Enclosure 3

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MITRE

Center for Advanced Aviation System Development

Weather Analysis for Toluca Airport

Prepared for

Grupo Aeroportuario de la Ciudad de México

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Principal Acronyms and Abbreviations

AWOS	Automated Weather Observing System
CAT	Category
FAA	United States Federal Aviation Administration
GACM	Grupo Aeroportuario de la Ciudad de México
H-IMC	High-Instrument Meteorological Conditions
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
kt	knot
L-IMC	Low-Instrument Meteorological Conditions
MITRE	The MITRE Corporation
MMC	Marginal Meteorological Conditions
NAICM	Nuevo Aeropuerto Internacional de la Ciudad de México
SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
sm	Statute Mile
TMA	Terminal Maneuvering Area
U.S.	United States
VMC	Visual Meteorological Conditions

1. Introduction

The MITRE Corporation (MITRE) is assisting, through the Grupo Aeroportuario de la Ciudad de México (GACM), the aviation authorities of Mexico with the development of a new airport to serve Mexico City, referred to in this document as Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM), to replace the current Aeropuerto Internacional de la Ciudad de México. MITRE has been working closely with Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) in developing an airspace design for the new Mexico City Terminal Maneuvering Area (TMA) to support NAICM. Toluca Airport plays an important role in meeting the aviation demand of the Mexico City area. Therefore, it is important to consider operations at Toluca Airport when designing the new Mexico City TMA to ensure that capacity-limiting airspace interactions do not adversely impact operations at NAICM.

A key factor in conducting airspace analyses are meteorological conditions, which can affect traffic flow scenarios and operational matters. Therefore, it is essential to examine meteorological conditions at Toluca Airport to obtain a better understanding of prevailing wind and weather patterns. For example, it is important to examine wind data to determine the potential for flexibility in Toluca Airport runway usage and to identify traffic flows that could minimize airspace conflicts between Toluca Airport and NAICM, if necessary.

The objective of this document is to provide a comprehensive summary of weather and wind conditions at Toluca Airport. The analysis is based on data from an on-site Automated Weather Observing System (AWOS), covering a period from 1 January 2009 to 30 November 2016.

This document is structured as follows:

- Section 2 provides some general information on Toluca Airport weather data, as well as the weather category assumptions made in this analysis
- Sections 3 and 4 provide the results of MITRE's weather analysis
- Section 5 provides a summary of findings

2. Data and Weather Categories

The Toluca Airport on-site AWOS records weather data on an hourly basis (routine observations), or more frequently during bad weather conditions (special observations – SPECI). The AWOS records numerous weather variables of which, those most relevant to this study are ceiling, visibility, wind velocity, and wind direction.

SENEAM provided MITRE AWOS data on a monthly basis. Upon receipt of data, MITRE weather analysts assessed their completeness and, where appropriate, provided feedback to SENEAM on sensor malfunctions or other potential problems with the AWOS data, as necessary. All in all, MITRE has analyzed more than 71,600 routine and special weather observations over the course of 94 months. MITRE did not receive weather data for one month only: November, 2013. The weather data received by MITRE covered about 97 percent of the entire period from 1 January 2009 to 30 November 2016, i.e., on average, only 3 percent of data was lost. This is a good rate of data availability for the purposes of the work MITRE is performing, as mentioned above.

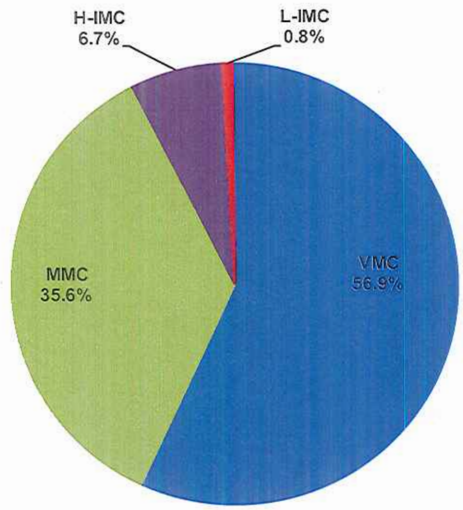


Figure 1. Toluca Airport: Overall Weather Conditions (0700-2300, 1 January 2009 through 30 November 2016)

Hourly fluctuations in weather conditions aggregated over the entire study period are provided in the graph in Figure 2. The graph shows that the weather conditions (i.e., lower visibility and/or ceiling conditions) fluctuate during the day, generally getting worse in the early morning and late afternoon hours. For example, MMC conditions are most frequent during afternoon hours, from 1300 to 1600, occurring on average 45 percent of that period, while H-IMC conditions were most frequent from 0600 to 0930 in the morning, occurring on average about 22 percent of that period. L-IMC conditions were most common from 0600 to 0830 in the morning, occurring on average more than 5.5 percent of that period. Overall, the site experiences MMC conditions or worse at all time periods (considering 24-hour days), more than 42 percent of the time.

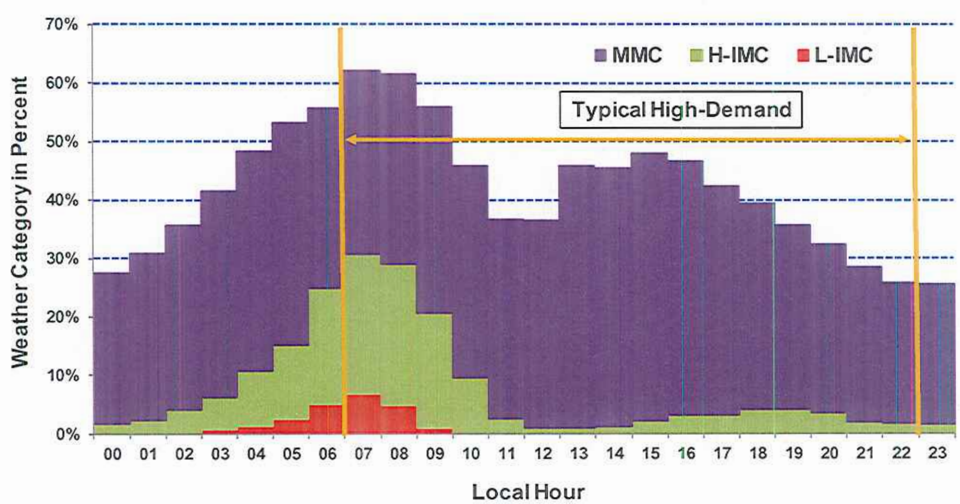


Figure 2. Toluca Airport: Weather Conditions, by Time of Day (1 January 2009 through 30 November 2016)

It is also important to understand the seasonality of weather conditions to determine if there are any months during which the weather gets particularly worse. Therefore, MITRE analyzed the weather conditions by each month for the entire period, for both typical high-demand operational hours and 24-hour-day periods. The results of the analysis are shown in Figure 3. The results during the typical high-demand operational hours (from 0700 to 2300) are shown on the upper graph, and for the 24-hour day on the lower graph.

The graphs show that although H-IMC and L-IMC weather conditions occur throughout the year, they are more frequent from August to December. The most frequent L-IMC weather was observed in November 2011, 5.3 percent of the time, while the most frequent H-IMC weather was observed in September 2013, 17.8 percent of the time. September 2013 also happens to be the month with the most H-IMC and L-IMC weather conditions (combined), 19.4 percent of the time.

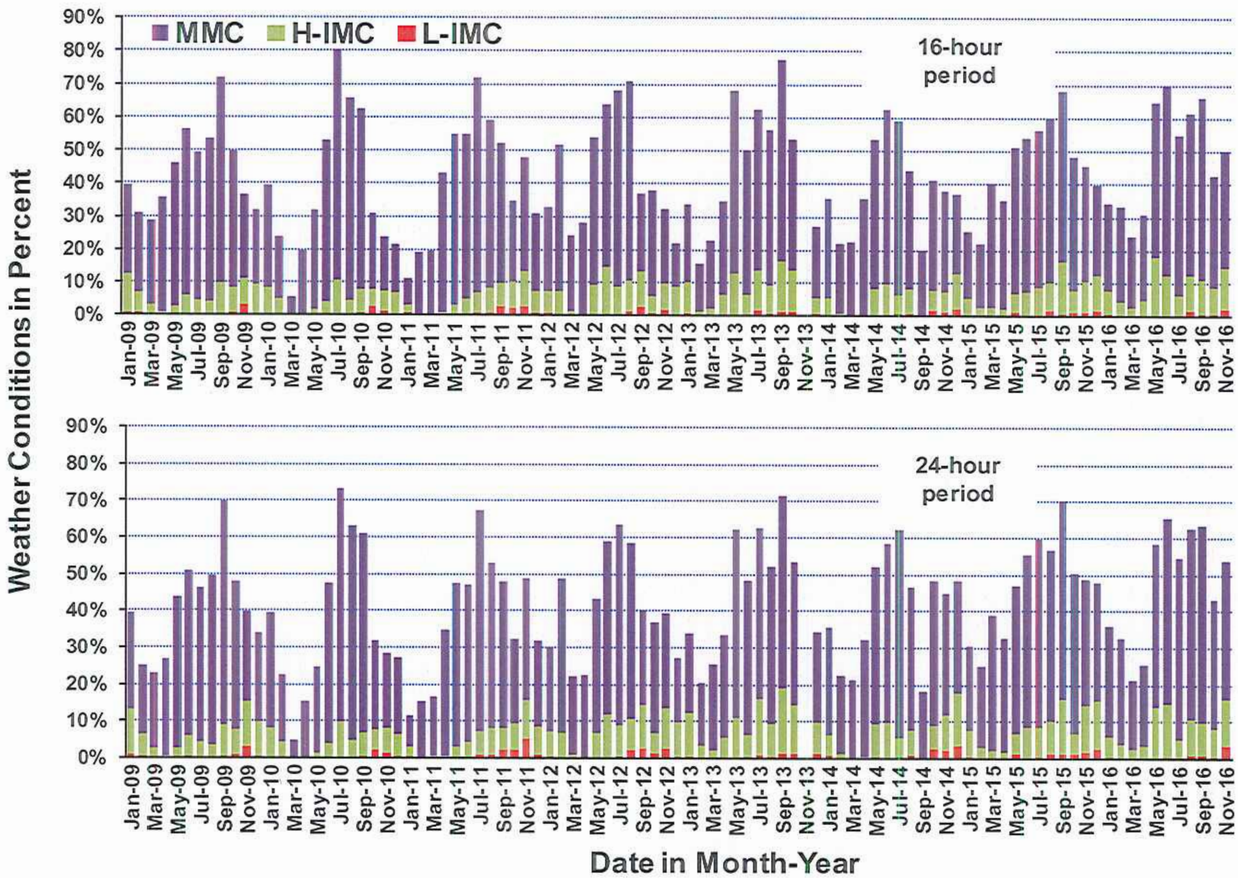


Figure 3. Toluca Airport: Overall Weather Conditions, by Month (0700-2300 and 24-hour, 1 January 2009 through 30 November 2016

As shown above, even though, on average and for the entire period L-IMC weather conditions are rare (occurring 0.8 percent of the time), there are months when such conditions occur more frequently (i.e., from August to December). Therefore, MITRE conducted a detailed analysis of weather patterns during L-IMC conditions (i.e., the conditions when CAT II and CAT III approaches at Toluca Airport would tend to be required).

3.2. L-IMC (CAT II/CAT III) Conditions

MITRE analyzed the L-IMC weather conditions at Toluca Airport in more detail, to show how frequently an ILS CAT II/CAT III procedure may be truly needed.

During the period 1 January 2009 to 30 November 2016, L-IMC conditions occurred on 298 days for a total of 634 hours, over a 24-hour period. This weather:

- Is equivalent to approximately 81 hours of CAT II/CAT III weather per year on average
- Occurs on average over the course of 38 days per year

As discussed above, L-IMC was observed predominantly in the early morning and stretches to the late morning hours. Figure 4 summarizes MITRE's findings on the aggregate L-IMC data by time of the day.

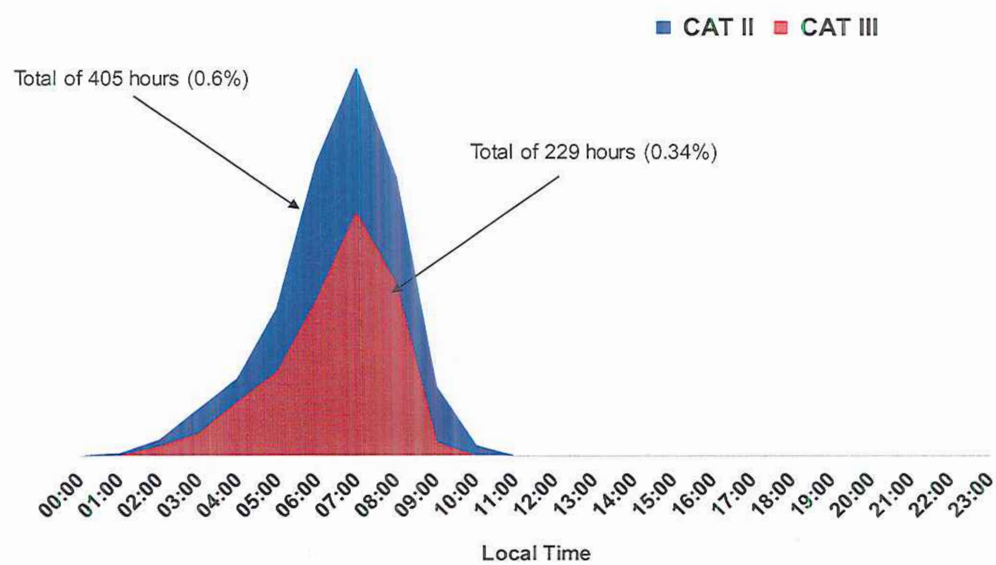


Figure 4. Toluca Airport: L-IMC Occurrence by Hour (1 January 2009 through 30 November 2016)

When L-IMC conditions occur at Toluca Airport, they may continue for several hours. For example, in 214 out of 298 days (about 72 percent), L-IMC conditions were observed for more than 1 hour, and in 67 out of those 214 days, L-IMC lasted at least 3 hours. This shows a significant occurrence of L-IMC weather, especially during busy morning hours.

Figure 5 shows the frequency (by days) and duration (by hour) of L-IMC weather within the period of the analysis. As can be seen, continuous poor weather conditions, (i.e. exceeding 1 hour) are very common at Toluca Airport.

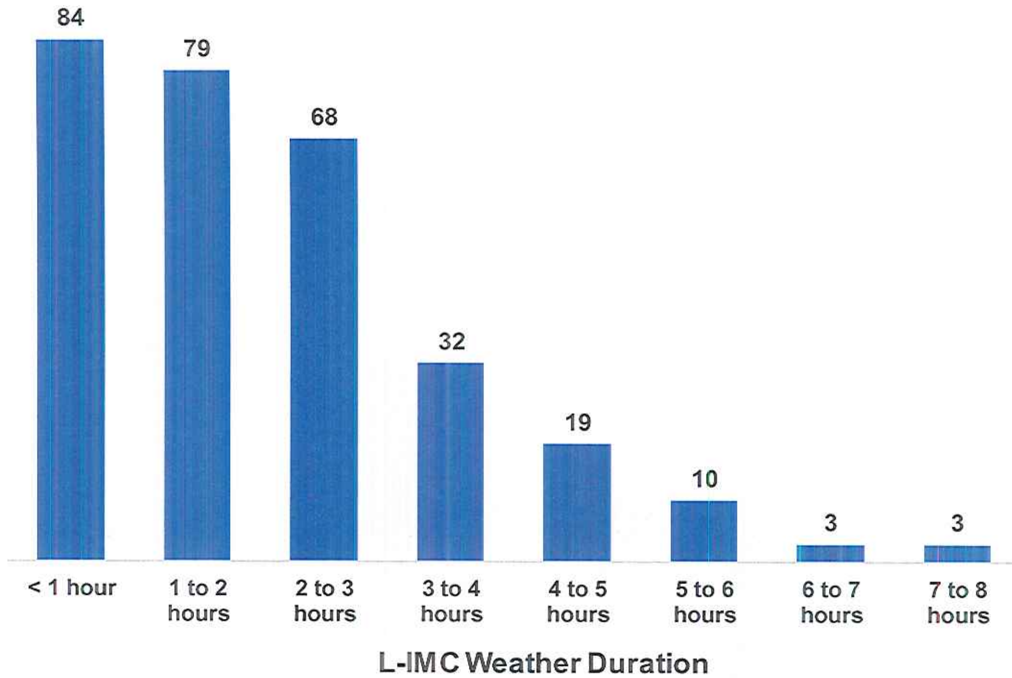


Figure 5. Toluca Airport: Number of Days (total of 298) and Duration of L-IMC Weather (1 January 2009 through 30 November 2016)

There were three days during this period when the airport experienced CAT II/CAT III weather for almost 8 hours. For example, on 14 January 2011, L-IMC weather (CAT III) was observed starting 0300 until 0830, or 5 and a half hours. Then the weather improved slightly to CAT II and lasted until 1045, or 2 hours and 25 minutes, lasting in total 7 hours and 45 minutes.

Another noteworthy example is November 2011, the month with the most L-IMC weather. During this month, L-IMC conditions occurred on 12 days and totaled more than 37 hours. Some notable examples include:

- 24 November 2011 – more than 7 hours, from 0230 to 0942
- 14 November 2011 – almost 4 hours, from 0545 to 0930
- 4 November 2011 – 3 hours, from 0530 to 0830

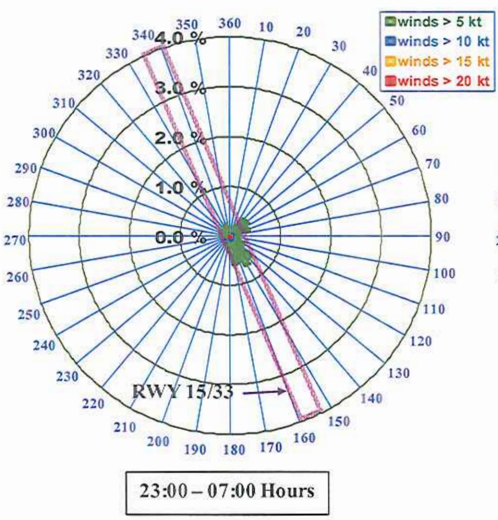
4. Toluca Airport Wind Conditions

Wind direction and wind velocity are important determinants of runway usage, which dictates traffic flow scenarios. To determine how winds impact runway usage at Toluca Airport, MITRE analyzed overall wind patterns and also determined runway availability by crosswind and tailwind component limitations. For example, aircraft can safely takeoff and land with crosswinds until they exceed a specific crosswind limitation component. Those limits depend on several factors, such as the type of aircraft, weather conditions, and airline operational procedures. In a one-runway airport, such as Toluca Airport, excessive crosswind components may result aircraft electing not to land.

Tailwinds are also an important consideration since they influence runway direction usage (e.g., north flow vs. south flow). For example, aircraft typically can land with as much as a 5-knot (kt) tailwind component. However, when that tailwind component is higher the landing direction would likely be switched to the opposite direction.

Wind velocity and direction tend to fluctuate during the day, so it is important to analyze wind patterns as a function of the time of the day, especially during likely high-demand operational hours.

The meteorological "wind-rose" shown in Figure 6 shows the percentage of time that winds are observed from various directions at two different times of the day. The graph on the left shows wind patterns during low-demand operational hours between 2300 and 0700 and on the right, for the high-demand operational hours between 0700 and 2300. The color-coded bars represent the direction and velocity of the winds. For example, winds exceeding 5 kt from direction 40 degrees were observed 2 percent of the time during typical high-demand operational hours from 0700 to 2300 hours (see the graph on the right). The purple bar across the graph represents the runway orientation at Toluca Airport (i.e., 157°/337° based on True North), and is provided for reference only.



Note: Runway 15/33 is provided for reference only

Figure 6. Toluca Airport: Prevailing Winds (1 January 2009 through 30 November 2016)

As shown in Figure 6, winds at Toluca Airport are very mild during low-demand nighttime hours—rarely exceeding 5 kt. Winds are stronger during typical high-demand operational hours, but still mild, coming predominantly from the south-southeast and the northeast. In rare cases when strong winds (> 15 kt) do occur, they come from the south-southeast.

Figure 7 illustrates the overall wind distribution by velocity. The maximum wind velocity recorded was 41 kt, but 97.5 percent of the time the wind velocity was below 16 kt.

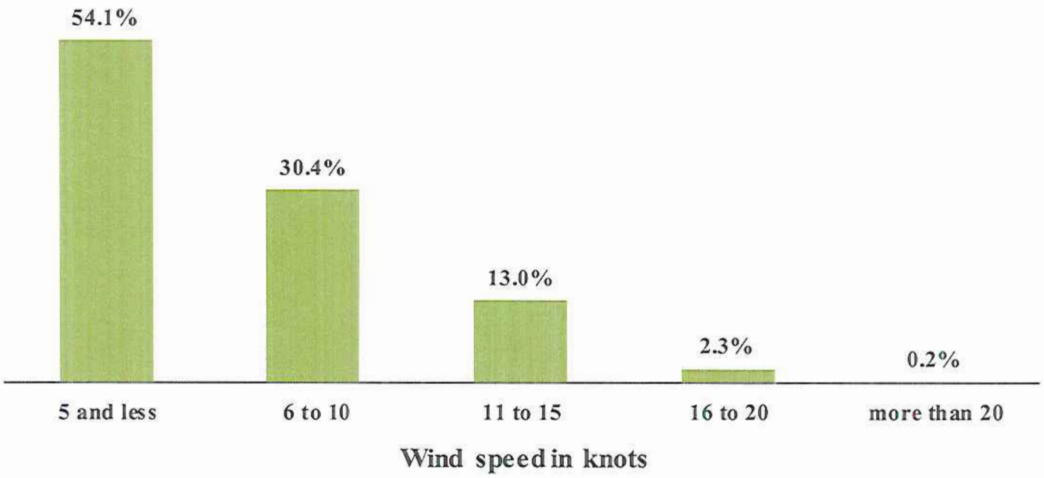


Figure 7. Toluca Airport: Overall Wind Velocity (0700 – 2300, 1 January 2009 through 30 November 2016)

The International Civil Aviation Organization (ICAO) states that for planning purposes, it should be assumed that landing or takeoff of aircraft would be precluded when the crosswind component exceeds 20 kt in the case of large and heavy jet aircraft. ICAO indicates that a 13-kt crosswind component limitation should be used in the case of large general aviation aircraft and turboprop aircraft, and 10 kt in the case of small general aviation aircraft. Air carrier aircraft can typically operate with higher crosswind component limitations than those mentioned above. For example, some air carrier aircraft types will operate with a crosswind component limitation of 25 kt or higher during most weather conditions.

Figure 8 shows the crosswind component distribution for All Weather conditions by the limitation criteria described above, for typical high-demand operational hours. The crosswind component exceeded 20 kt less than 0.05 percent of the time. The implication is that airport availability is unlikely to be limited due to high crosswind components, especially for large aircraft.

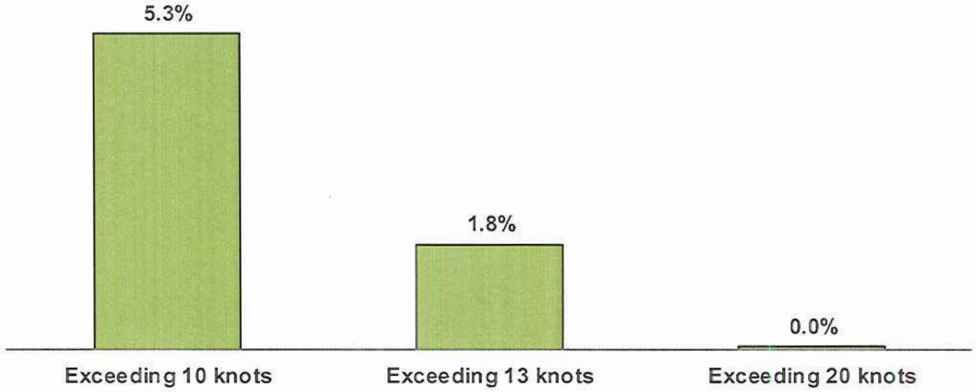


Figure 8. Toluca Airport: Crosswind Components (0700 – 2300, 1 January 2009 through 30 November 2016)

MITRE analyzed wind conditions during L-IMC weather. The meteorological "wind-rose" in Figure 9 shows the percentage of time that winds are observed from various directions. As expected, winds during L-IMC weather rarely exceeded 5 kt, and are not determined to be a limiting operational factor for conducting CAT II/CAT III approaches.

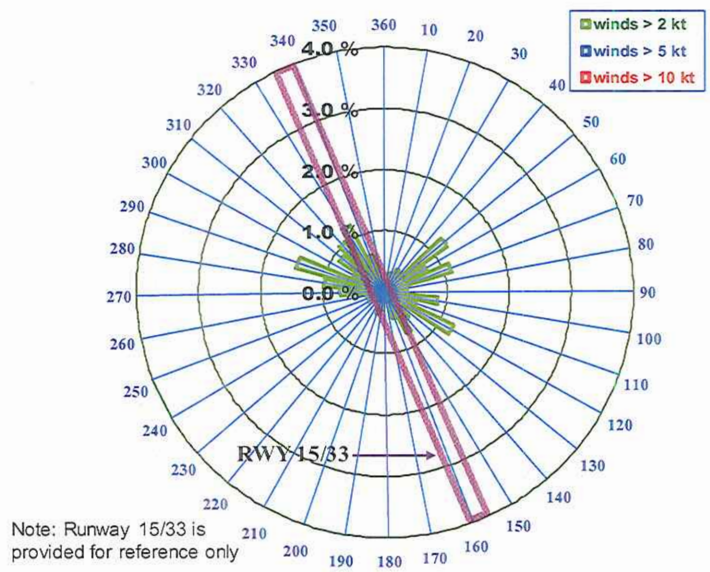


Figure 9. Toluca Airport: Prevailing Winds During L-IMC Weather (1 January 2009 through 30 November 2016)

MITRE also examined the crosswind component limitation during periods of H-IMC and L-IMC. The following wind patterns were observed:

- There were no winds 80.3 percent of the time
- During the remaining 19.7 percent of the time, crosswinds did not exceed 6 kt

Based on these numbers, MITRE concludes that when CAT I, CAT II and CAT III procedures are being conducted at Toluca Airport, crosswind limitations should not be an issue.

Figure 10 provides the tailwind component distribution by runway end during typical high-demand operational hours. For this analysis, MITRE assumed that aircraft could land with a maximum of a 5-kt tailwind component. The figure shows that northwest flow operations would be required approximately 8 percent of the time (since Runway 15 was estimated not to be available due to excessive tailwinds), compared to approximately 21 percent of the time required for southeast flow operations (since Runway 33 was estimated not to be available due to excessive tailwinds). Either direction could have been used approximately 71 percent of the time (tailwinds for either direction did not exceed 5 kt). Therefore, MITRE concludes in terms of the tailwind component distribution analysis that wind conditions are more favorable for Runway 15 operations than for Runway 33. Also, the high percentage of relatively calm wind conditions may allow for some flexibility in runway usage. For example, during periods of calm wind conditions, it may be possible to use either runway direction.

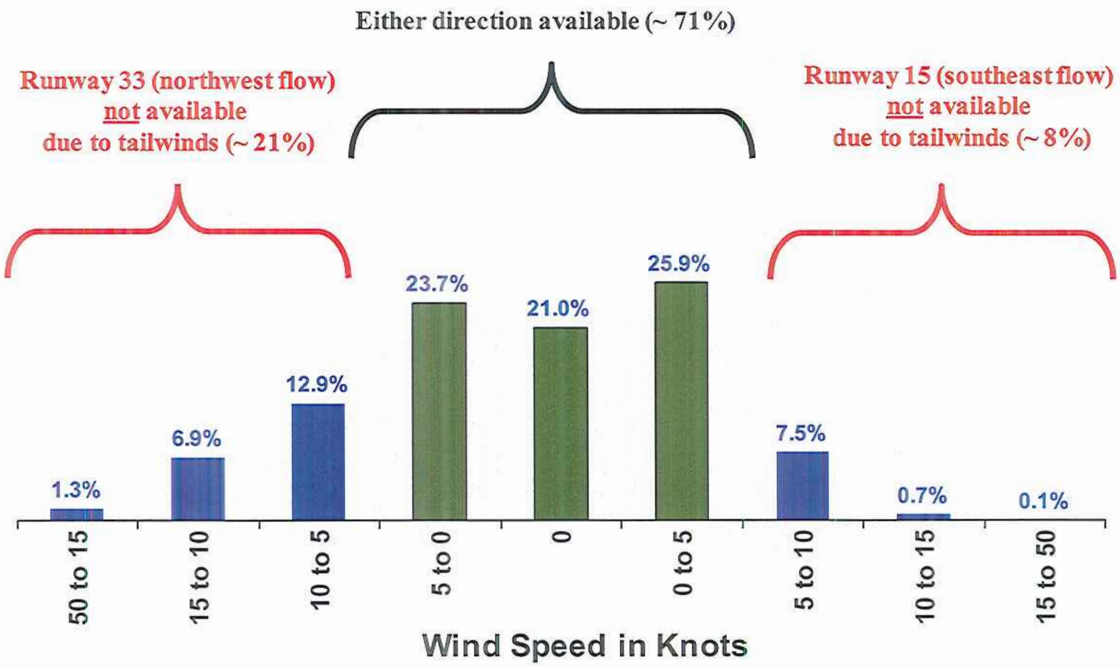


Figure 10. Toluca Airport: Runway 15 and Runway 33 Availability due to Tailwinds (0700 – 2300, 1 January 2009 through 30 November 2016)

5. Summary of Findings

MITRE analyzed Toluca Airport AWOS data from 1 January 2009 to 30 November 2016. The data provided to MITRE was complete, missing only one month (i.e., November 2013).

The analysis of the data shows that winds at Toluca Airport are typically calm, rarely exceeding 15 kt. Winds are observed mostly from the south-southeast and the northeast. Winds at night and during bad weather (ceiling and visibility) conditions are extremely rare. The analysis of wind data also shows that there may be some flexibility in runway usage, which could aid in traffic flow scenarios to assist in airspace design, if necessary.

Weather conditions during typical high-demand operational hours are good most of the time, with VMC and MMC conditions occurring almost 93 percent of the time. Although poor weather conditions requiring CAT II/CAT III procedures (i.e., L-IMC) are observed on average less than 1 percent of the time, they occur mostly during important early morning operational hours and often last more than 1 hour. For example, L-IMC conditions are most common from 0600 to 0830 in the morning, occurring on average about 5.5 percent of that morning period. Additionally, L-IMC weather occurs more frequently during the months of August to December, peaking in November. This may result in significant weather-related operational disruptions at Toluca Airport.