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Accuracy of Flight Delays Caused by Low Ceilings and Visibilities at Chicago's Midway and O'Hare International Airports

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ABSTRACT

In 2013 the Federal Aviation Administration found that over 28,000 flights were delayed out of the Chicago's Midway and O'Hare International Airports and that 69% of flights are delayed by weather. This paper examines the accuracy of flight delays caused by low ceilings and visibilities from November 2015 to March 2016. Terminal Aerodrome Forecasts were used to determine the cause of delays while Automated Surface Observing System was used to determine the accuracy of each flight delay. It was found that low ceilings and visibilities caused 75% of the flights delayed by weather and that 13% of delays caused by low ceilings and visibilities were inaccurate. Over half of all inaccurate delays were caused by the Terminal Aerodrome Forecasts predicting precipitation to last longer than what was observed.

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1. Introduction

Every year, thousands of flights are delayed at airports around the United States. According to the Federal Aviation Administration (FAA), in 2013, 69% percent of flight delays lasting 15 minutes or more were caused by weather leading to over 10 million minutes of delays and cost airlines on average three thousand dollars an hour (FAA). The delays cost airlines millions of dollars every year and impact thousands of travelers. To determine whether a delay due to weather is necessary, airports look at a combination of weather forecasts and current observations. Since weather forecasts play such a huge role in determining whether a flight should take off on time, it is very important to have the most accurate forecasts to eliminate unnecessary delays.

Newark International Airport experiences a large number of flight delays and Allan et al. (2001a) looked at the causation of the delays from September 1998 to August 2001. The data used in this study for flight and delay information was the Consolidated Operations and Delay Analysis System (CODAS). During the

time of the study, however, there was a change in data systems so the Aviation System Performance Metrics (ASPM) was also used. The study utilized weather data from the National Climate Data center and the Integrated Terminal Weather System (ITWS). The delays were first broken up into different categories based on the cause, weather or something else, e.g., mechanical problem or incoming aircraft delay. The weather delays were broken down further into three categories depending on the weather that caused them. The three types of weather examined were convection, low ceiling and visibility and high surface winds. This study found that convective weather caused the majority of delays. However, low ceilings and visibilities accounted for 28% of the delays, with 50% of those delays being preplanned departure delays. One major source of error in this study is that neither of the systems used for flight delay data recorded the exact cause of the delay; it was up to the researchers to use weather data to determine causation. Determining the cause is difficult since delays can be affected not only by surface weather but also upper air conditions, convection on flight route, and weather at the arrival airport. Even though this study used multiple weather sources to determine the cause of the delay, other factors could have actually caused the delay.

Allen et al (2001b) did another study looking at causation of delays at the three major airports in New York. Part of this study looked at "avoidable" delays at Newark International Airport due to low ceiling and visibilities and the benefits of having more accurate forecasts. A case study from February 12, 1999 was examined. On this day, low ceiling and visibility conditions improved much earlier than predicted. Flights were delayed due to the forecasted conditions. However, conditions had improved enough for flights to be able to take off on time. To find the effects of these unnecessary delays, a model was used to simulate the airport running at capacity during the time period in which conditions had improved but wasn't running at capacity. The model showed that 230.9 hours of avoidable delays had occurred. The study also looked at the monetary value of this and found that over 1.4 million dollars could have been saved if the airport ran at capacity when the low ceilings and visibilities had improved. This shows how important it is to have accurate forecasts in aviation; it is costly to have planes grounded for longer than necessary.

The past two studies have shown weather can have a significant impact on on-time departures and these unnecessary delays have negative consequences. It is therefore very important to have the most accurate forecasts and equipment that reduce these unnecessary delays. Evans and Ducot (1994) looked at weather delays to determine what data should be included in the ITWS so that it could help reduce delays. The data used was from the National Airspace Performance Reporting System (NAPRS) from Chicago's O'Hare International Airport. This data was then extrapolated to represent what delays

would occur for other airports. This study found that low ceilings and visibilities accounted for 35% of all weather delays. Since this is such a large percentage of flight delays, it is important to be able to accurately predict the beginning and end of events that cause low ceilings and visibilities. As Allen et al (2001b) found it can be quite costly to have flights delayed when it could be avoided with improved forecasts. Evans and Ducot found that adding Automated Surface Observing System (ASOS) and the Aviation Gridded Forecast Model to the ITWS could help improve the system's forecasting. These two products together would help airports have a better idea when low ceilings and visibilities occur and when conditions are likely to improve.

The research shows that there is a significant need for delay accuracy at airports as many hours and dollars are lost due to unnecessary delays. It also shows that low ceilings and visibilities are a major contributor to weather delays accounting for anywhere from 28-35% of all weather-related delays. Therefore, it is important to look at the forecasts of the ceilings and visibilities and make sure they are as accurate as possible to eliminate avoidable delays.

Many airports experience flight delays due to weather with New York and Chicago being the two cities with the most flight delays. According to the FAA (2015), in 2013 Chicago's O'Hare and Midway International Airports had over 28,000 flights delayed 15 minutes or more. Chicago sees many days with fog and is geographically susceptible to winter storms. These conditions lead to low ceilings and visibilities during the winter months. This study analyzed the causation of weather delays and looked at how many of the weather delays caused by low ceilings and visibilities at both Chicago airports could have been avoided by more accurate forecasts.

2. Data and methods

a. Delay data

The dates selected for this research were 1 November 2015 through 31 March 2016. These dates were selected since a study done by Friedlein (2004) found that Chicago sees 75% of its dense fog cases between November and March. Chicago and especially O'Hare International Airport are often affected by fog due to their proximity to Lake Michigan. During the winter months the lake is warmer than the ground near it and often the wind advects this warm air westward and may lead to the formation of fog.

The delay data was gathered for both O'Hare International Airport and Midway International Airport from the United States Department of Transportation's Bureau of Transportation Statistics. The Bureau of Transportation Statistics tracks the cause of delay and puts it in one of five broad categories, one of which is weather. First, flights were organized by cause of delay. The flights delayed by weather were then sorted by duration of delay. They were eliminated if the delay was less than 15 minutes. This is because the Bureau of Transportation Statistics (2016) considers

a flight delayed only if it departs 15 minutes or more after its scheduled time in the Computerized Reservation System (CRS). Out of the 3456 weather-related delays, the 2683 flights found to have been delayed by weather for more than 15 minutes were further analyzed.

b. Delay causation

Delay Causation was determined using Terminal Aerodrome Forecasts (TAF) created by the Aviation Weather Service. Each flight delayed by weather was analyzed to see if low ceilings or visibilities were the cause. Since TAF reports are typically created every 6 hours and are valid for 24 hours, the TAF created closest to the flights originally scheduled departure time was used. TAF makes note of when it predicts forecasts to change. If there was a from (FM) group, which notes a sudden change in conditions that was closer to the flight's departure time, that forecast was used. A flight was considered delayed by low ceilings if forecasted conditions had ceilings at 3500 feet or less and sky cover was broken or overcast. A flight was considered delayed by low visibilities if conditions were less than 5 statute miles (Allen et al 2001b). It was also noted whether or not precipitation was expected along with the low ceilings and visibilities. If forecasted low ceilings or visibilities did not meet the criteria, the flight's cause of delay was listed as unknown. 2002 flights met the criteria and were classified as being caused by low ceilings and visibilities and checked for accuracy.

c. Delay accuracy

The accuracy of each delay was determined using Automated Surface Observing System (ASOS) data from the Iowa Environmental Mesonet. Each flight delayed by forecasted low ceilings or visibilities were examined to determine if observed conditions would lead to a delay. ASOS data is usually reported hourly or if conditions rapidly change. Since flights can leave at any time, very few fell on when the ASOS recorded data. Therefore, the conditions in the observation before the scheduled departure were analyzed since it was assumed that conditions that the flight was taking off in were similar to those reported. If the observed conditions were broken, or overcast skies less than 3500 feet, or visibilities were less than 5 statute miles, the delay was considered accurate. If a flight was delayed and the conditions did not meet the parameters it was considered inaccurate.

3. Results and analysis

Between November 2015 and March 2016 Midway International Airport had 212 flights delayed by low ceilings and visibilities. Of those 212 flights, 32 were found to be inaccurate as ceilings and visibilities were clear enough to allow flights to take off (Table 1). During the same period of time, O'Hare International Airport had 1790 flights delayed by low ceilings and visibilities (Table 1). Overall, O'Hare had more inaccurate delays but when compared to the number of delays caused by low ceilings and visibilities Midway had a higher percentage. Over the time period of this experiment Midway

Table 1. Total flights scheduled to depart, number of weather related delays, number of flights delayed due to low ceilings and visibilities (C & V), flights found to have inaccurate delays caused by low ceilings and visibilities (C & V) and percentage of inaccurate delays compared to number of delays caused by low ceilings and visibilities for the months of November through March for Midway and O'Hare International Airports.

Midway International Airport						
	November	**December**	**January**	**February**	**March**	**Total**
Total Flights	6915	7102	6679	6208	7327	34231
All Weather Delays	67	66	41	57	50	281
Delays Caused By Low C &V	52	63	23	52	22	212
Inaccurate Delays (for low C & V)	12	7	3	5	5	32
Percentage of Inaccurate Delays	20.9%	11.1%	13.0%	9.6%	22.7%	15.1%
O'Hare International Airport						
	November	**December**	**January**	**February**	**March**	**Total**
Total Flights	26078	25579	18610	17764	19904	107935
All Weather Delays	495	607	503	588	209	2402
Delays Caused By Low C &V	347	583	362	314	184	1790
Inaccurate Delays (for low C & V)	39	30	92	5	41	207
Percentage of Inaccurate Delays	11.2%	5.1%	25.4%	1.6%	22.3%	11.6%

averaged 15.1% inaccurate delays related to low ceilings and visibilities per month while O'Hare averaged 11.6% (Fig 1). After running statistical tests, it was found that the number of inaccurate delays was statistically significant for O'Hare ($p < .0001$) but not for Midway ($p = .2422$).

During 4 of the 5 months, Midway experienced a higher percentage of inaccurate delays. However in January, O'Hare had the highest percentage of inaccurate flights in one month. January 2016 saw 25.4% of low ceiling and visibility-delayed flights found to be inaccurate. Most of the inaccurate flight delays during January at O'Hare were following an event where low ceilings and visibilities were caused by snow. Many times either the low ceilings or visibilities

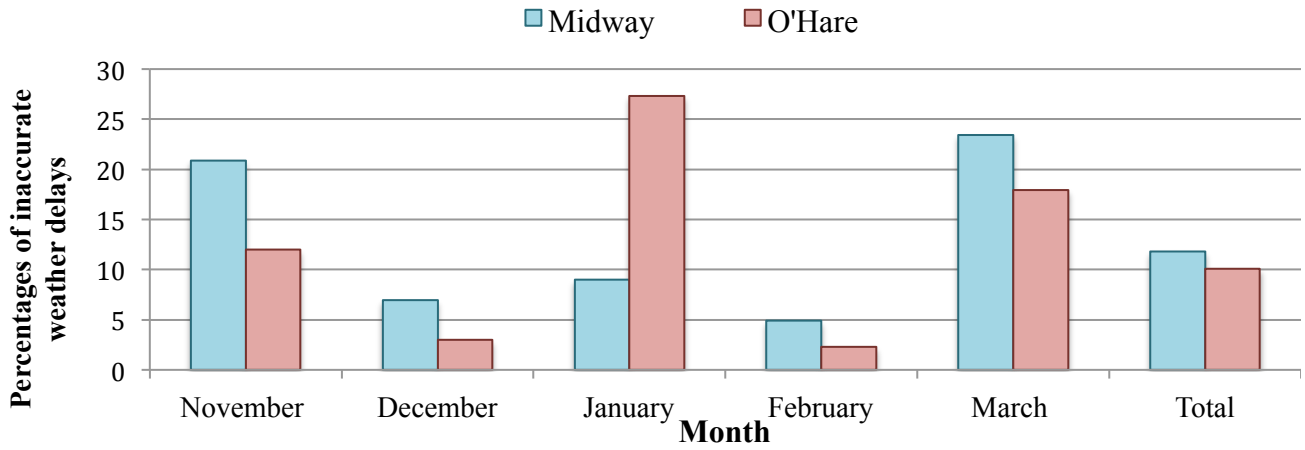

Fig. 1. The percentage of flights inaccurately delayed by low ceilings and visibilities with respect to all the flights delayed by low ceilings and visibilities between November 2015 and March 2016 and total inaccurate flights for Midway and O'Hare Airports.

associated with the snowfall would improve earlier than forecasted or snowfall would end earlier than predicted. In January 67 of the 92 inaccurate flights were caused by inaccurate predictions of the ending of snow events.

A similar pattern was observed in November at O'Hare. A major snowstorm came through November 21st into the 22nd and dropped 11.2 inches of snow at O'Hare and 5.8 inches at Midway (NOAA). The TAF predicted low ceilings to continue for hours after the end of the snowstorm. However, skies cleared earlier than expected which led to 27 inaccurate flight delays. Another interesting thing observed with this snowstorm was, despite the fact that snow had ended hours earlier, there were approximately 100 flights over the next 24 hours delayed by weather. At the time of these delays none of the forecasted conditions or observed conditions should have led to a delay.

Overall, O'Hare saw the higher amount of minutes delayed each month due to inaccurate delays. The total number of minutes includes only weather delays. It does not include any other additional minutes from things such as slow boarding or mechanical issues. This is to be expected since O'Hare had more total flights delayed inaccurately than Midway. Over the entire period O'Hare had the higher average for minutes delayed. They averaged 58 minutes per flight while Midway averaged 46 minutes per flight (Fig 2). Despite November having a smaller percentage of flights delayed for O'Hare it saw the most minutes delayed and had the highest percentage of weather-delayed minutes. The average length of delay for the month of November at O'Hare was 130 minutes. 4,343 of the 4,971 minutes in November are associated with the snowstorm mentioned earlier that dropped 11.2 inches at O'Hare. This shows how mis-timing the end of low ceilings and visibilities can impact an airport.

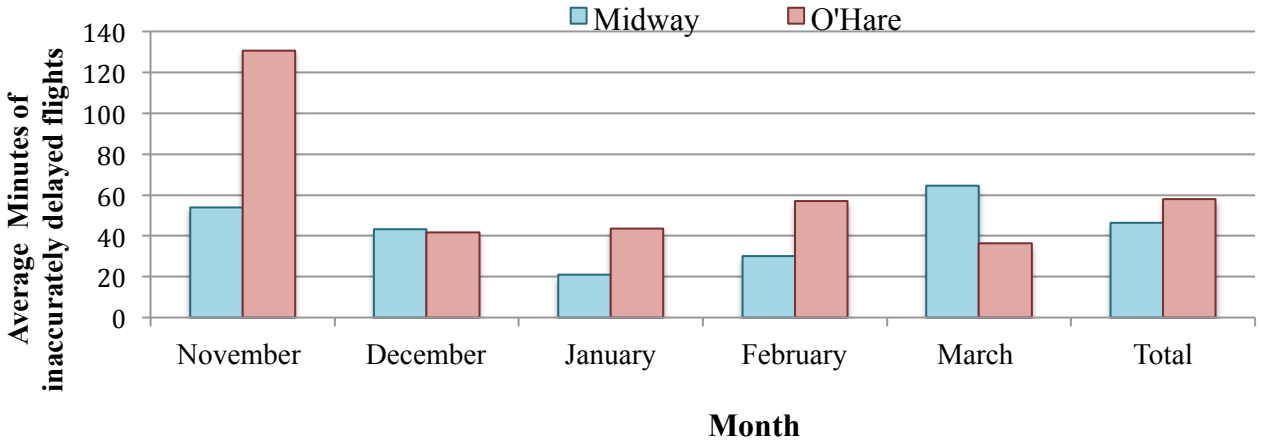

Fig. 2. The average number of minutes delayed for all inaccurately delayed flights per month for Midway and O'Hare Airports

The overall impact of the inaccurate flights due to low ceilings and visibilities compared to all the flights that were scheduled to depart from the two airports is very small (Fig. 3). A statistical test was done to see if the amount of flights inaccurately delayed was significant when compared to the total number of flights scheduled to depart each airport. It was found to be statistically significant for O'Hare ($p < .0001$) and insignificant for Midway ($p = .1310$). Interestingly, despite having a lower percentage of flights inaccurately delayed when compared to just weather delays, O'Hare had a higher percentage when compared to the total flights. Over the course of the 5 months of the study, O'Hare had .19% of all flights inaccurately delayed, while Midway saw .09% of total flights inaccurately delayed. When looking at the statistical significance of the number of inaccurately delayed flights compared to all the flights delayed by weather, it was found that only O'Hare

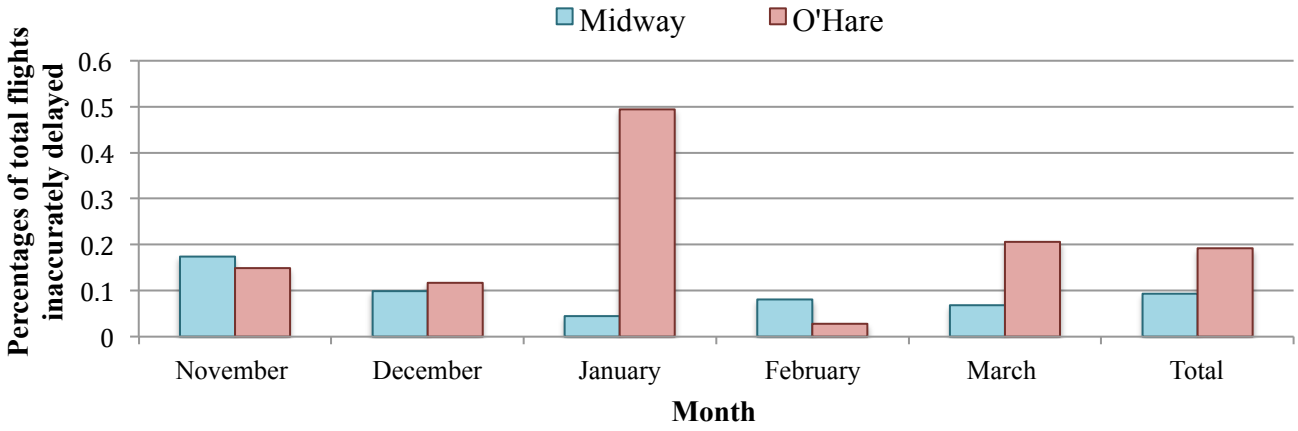

Fig. 3. The percentage on inaccurate flights due to low ceilings and visibilities compared to the total number of flights scheduled to depart each month and the total percentage of inaccurate delays caused by low ceilings and visibilities of all flights from both airports

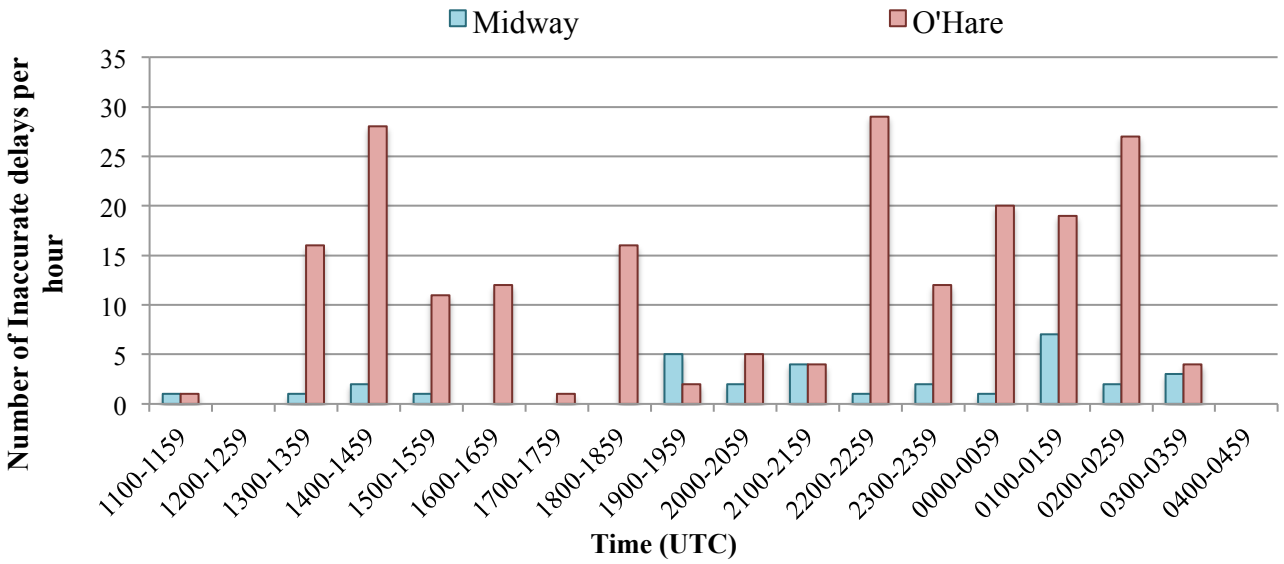

Fig. 4. The total number of flights inaccurately delayed by the hour at both O'Hare and Midway Airport

had a statistically significant number of inaccurate delays ($p < .0001$).

When looking to see if certain times had more inaccurate flight delays than others, there was not a clear pattern or a certain time of day with more delays than others (Fig. 4). This is due to the fact that most of the inaccurate delays were caused by inaccurately forecasting the end of precipitation events that cause low ceilings and visibilities. Since these events, like snow and rain, can happen at any time of day, the inaccurate delays associated can happen at any time. The hours that do have higher amounts are often associated with one of the snow or rain events observed during the period of time. This is contrary to was expected. Since Chicago sees a majority of its fog between November and March it was expected that there would be many more inaccurate delays in the morning when fog more commonly occurs. Expectations were that there would be more inaccuracies with the timing of the end of fog events. This however was found to be untrue as over half of the inaccurate delays were associated with precipitation or mis-forecasting of ceiling heights (Table 2). Fog or low visibilities only accounted for a total of 7 inaccurate delay. It was precipitation and low ceilings that were more likely to be inaccurately forecasted.

Table 2. The number of inaccurate flights based on forecast conditions of low ceilings and visibilities (C & V) caused by precipitation, fog or low visibilities, and low ceilings.

	Midway	O'Hare	Total
Low C & V caused by precipitation	11	109	120
Fog/low visibilities	7	0	7
Low ceilings	14	98	112

4. Discussions and conclusions

The number of flights delayed inaccurately due to low ceilings and visibilities was significant when looking at the total flights that were scheduled to depart from O'Hare. It found to be insignificant for Midway. This is due to the fact that Midway has a significantly less amount of air traffic. Over the time period of this experiment 142,166 flights were scheduled to take off and only 239 flights found to be inaccurately delayed. When looking at the number of inaccurate delays compared to the number of delays caused by weather, it was found that the number of delays was statistically significant for O'Hare International Airport but not Midway. This means that improved forecasts, especially the endings of precipitation events could have an impact on O'Hare International Airport. Since often times conditions improved as much as two hours before the TAF predicted, this had a larger impact at O'Hare since O'Hare sees a much larger volume of flights. Therefore, having better forecasts that can predict the ending of precipitation events that cause low ceilings and visibilities could help reduce the number of delays.

Between November and March flights were delayed 13,501 minutes due to inaccurate forecasting; that is 225 hours worth of delays. As previously mentioned, the FAA found that for every hour of delay it costs the airline $3,000 on average. For just the time period of this study, inaccurate delays cost airlines over $650,000. The month most impacted by inaccurate delay minutes was November for O'Hare; the airport averaged 130 minutes for each inaccurate flight. That impact falls not only on the carriers but also on passengers on those flights. It has the greatest effect on passengers with connections at other airports because an inaccurate flight delay could cause them to miss their connection, whereas an on-time flight would not. Unnecessary flight delays cause ripple effects since planes arriving late to the next airport will cause delays for passengers on future flights. This shows just how important it is to have flights departing on time when they can and minimizing delay minutes.

Previous work done on causation of weather-related flight delays found that between 28-35% of flights were delayed by low ceilings and visibilities. For the two Chicago International Airports it was found that low ceilings and visibilities caused 75% of weather-related delays. The discrepancies in these numbers are caused by the time frame differences of the studies. This study was conducted over a five-month period while others spanned over years. Another difference between this study and others are this one focused only on the winter months, whereas the other study included the entire year. Typically, during the winter months, especially in the Midwest, there is a lower chance of seeing convection, which was found to have caused a significant number of delays in previous studies.

Flight delays have a substantial impact on the operations of airports across the country. If one airport isn't able to run at capacity, it can create a domino effect

causing delays at future airports. Therefore, it is important to have the most accurate weather forecasts so unnecessary delays don't occur. Eliminating these could help airlines save thousands of dollars and also help passengers get to their destinations on time and spend less time in airports.

5. Future work

Since this study was conducted only for winter months, it would be beneficial to look at the accuracy of the delays over a larger span of time and to look at the entire year. This study should be expanded to look at the accuracy of all types of weather delays over multiple years. By expanding it to include all weather types it could find if forecasts can accurately predict convection and winds. If one of these events were found to be causing significant delays, further studies could be done to look into ways to improve these forecasts and eliminate unnecessary delays.

6. Acknowledgements

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