Enclosure 1

(Referenced in Technical Letter F500-L15-007)

MITRE

Center for Advanced
Aviation System Development

Weather Analysis for the Nuevo Aeropuerto Internacional de la Ciudad de México Site

Prepared for

Aeropuertos y Servicios Auxiliares

January 2015

Principal Acronyms and Abbreviations

AICM	Aeropuerto de la Ciudad de México
ASA	Aeropuertos y Servicios Auxiliares
AWOS	Automated Weather Observing System
CAT	Category
DGAC	Dirección General de Aeronáutica Civil
FAA	U.S. Federal Aviation Administration
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
RVR	Runway Visual Range
SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
sm	Statute Mile
U.S.	United States
VMC	Visual Meteorological Conditions

1. Introduction

Meteorological conditions are an important consideration when determining the suitability of a site for an airport. Frequent periods of low ceilings or poor visibility can cause an airport to close an undesirable percentage of the time. Likewise, a careful and accurate analysis of prevalent winds at the site is crucial in assessing the appropriateness of potential runway orientations. Therefore, it is critical to conduct a detailed analysis of accurate and reliable weather data to ensure that meteorological conditions are suitable. That is what is being done for the Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM) site at Texcoco through the use of on-site weather data obtained from an Automated Weather Observing System (AWOS).

Weather data collection from the Texcoco AWOS started in January 2009, during MITRE's previous project with the Dirección General de Aeronáutica Civil (DGAC). Since then weather data have been periodically analyzed and feedback provided to the Mexican aviation authorities on weather conditions at the NAICM site. The objective of this document is to provide a comprehensive summary of weather conditions at the NAICM site based on more than 5 years of data collected by the Texcoco AWOS.

The rest of this document provides some general background information, describes the weather data and weather category classifications, as well as the weather criteria applied in the study. The results of the analysis are then presented, followed by a summary of findings and recommendations.

2. Background

The International Civil Aviation Organization (ICAO) recommends obtaining five years of wind data to determine the orientation of runways at an airport. Additionally, ICAO recommends the wind data be associated with other weather variables such as visibility and ceiling. The United States (U.S.) Federal Aviation Administration (FAA) prefers 10 years of wind data. In cases where a sufficient amount of data is not available, some agencies allow a substitute weather evaluation. For example, U.S. FAA guidelines indicate that a minimum of one year of on-site wind observations may be used if augmented by weather observations from other sources (e.g., wind-bent trees, interviews with the local population, etc.) to ascertain if a discernible wind pattern can be established. Although such substitutions may sometimes be useful or practical, they may increase the uncertainty of the results of an analysis.

In late December 2008, Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) acquired and installed a new AWOS at the NAICM site. Figure 1 shows the location of the Texcoco AWOS. MITRE provided support, as needed, for the installation.

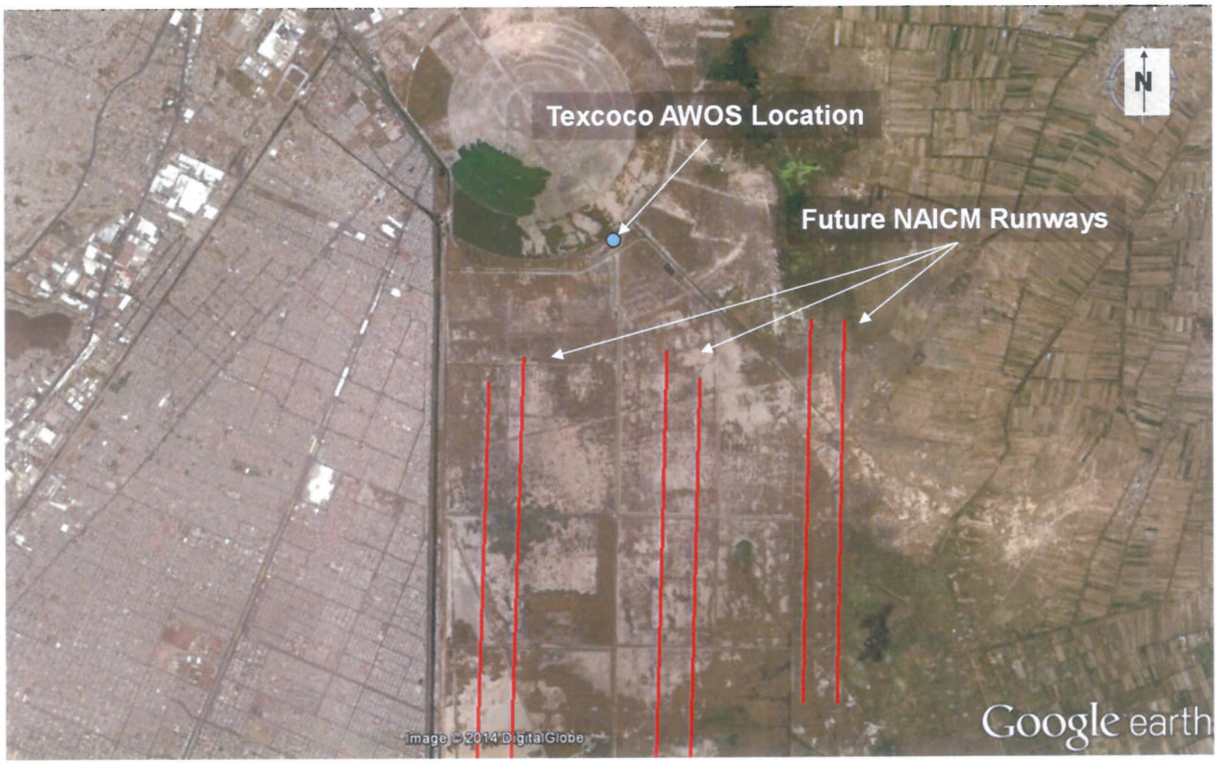

Image Source: Google Earth

Figure 1. Location of the Texcoco AWOS at the NAICM Site

3. Texcoco AWOS Data

The Texcoco AWOS records a large number of weather variables every half-hour. Of these, the ones of most relevance to the MITRE project are ceiling, visibility, wind speed and direction, present weather conditions, and temperature. These data are downloaded from the AWOS by officials from SENEAM every month. Upon receipt of data, MITRE weather analysts assess its completeness and, where appropriate, provide feedback to SENEAM on sensor malfunctions or other potential problems with the AWOS data.

Figure 2 shows the Texcoco AWOS data completeness chart for three types of data: wind (direction and velocity), ceiling, and visibility. The chart shows the percentage of time in each month the AWOS collected and stored data, with 100 percent indicating no loss of data.

Over the past years there were some periods of complete or partial data loss. For example, MITRE observed progressive worsening of the ceilometer data from January to April 2009. MITRE reported the malfunction to SENEAM, who corrected the problem. (Notice the sharp improvement of ceiling data, shown in green on the chart, in May 2009 after SENEAM corrected the problem.) Therefore, MITRE decided to only incorporate ceiling data into its subsequent analysis starting 1 May 2009.

Another AWOS malfunction was observed starting in the first half of September 2010, which resulted in a loss of data for the rest of the month and a few days in the following month. Some additional, but insignificant data loss was observed in the month of December 2013 and from

January to April 2014, as well as some other months. In October 2014, MITRE was informed of an AWOS power supply failure, which resulted in a complete data loss. The power supply to the Texcoco AWOS was eventually restored and the weather sensors were calibrated in late November.

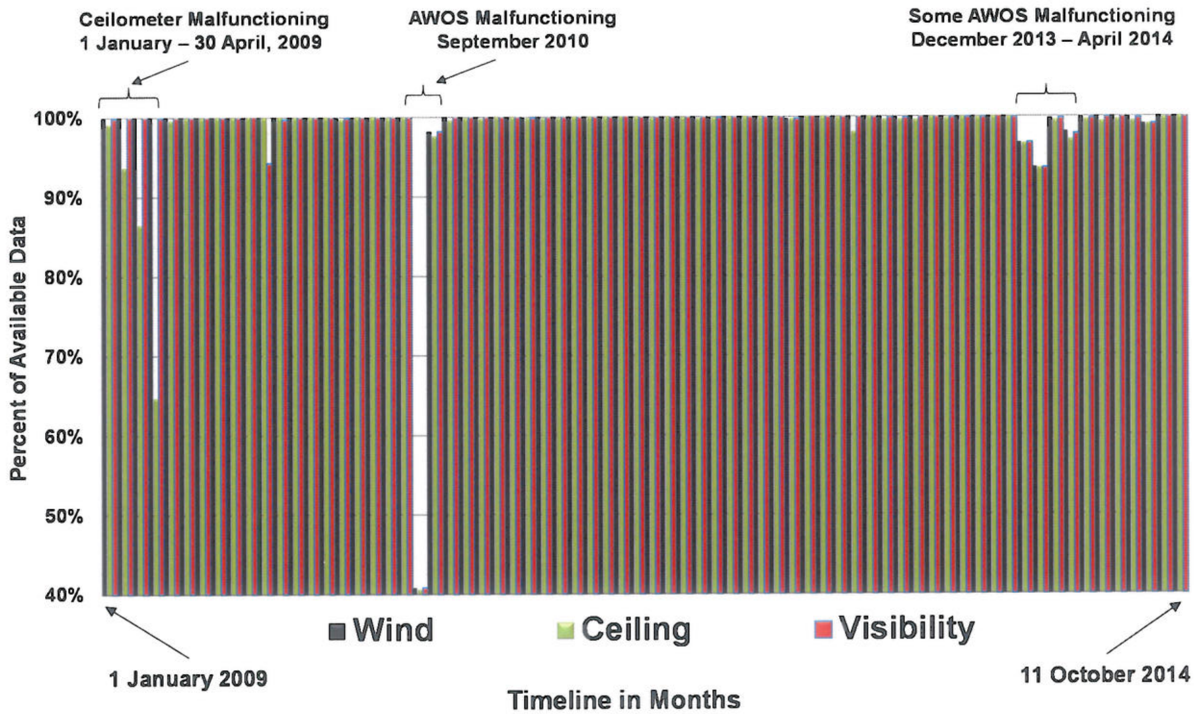

Figure 2. Texcoco AWOS Data Completeness Chart (1 January 2009 to 11 October 2014)

Considering the above-mentioned AWOS malfunctions, and to ensure that the most accurate, reliable, and complete weather information is being analyzed, MITRE decided to utilize the following data for this analysis:

- Ceiling and visibility – 1 May 2009 through 11 October 2014
- Wind (direction and speed) – 1 January 2009 through 11 October 2014

Despite the data loss and other minor malfunctions, MITRE believes there are sufficient and reliable data available for conducting a comprehensive study on the appropriateness of the potential runway orientation at NAICM, as well as weather conditions.

4. Weather Category Assumptions

Four weather "categories" are defined in this report based on ceiling and visibility conditions. A weather category is determined by the lower of the two weather measurements (i.e., ceiling or visibility). Table 1 below details the weather categories, as well as the corresponding types of procedures typically required to land during those weather conditions.

Table 1. Weather Categories Used in this Analysis

Weather "Category"	Ceiling Height Above Airport (HAA) in feet (ft)	Visibility in Statute Miles (sm)	Notes
Visual Meteorological Conditions (VMC)	≥ 5000 ft	≥ 5 sm	Conditions during which visual approach procedures would likely be conducted[1]
Marginal Meteorological Conditions (MMC)	< 5000 ft and ≥ 1000 ft	< 5 sm and ≥ 3 sm	Conditions during which instrument procedures may be conducted during the first portion of the approach and visual approach procedures during the final portion
High-Instrument Meteorological Conditions (H-IMC)	< 1000 ft and ≥ 200 ft	< 3 sm and ≥ ½ sm	Conditions that may require the use of a Category (CAT) I Instrument Landing System (ILS) approach procedure
Low-Instrument Meteorological Conditions (L-IMC)	< 200 ft	< ½ sm	Conditions that may require the use of a CAT II or CAT III ILS approach procedure. Specialized aircraft and ground equipment, as well as pilot training are required.

Note: Some of the weather conditions mentioned above were defined by MITRE for planning purposes only. A weather condition in this table is determined by the lower of the two weather measurements (i.e., ceiling or visibility).

Within the L-IMC weather category, MITRE also analyzed the frequency of weather conditions requiring CAT II and/or CAT III approach procedures. For CAT II and CAT III weather, ICAO requires that visibility data are collected by Runway Visual Range (RVR) sensors. Since the Texcoco AWOS does not have RVR sensors, the visibility data from the AWOS visibility sensor was used as a surrogate. Although in the absence of RVR data the visibility sensor information may be a close approximation, the results presented in this document on CAT II or CAT III weather should not be considered as final.

5. Texcoco AWOS Data Analysis

This section describes the results of the weather analysis of the NAICM site. Ceiling and visibility data were analyzed together in order to characterize weather conditions based on the weather criteria shown in Table 1 above. In its analysis, MITRE considered the overall weather

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[1] Note that actual ceiling and visibility requirements to conduct visual approaches at Texcoco will be established by SENEAM based on operational requirements and may be different.

characteristics, the variability of the weather patterns by time of the day, as well as weather seasonality by months. As a result, the analysis emphasizes the periods where wind and weather conditions are more likely to affect operations at NAICM.

Moreover, where appropriate, MITRE differentiated between typical high-demand operational hours and the hours when the airport is likely to experience lower demand. Based on operations data from the current Mexico City International Airport from 12-18 August 2007 (a relatively high-demand week), MITRE determined that the majority of operations occur between 0700 and 2300, approximately 16 hours.[2] (All times in this report are local unless otherwise specified.) MITRE's analyses, unless otherwise noted, focus on this time period.

Overall weather conditions are described in the next section, followed by more detailed discussions on poor weather occurrences (i.e., L-IMC) at the NAICM site.

5.1 NAICM Weather Conditions

The overall weather conditions that occurred at the NAICM site from 1 May 2009 to 11 October 2014 during the typical high-demand operational hours are shown in Figure 3. The data suggest that the weather was either VMC or MMC almost 99 percent of the time, of which MMC occurred only about 9 percent of the time. The analysis shows that low ceiling or visibility conditions that would require CAT I ILS approaches (i.e., H-IMC) occurred only 1 percent of the time, while weather conditions that would require CAT II or CAT III approaches (i.e., L-IMC) were observed only about 0.2 percent of the time.

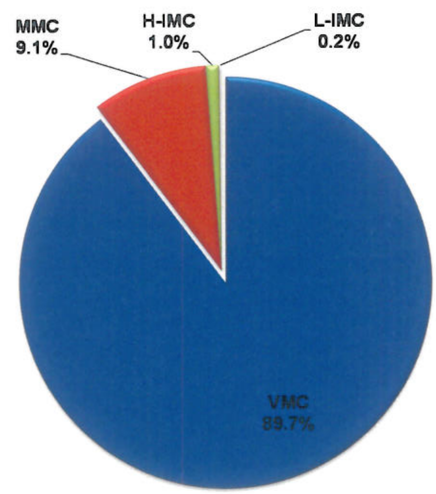

Figure 3. Texcoco AWOS Data: Weather Conditions (0700-2300, 1 May 2009 through 11 October 2014)

[2] The Texcoco AWOS archives weather data every 30 minutes, starting 5 minutes after the hour (e.g., 0005, 0035, 0105, etc.). In this report, MITRE uses the start of the hour (e.g., 0700, 0730, etc.) instead of the reported time for simplicity. Note that a data entry is a summary of the weather from the previous half-hour. Thus, for example, weather data associated with a time stamp of 0805 is referred to as the weather during the time interval of 0730-0800.

The fluctuations in weather conditions throughout the day in half-hour time periods are shown in Figure 4. The weather was worse (i.e., lower visibility and/or ceiling conditions) during the morning hours. For example, from 0700 to 1000, MMC conditions were observed on average about 17 percent of the time, compared to only about 5 percent from 1400 to 1800. H-IMC conditions averaged about 3 percent of the time from 0700 to 1000. H-IMC conditions were rare (less than 1 percent) during the afternoon and evening hours. L-IMC conditions also occurred rarely (less than 1 percent), mostly during the early morning hours.

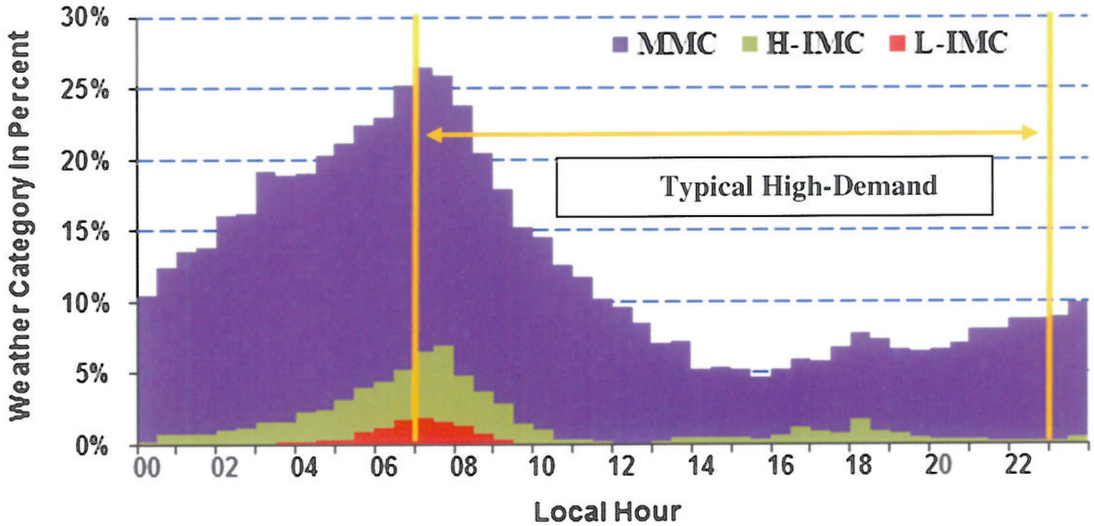

Figure 4. Texcoco AWOS Data: Overall Weather Conditions by Time of Day (1 May 2009 through 11 October 2014)

Figure 5 shows the weather conditions by month during the typical high-demand operational hours (from 0700 to 2300) on the top and over a 24-hour day period on the bottom. For all months, the weather conditions were L-IMC or H-IMC only a small percentage of the time. The figure also shows that there is some seasonality in weather patterns: low visibility and ceiling conditions occurred relatively more often (but still at a low percentage) in the fall and early winter.

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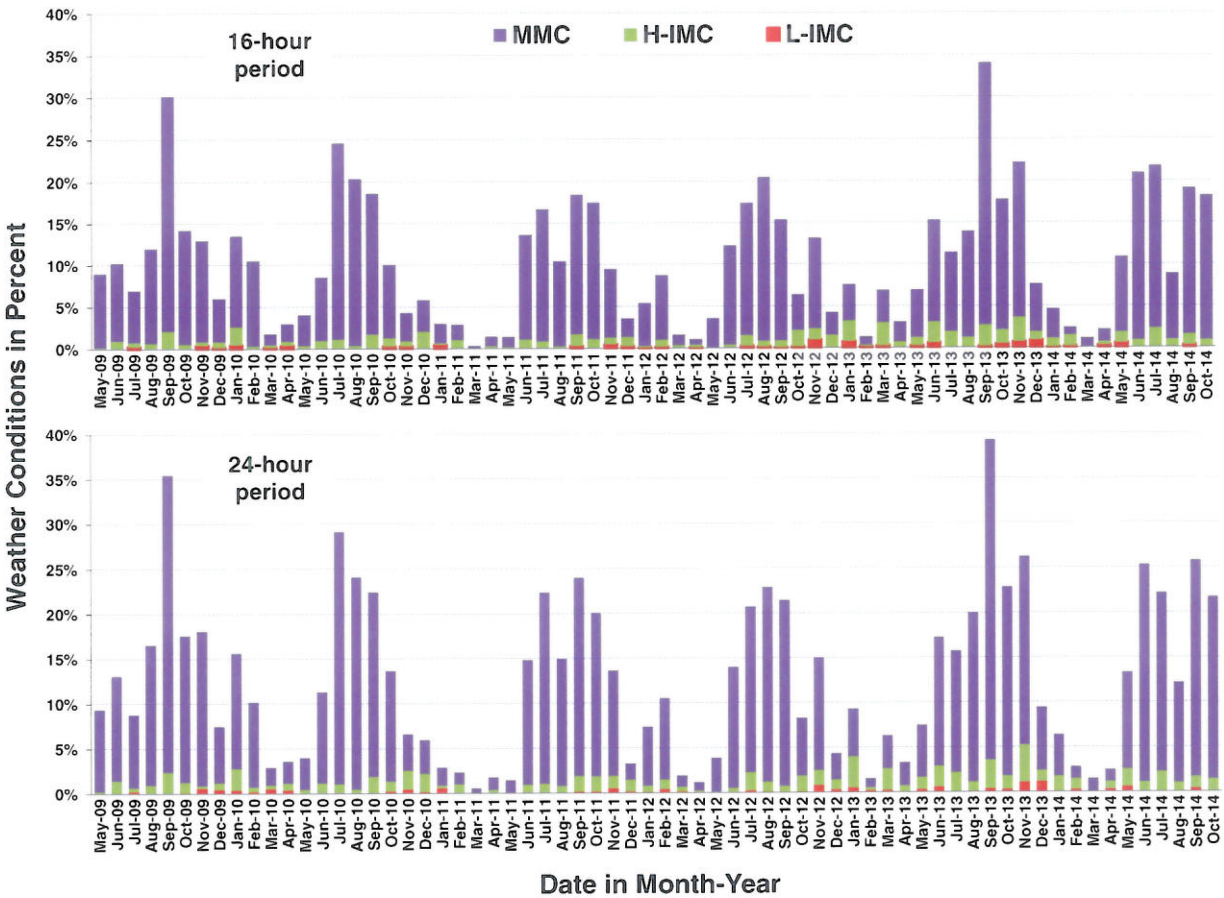

Figure 5. Texcoco AWOS Data: Overall Weather Conditions by Month (0700-2300 and 0000-2359, 1 May 2009 through 11 October 2014)[3]

Although L-IMC weather conditions are rare at NAICM, a more detailed analysis is necessary to determine the potential need for CAT II and CAT III approaches at NAICM.

5.1.1 L-IMC (CAT II/CAT III) Conditions

MITRE analyzed the L-IMC weather conditions at the NAICM site in more detail, to show how frequent an ILS CAT III procedure may be truly needed. During the period 1 May 2009 to 11 October 2014, L-IMC conditions occurred on 81 days for a total of 111 hours, over a 24-hour period. This weather:

- Is equivalent to approximately 20 hours of CAT II/CAT III weather per year on average
- **Occurs on average over the course of 15 days per year**

[3] Due to the malfunctioning of the ceilometer in the months of January through April 2009, those months are not shown in the chart.

- It is a short-duration event: in 29 out of the 81 days, L-IMC conditions lasted only 0.5 hours

Figure 6 shows all the days (total of 52) within the period from 1 May 2009 to 11 October 2014 during which L-IMC condition occurred for more than 0.5 hours. Often times, but not always, when poor weather conditions occur for more than 0.5 hours, they are continuous. As can be seen, the poor weather conditions rarely exceeded 2.5 hours during the day.

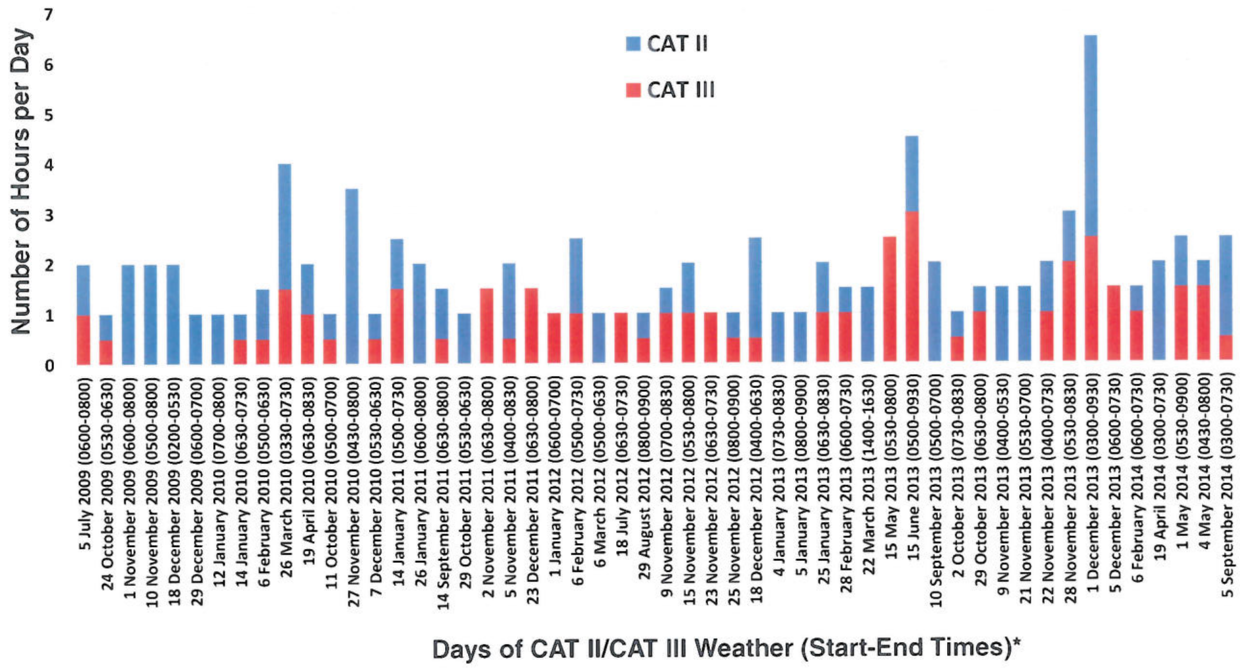

Figure 6. Texcoco AWOS Data: Days that L-IMC Occurred for More than 0.5 hours (0000-2359, 1 May 2009 through 11 October 2014)

**Note that the difference between the start and end times shown in parenthesis on the figure sometimes exceeds the number of hours reported. This occurs when CAT II/ CAT III weather conditions get interrupted for some time by improving weather during that period. For example, on 10 November 2009, L-IMC conditions were first observed at 0500, which lasted for 1.5 hours. Starting at 0630, the weather conditions improved (to H-IMC) until 0730, at which point the weather conditions deteriorated again to L-IMC until 0800, before improving for the rest of the day. Therefore, there were only two hours of L-IMC weather observed during the 3-hour time period (0500-0800).*

In December 2013, the month with most frequent poor weather over a 24-hour-day period, a total of 8.5 hours of L-IMC weather was observed during three days. The hours were distributed as follows:

- 1 December 2013 - 6.5 hours, from 0300 to 0930
- 5 December 2013 - 1.5 hours, from 0600 to 0730
- 11 December 2013 - 0.5 hours, from 0800 to 0830 (not shown on Figure 6)

Another noteworthy example is November 2012, the month with the most L-IMC weather during high-demand operational hours (i.e. 16-hour-day period). During this month, L-IMC conditions occurred in four days only:

- 9 November 2012 - 1.5 hours, from 0700 to 0830
- 15 November 2012 - 2.5 hours, from 0530 to 0800, of which only 1 hour occurred during the high demand period
- 23 November 2012 - 1 hour, from 0630 to 0730, of which only 0.5 hour occurred during the high demand period
- 25 November 2012 -1 hour, from 0800 to 0900

As discussed above, L-IMC was observed predominantly in the early morning hours. Figure 7 summarizes findings on the aggregate L-IMC data (111 hours) by time of the day.

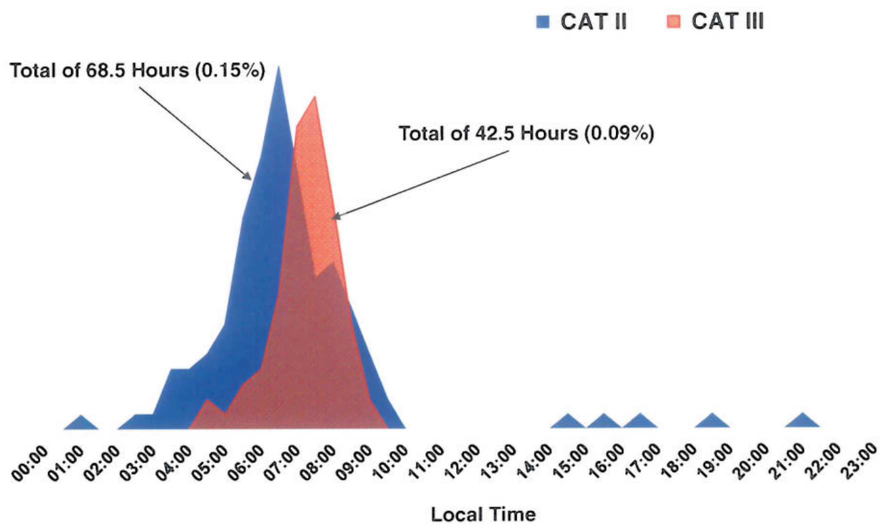

Figure 7. Texcoco AWOS Data: L-IMC Occurrence by Hour (1 May 2009 through 11 October 2014)

5.2 NAICM Wind Conditions

MITRE also analyzed wind conditions (i.e., wind direction and speed) at the NAICM site based on the Texcoco AWOS data from 1 January 2009 through 11 October 2014. Note that the wind gust data were also included in MITRE's wind analysis.

Wind direction and wind speed influence the orientation of a runway and its usage. 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.

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 speed 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 airport operational hours.

Figure 8 shows the percentage of time that winds are coming from a particular direction. The color-coded bars represent the direction and speed of the winds. The purple bar across the graph represents the runway orientation planned for NAICM (i.e., 002°/182° based on True North). Winds for certain hours of the day are shown in the chart (on the left for the low-demand hours between 2300 and 0700) and on the right for the high-demand hours between 0700 and 2300.

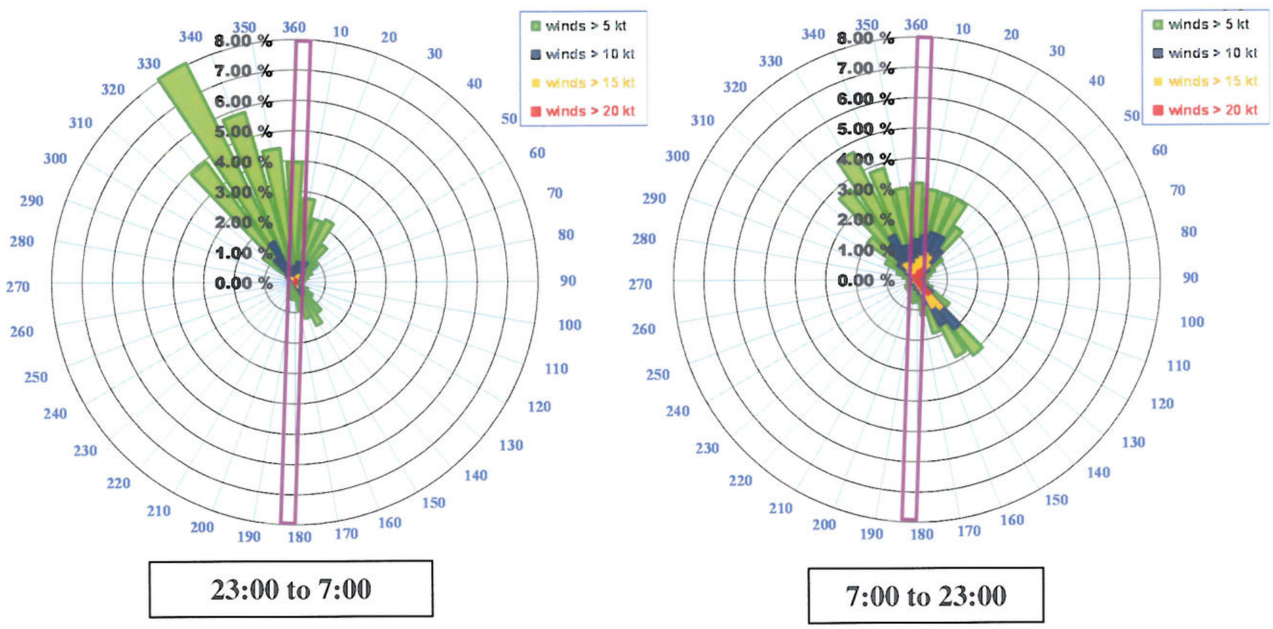

Figure 8. Texcoco AWOS Data: Meteorological Wind-Roses Showing Prevailing Winds (1 January 2009 through 11 October 2014)

As shown in Figure 8, winds at the NAICM site tend to be milder during low-demand nighttime hours—rarely exceeding 10 kt, but much stronger during typical high-demand operational hours. The results also show that, for the period under consideration, winds occurred predominantly from the north-northwest, north, and north-northeast. Additionally, during typical high-demand operational hours, strong winds from the south-southeast occurred frequently.

Figure 9 illustrates the overall wind distribution by speed during the typical high-demand hours from 1 January 2009 through 11 October 2014. The maximum steady-state wind recorded was 32 kt and the maximum gust was 43 kt.

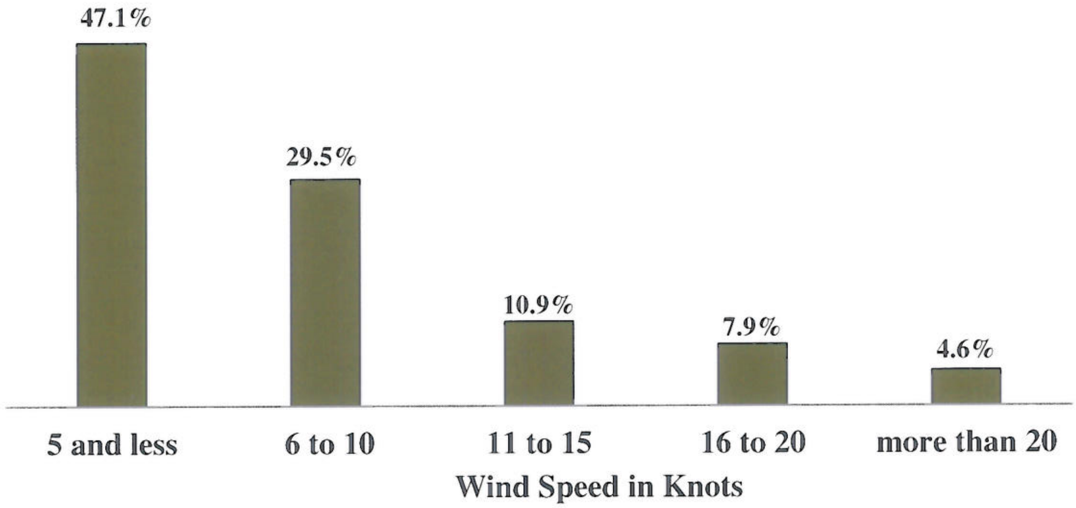

Figure 9. Texcoco AWOS Data: Wind Speed (0700 – 2300, 1 January 2009 through 11 October 2014)

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. Note that the large majority of aircraft envisioned to operate at NAICM are in this category. 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.

For planning purposes, ICAO recommends that the number and orientation of runways at an airport should be such that the airport meets the above conditions not less than 95 percent for the aircraft that the airport intends to serve (20 kt in the case of NAICM). The 95 percent criterion is applicable to all conditions of weather (denoted in this section as "All Weather" conditions).

Figure 10 shows the crosswind component distribution for All Weather conditions by the limitation criteria described above. Note that the crosswind component (for runway orientation 002°/182°) exceeded 20 kt only about 0.4% of the time.

It is important to note, however, that air carrier aircraft can typically operate with higher crosswind component limitations than those mentioned above. For example, some air carrier aircraft, depending on the airline operating practices and other considerations (e.g., weather, aircraft type, etc.), can operate with a crosswind component limitation of 25 kt or higher during most weather conditions.

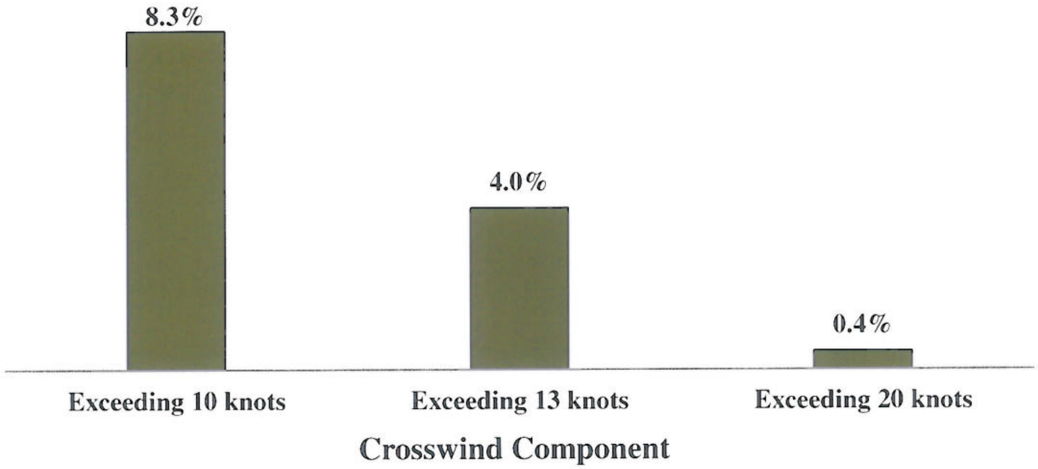

Figure 10. Texcoco AWOS Data: Crosswind Component Distribution (0700 – 2300, 1 January 2009 through 11 October 2014)

MITRE also examined the direction and velocity of winds during periods of poor weather conditions. More specifically, MITRE examined if during L-IMC weather there have been occasions when crosswind components exceeded 10 kt, a crosswind component limitation associated with CAT II and CAT III approaches.[4] Figure 11 shows the percentage of time that winds are coming from a particular direction during L-IMC weather.

In summary, during L-IMC conditions the following wind patterns were observed:

- Winds are coming from the northwest most of the time
- No winds - about 42 percent of the time
- Less than 10-kt crosswind component - about 56 percent of the time
- More than 10-kt crosswind component - about 2 percent of the time, or 2.5 hours total

Based on these numbers, it is safe to conclude that if CAT II and CAT III procedures were to be implemented at NAICM, crosswind limitations should not be an issue. In addition, when such conditions exist, the airport is likely to be operating in a north flow configuration (i.e., arriving from the south and departing to the north).

[4] Autoland systems are commonly used for CAT II and III operations. These systems are often limited to 10 kt of crosswind.

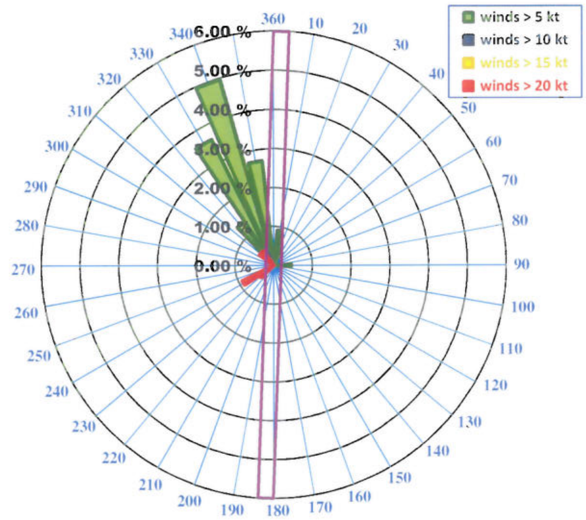

Figure 11. Texcoco AWOS Data: Meteorological Wind-Rose Showing Prevailing Winds during L-IMC (0000-2359, 1 January 2009 through 11 October 2014)

Figure 12 provides the tailwind component distribution by runway ends 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 for Runway 002°/182°, north flow operations (due to tailwinds exceeding 5 kt for Runway 182°) would be required approximately 32 percent of the time, compared to approximately 13 percent of the time for required south flow operations. Either direction could have been used approximately 55 percent of the time.

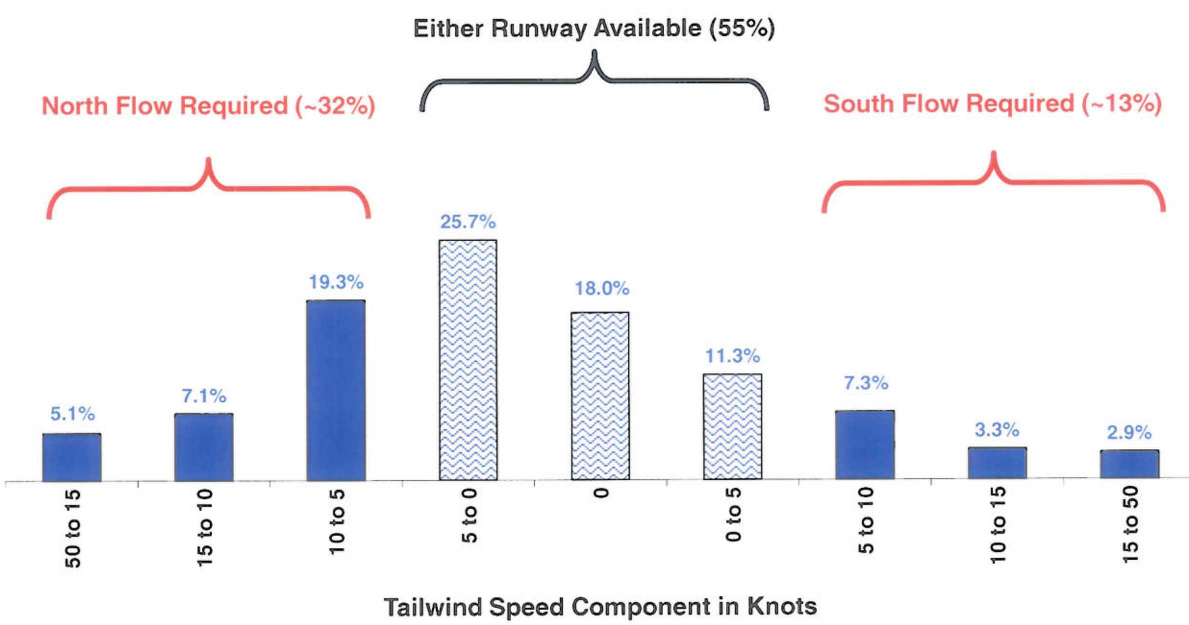

Figure 12. Texcoco AWOS Data: Tailwind Component Distribution (0700 – 2300, 1 January 2009 through 11 October 2014)

Finally, it is important to examine runway usability due to winds at various weather (ceiling and visibility) conditions.

As shown in Table 2, the runway orientation meets the 95 percent usability factor (highlighted in red) at a 20-kt crosswind component limitations during All Weather conditions, as well as VMC/MMC and H-IMC/L-IMC conditions. The 95 percent usability factor is also met for a 13-kt crosswind component limitation during VMC/MMC and All Weather conditions. As a result, the 002°/182 runway orientation provides appropriate wind coverage for the type of aircraft operations expected to regularly operate at NAICM (i.e., large to heavy air carrier aircraft). The 95 percent usability factor criteria is not met during VMC/MMC, H-IMC/L-IMC, or All Weather conditions considering a 10-kt crosswind component limitation, and during H-IMC/L-IMC considering a 13-kt crosswind component limitation. This should not be an issue as the large majority of the type of aircraft expected to operate at NAICM are not impacted by these crosswind component limitations.

Table 2. Texcoco AWOS Data:
NAICM Runway Usability Factors Based on Crosswind Component Limitations
(0700-2300, 1 January 2009 through 11 October 2014)

Proposed Runway	VMC/MMC			H-IMC/L-IMC			All Weather		
	10 knot	13 knot	20 knot	10 knot	13 knot	20 knot	10 knot	13 knot	20 knot
Both Directions	91.7%	96.1%	99.6%	88.1%	91.3%	96.5%	91.7%	96.0%	99.6%

Note: for the months of January-April, 2009 only visibility sensor data have been analyzed, as complete cloud layer (i.e., ceiling) information was not available due to equipment failures.

As previously mentioned, it is important to keep in mind that the majority of aircraft intended to operate at NAICM are large and heavy commercial jet aircraft that in reality are able to operate with higher crosswind component limitations (depending on aircraft type, weather condition, and airline operating practices) than those recommended by ICAO for planning purposes. For example, during All Weather and VMC/MMC conditions the runway usability considering a 25-kt crosswind component limitation is almost 100 percent.

6. Summary of Findings and Recommendations

Texcoco AWOS data from 1 May 2009 to 11 October 2014 suggest that good weather conditions (ceiling and visibility) at the NAICM site occur almost 99 percent of the time. Winds are generally calm, rarely exceeding 20 knots, and are in most cases aligned with the proposed NAICM runway orientation. Poor weather conditions requiring CAT II/CAT III procedures are rare, occurring on average only about 20 hours per year.

The following findings summarize MITRE's analysis of more than five years of wind, ceiling and visibility data:

- The proposed 002°/182° (based on True North) runway orientation provides more than 99 percent of operational availability considering a 20-kt crosswind component limitation (i.e., applicable to air carrier operations) considering All Weather, VMC/MMC and H-IMC/L-IMC conditions.
  - Small to medium lighter aircraft operations, however, may at times be limited due to excessive crosswinds. For example, during H-IMC/L-IMC weather the runways will be available about 91 percent of the time considering a 13-kt crosswind component limitation.
- Due to the prevailing winds, aircraft operations will likely be conducted in a north flow direction most of the time
- Approximately 99 percent of the time weather conditions were good (VMC or MMC)
- Weather conditions requiring CAT II and CAT III approach procedures are rare, occurring only about 0.15 percent (68.5 hours) and 0.09 percent (42.5 hours) of the time, respectively. When such conditions occur, winds are usually calm or favor a north flow, with the crosswind component rarely exceeding 10 kt.

Considering the above-mentioned findings, it is recommended that a thorough review be conducted by the Mexican aviation authorities to determine if CAT II and CAT III approach procedures are required. If CAT III operations are believed to be required, it is necessary to determine the level of CAT III to be supported, which involves collecting RVR data at the NAICM site. **An appropriate, good quality, well-adjusted RVR device should be installed as soon as possible.**

It is also important to mention that MITRE's preliminary CAT II/III approach designs indicate that under U.S. FAA criterion, eleven out of the 12 runway ends (considering the ultimate development of the airport) at NAICM would *not be eligible* for CAT II/III approach procedures due to issues with Climb Gradients on missed approaches and precipitous terrain. However, if CAT II/III approach procedures are determined to be necessary, then Mexican authorities may need to conduct an Equivalent-Level-of-Safety (ELS)[5] study to allow for the establishment of CAT II/III approach procedures at additional runway ends at NAICM.

Since the Texcoco AWOS is already installed, MITRE recommends the continued collection of weather data as long as possible. This will allow MITRE to conduct additional weather analyses as the airport is constructed.

[5] An ELS study establishes that alternative actions may provide a level of safety equal to that provided by the airworthiness standards for which equivalency is being sought.

Finally, MITRE recommends that this document be provided to other Mexican aviation authorities and project stakeholders, and discussed with knowledgeable weather authorities to ensure the results presented in this report are consistent with known patterns of past weather.