 thunderstorms and in the Orlando area typically 78 thunderstorms a year are observed (Martin Marietta Air Traffic Systems, 1994). The number of thunderstorms jump up to 61 and 92 for the 10 nm and 50 nm radius around DFW. In Orlando, the number of thunderstorms one might expect range from 135 to 157 for a 10 nm and 50 nm

| Site | Average Climatology | Adjusted Climatology (10 nm) | Adjusted climatology (50 nm) |
|------|---------------------|------------------------------|------------------------------|
| DFW  | 37                  | 61                           | 92                           |
| MCO  | 78                  | 135                          | 157                          |

**Table 2.** Adjusted yearly averaged thunderstorm climatologies for Dallas Ft. Worth and Orlando.

radius around the airport. The 10 nm climatologie represents at least a 65 % increase over the observed thunderstorm days and at least a 100 % increase is seen in the 50 nm climatological statistics.

#### 4. APPLICATION TO BENEFIT ASSESSMENTS

Climatological weather information is one of the primary variables used in cost-benefit analysis of new or improved weather surveillance resources procured by the US government. This information also dictates the deployment locations of these resources. The general methodology used in the assessment of benefits for both the FAA ITWS and ASR9 WSP systems began with a demonstration of the system’s products at the air traffic control (ATC) and airline facilities during the thunderstorm season. The demonstration was followed by interviews with personnel using the products to compile a list of “benefit categories”. Benefit categories are tasks in which the weather products provide information which is relevant to operational decisions. The interviewees were asked to estimate the number of aircraft that benefit from decisions impacted by the weather information, and also the amount of delay reduction per aircraft. It was then assumed that the amount of delay which could be avoided is proportional to the product of number of aircraft operations and the thunderstorm occurrence rate. Government accepted figures for the value of passenger time and industry estimates for the rate of fuel consumption and operating costs are used to convert the delay hours into an equivalent economic cost of the avoidable delay (Rhoda and Weber, 1996).

In this type of analysis, the climatological weather information is linearly proportional to the dollar costs of the delays. Given the assumption that a spatially representative estimate of thunderstorm frequency is more representative of the number of thunderstorms which impact airport operations, it is possible to scale the results of previous benefits assessments to reflect the more accurate thunderstorm frequencies. Table 3 is an example which illustrates benefits assessment results for the initial capability products of ITWS at 45 airports across the country which have a TDWR (Evans and Ducot, 1994). This table presents the original benefit calculations, and the benefits values adjusted to represent the more conservative of the two spatially representative thunderstorm climatologies. The adjustments take into consideration whether the user-identified payoff area is directly over the airport or outside of the airport but within the TRACON, and uses the appropriate correction factors. For this particular example, there was a increase in total

| User-Identified Payoff Area                  | Correction Factor | Annual Benefit (Millions of \$) | Adjusted Benefit (Millions of \$) |
|--|-------------------|---------------------------------|-----------------------------------|
| Higher airport capacity during thunderstorms | 1.65              | 7                               | 11.6                              |
| Anticipation of ATA/DTA closures/reopenings  | 2.01              | 51                              | 102.5                             |
| Anticipation of runway impacts               | 1.65              | 36                              | 59.4                              |
| Better terminal-area traffic patterns        | 2.01              | 3                               | 6.0                               |
| Optimization of traffic flows                | 2.01              | 39                              | 78.4                              |
| Optimization of airline operations           | 1.65              | 19                              | 31.4                              |
| <b>Total</b>                                 |                   | <b>155</b>                      | <b>289.3</b>                      |

**Table 3.** Revised projected ITWS benefits for initial capability products installed at 45 TDWR airports.

benefit from the ITWS initial capability products of nearly 87 %.

## 5. CONCLUSIONS

Climatological data on convective storms is a key factor in assessment of both safety hazards and aircraft delays imposed by thunderstorms. To be effective, this data must be representative of phenomena as it impacts aviation. The present study has improved upon the currently used ‘thunderstorm day’ climatology to make it more representative of how thunderstorms actually impact aircraft safety and airspace efficiency. This was accomplished through a spatially representative climatology which more accurately represents how thunderstorms impact airport operations, both near the airport and throughout the entire TRACON. Utilizing a spatially representative climatology increases the number of days a thunderstorm might directly impact the airport by over 65 % and increases the number of days that a thunderstorm might impact the TRACON by 100 % over the commonly used ‘thunderstorm day’ climatology. These statistics indicate that the ‘thunderstorm day’ climatology significantly underestimates the frequency in which thunderstorms may pose a safety threat to aviation. The results of this study also reveal that benefit assessments of government weather surveillance resources are also underestimated when the ‘thunderstorm day’ climatology is used. In the example presented here, an increase of nearly 87 % in benefits from the ITWS initial capability products is realized when a spatially representative climatology was used. Although a larger spatially representative data set would be desirable to more accurately quantify its relationship to the ‘thunderstorm day’ observations, it appears that this ap-

proach better represents the frequency in which convective weather impacts aviation operations.

## 6. ACKNOWLEDGMENTS

The authors gratefully acknowledge Dale Rhoda for his review and insightful comments.

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