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Microburst nowcasting for the Havana's Airport José Martí using a weather radar†

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Abstract: This paper is about the development of a nowcasting method of low-level wind shear produced by microburst at the Havana's International Airport José Martí using a weather radar. There were identified the radio-echoes patterns that may produce microburst with wind gusts higher than 30 knots. For that, it was analyzed the radar observations regarding to the intensity of the radio-echoes in dBZ, the height and the morphology (shape) of them, as well as the proximity to the airport and the movement of the cumulonimbus clouds which may represent a potential danger for the aerodrome and the air traffic operations.

Keywords: microburst; low-level wind shear; nowcasting

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1. Introduction

It is known that the wind shear may be observed at every level of the atmosphere, but its presence in a lower layer of 500 m above the ground level, has a vital importance for airplanes, especially during the landing and the take-off [1]. Among those phenomena are the microbursts, that could induce an outburst of 150-mile-an-hour winds on the near ground [2,3].

Since 1987 noticeable improvements have been achieved on the Doppler Radars and the signal-processing technology [4,5]. Among those equipments may be referenced the Low-Level Wind Shear Alert System (LLWAS) [6], the Terminal Doppler Weather Radar (TDWR) [7] and the Integrated Terminal Weather System (ITWS) [8]. This advanced equipment is very expensive for its purchase and maintenance, and its use is limited for big airports with an elevated number of operations.

Due to the bad economic situation in Cuba, the José Martí International Airport does not have a method for the microburst forecast nor instruments for the low-level wind shear detection. In this aerodrome has occurred low-level wind shear which have provoke incidents and a catastrophic accident. This aerodrome is also the most affected by low-level wind shear provoked by storms [9,10]. Furthermore, many research and thesis papers have recommended to develop a microburst forecast method for this aerodrome [9].

This paper objective is to develop a nowcast method for low-level wind shear produced by microbursts related to storms, at José Martí International Airport.

2. Materials and Methods

2.1 Characteristics of the study area

The José Martí International Airport (Figure 1) is located at 22º59′ N y los 82º24′ W, in Boyeros Municipality, Havana, Cuba. Is the main airport of international and national flights. It is elevated 64m above main sea level. The runway is orientated at 60º/240º, and is identified as runway 06 or 24 depending on the direction authorized for its use [11].

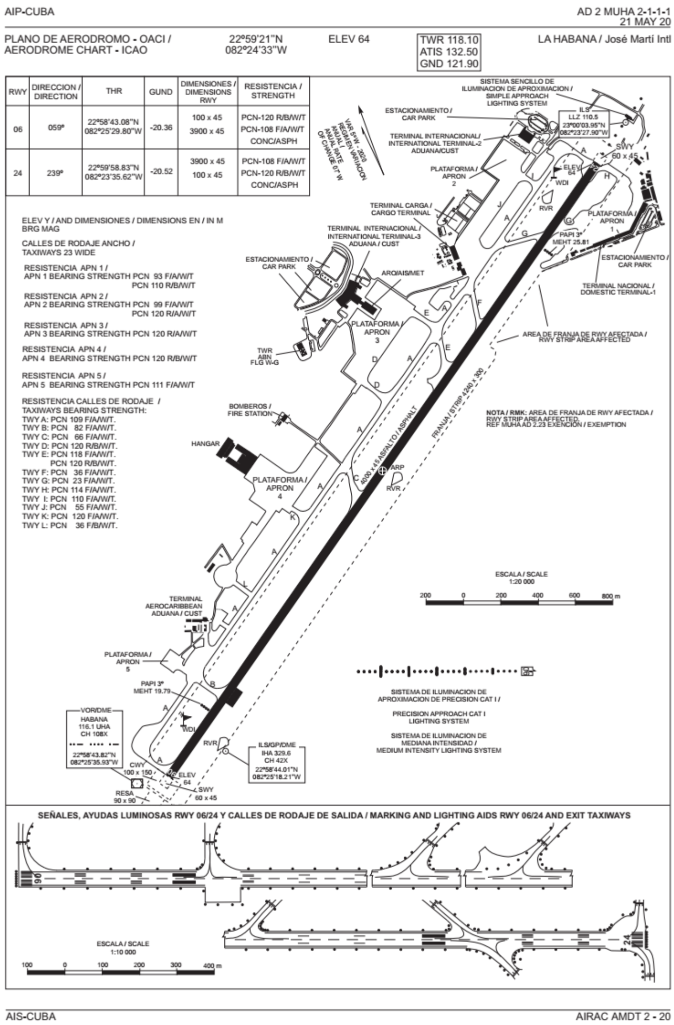


Figure 1. Study area. José Martí International Airport.

2.2 Data collection

For this research were used the wind speed and wind direction records obtained by the three anemometers of the aerodrome. Those anemometers are Vaisala WINDCAP® WMT700 ultrasonic wind sensors [12]. Also were used the METAR and SPECI reports sent by the Havana's Aerodrome Office (MUHA) and the Casablanca's Weather Station Radar observations, all of them belonging to 2016. This Weather Radar is an MRL-5.

2.3 Data processing

In the wind data record, it was searched for wind speed values equal to or higher than 30 KT. That value is the lowest range of wind speed produced by a microburst according to Wakimoto. In those days were analyzed the radar images.

For the Radar images processing was used Vesta-Process Software, mostly the products PPI (Plane Position Indicator), Max (Maximum values of reflectivity) and Cut (Vertical distribution of reflectivity in any direction of the radio-localization volume).

For the realization of this microburst nowcasting method, there were considered the echoes intensity, the height reached and morphology of them. In general, there were considered echoes intensity equal to or higher than 45 dBZ located at 3 km height or more as an indicator of hazard for microbursts to occur, echoes patterns as multicells lines and clusters, and weak echoes regions and strong echoes concentrations. Also was considered the storms stage and their proximity to the airport and movement.

3. Results and discussion.

After have been applied this methodology to the 366 days of the year 2016, there were found 19 cases in which occurred low-level wind shear related to microbursts. In 11 of those days occurred more than one microburst linked to the same storm. In total, 36 microbursts affected the aerodrome that year. The microbursts occurred on the rainy season of Cuba (from May to October), in which the most significant month was July (Figure 2). The most of the microburst that affected the aerodrome occurred between 2000 and 2200 UTC, with a peak at 2100 UTC, which represents the 47.2% of the total (Figure 3).

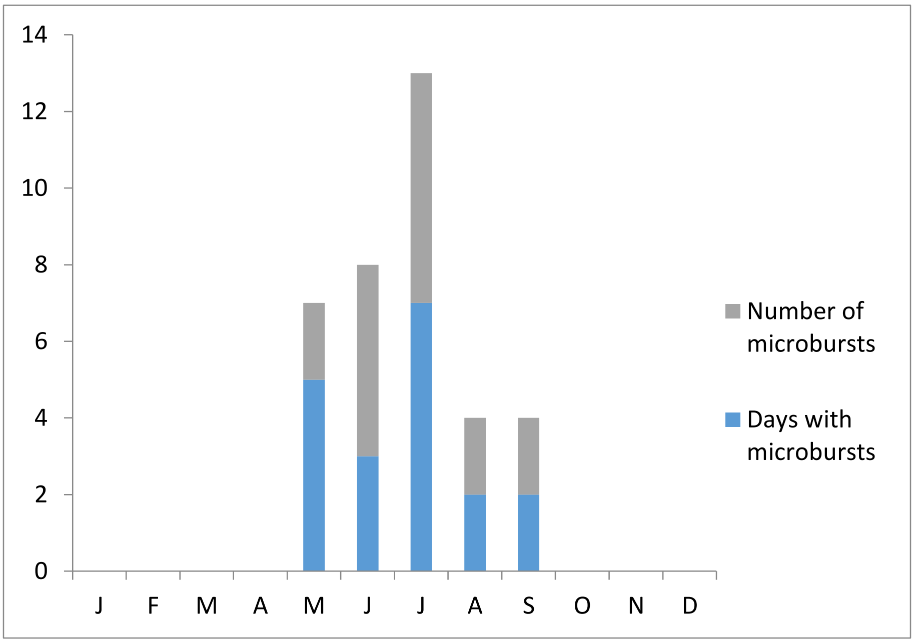


Figure 2. Monthly distribution of descending microbursts.

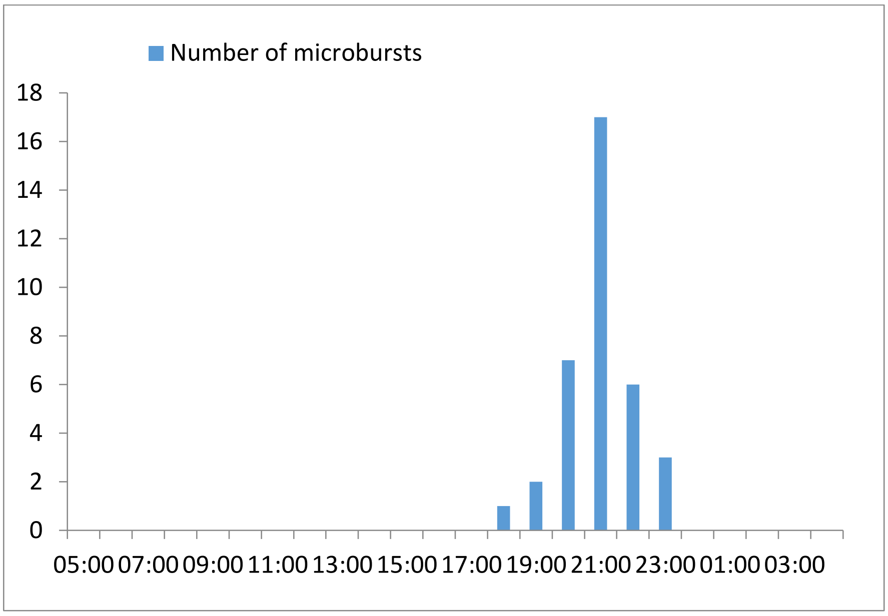
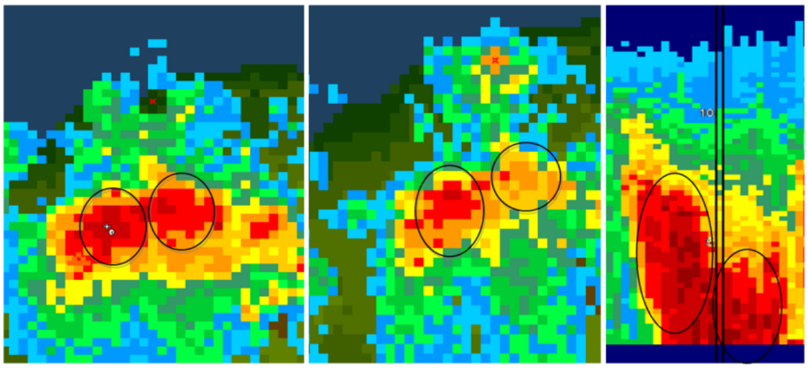


Figure 3. Horary distribution of descending microbursts.

For this method was proposed to consider the echoes equal to or higher than 45 dBZ at 3 km height or more. After have been analyzed and made the correlation between the radar images and the wind speed data, it was determined that only the storms with echoes of 50 dBZ or more located at 5 km height or more, were capable of produce microbursts. There were identified as morphologic patterns associated to the occurrence of microburst, the multicells lines and clusters (Figure 4).



(a) (b) (c)

Figure 4. Product (a) Maximum; (b) PPI at elevation ϴ=13.5º; (c) Maximum N-S. July 3rd, 2016, 21:20 UTC.

In the analysis of the radar images it was observed that, with a storm located at less than 10 km of the aerodrome, with an echoes area with reflectivity values of 50 dBZ (red echoes, as they are represented in the colors scale.) or more, and moving toward the aerodrome; the descent of those echoes occurred in a time lapse of 10 minutes after the observation, registering wind gust higher than 30 KT in the aerodrome. When the storms were located at less than 3 km of the aerodrome and in the radar images was appreciated the descent of the red echoes, in the aerodrome where registered wind gusts higher than 30 KT within the next 5 min after the observation. It was registered wind gusts of 34 KT average when the red echoes were located between 4 and 7 km of altitude, and wind gust of 42 knots average, when those echoes where located at altitudes higher than 7 km.

3.1 Method

After have been analyzed the 19 studio cases, it was defined microburst nowcasting method. For its application, it is necessary to have access to the Casablanca's weather radar observations in real time, as well as the Vesta Process software.

In presence of cumulonimbus clouds within a ratio of 20 km from the center of the International Airport José Martí, it most proceeds as follows:

1. All the cumulonimbus clouds with a reflectivity equal to or higher than 50 dBZ will be localized in the Vesta Process product: Max.

2. Once those echoes be localized, it will be determined the height reached by them using the Cut product or PPI layers with angles from ϴ=1.4º to ϴ= 21º, knowing that the storms with red echoes at 5 km height or more, can produce microbursts.

3. It must proceed to select from those storms those ones which are more organized, considering the morphologic patterns, knowing that the lines and clusters of multicells have more chances to produce a microburst than a single cell storm.

4. Using the PPI layers with different angles in a sequence of two or more consecutive observations, it will be determined the stage of the identified storms.

5. Only will be chosen those storms that will be near to the airport or moving towards it, determining their speed and direction using the provided tools in the Vesta Process Software.

Once it had been evaluated the meteorological situation, and the storms that represent a potential damage for the airport had been identified, the next steps will be followed in order to make a microburst nowcasting.

1. An alert for the possible occurrence of low-level wind shear due to a microburst will be emitted when a storm in a developing or mature stage, and moving to the airport, be at less of 10 km of any runway's heading. If in the next observation (10 minutes) the downburst has not occurred, the alert will remain.

2. An alarm of low-level wind shear due to a microburst will be emitted when a storm be at less than 3 km or over the aerodrome and in the last observation, the descent of the red echoes be observed.

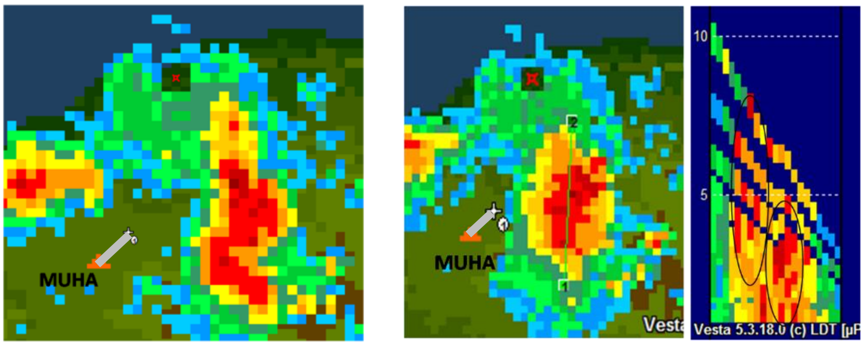
3. When the red echoes reach heights between 5 and 7 km, it might be forecasted wind gust of around 30 KT, meanwhile, when the height of that echoes exceed the 7 km, it might be forecasted wind gusts of at least 40 KT in the aerodrome. The movement of the storm will be considered to forecast the wind speed knowing that the storms that have a perpendicular movement to the airport will produce stronger winds and wind shear.

4. Once the microburst has occurred, the alarm will remain as long as the conditions for the microburst occurrence previously exposed endure. The alarm will be cancelled when the wind gust higher than 30 KT has finished and when the red echoes have disappeared.

3.2 Study case

It will be analyzed the July 3^{rd}, 2016.

In the observation realized at 2050 UTC it was appreciated a storm located at 13 km east to the aerodrome, with red echoes with values between 51 and 61 dBZ, which reached altitudes of up to 6.6 km. The storm was in a developing stage, with strong updrafts, and moving westward (Figure 5a).



(a) (b)

Figure 5. (a) Maximum product. 20:54 UTC; (b) "Maximum" and "Cut" realized at 21:04 UTC. July 3^{rd}, 2016.

In the next observation at 2100 UTC, the red echoes reach values of 62 dBZ, and altitudes of up to 8 km. It was defined as a multicells cluster in a mature stage with updrafts and downdrafts, [as it is observed in the vertical cut, pointed in Figure 5 (b)]. The storm kept the same movement. In that moment, according to the proposed method, it could have been emitted an alert because of the possible occurrence of low-level wind shear by a microburst (Figure 5b).

In the next observation, at 2110 UTC, the storm was situated at 3 km east of 24 runway's heading, and echoes nearby it reach values of 56 dBZ and altitudes of up to 7 km, the storm kept its mature stage and the same movement direction. In that moment an alarm could have been emitted (Figure 6).

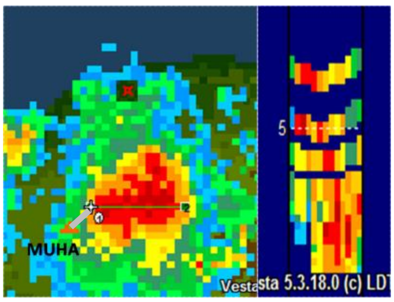


Figure 6. "Maximum" and "Cut" realized at 21:14 UTC, July 3^{rd}, 2016.

At 2120 UTC observation, the red echoes descent was observed. From 2124 UTC were registered wind gusts higher than 30 KT from NE in the 24 runway's heading anemometer. Those gusts reached the 70 kt. Also were registered strong wind gusts by the anemometer situated nearby the center of the runway (Figure 7).

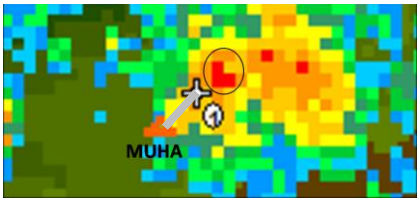


Figure 7. "PPI" product at ϴ=2.0º. 21:21 UTC July 3rd, 2016.

At 2130 UTC, in two vertical cuts realized was observed the descent of red echoes, indicating the presence of two new microbursts, registered in the three anemometers of the aerodrome (Figure 8).

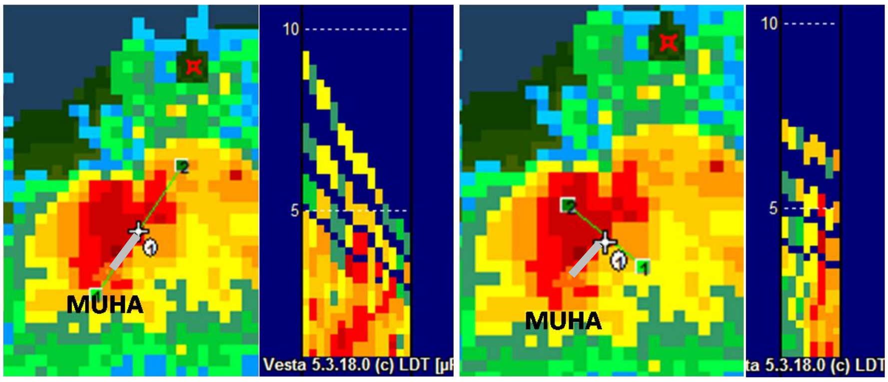


Figure 8. "Maximum" and "Cuts" realized at 21:34 UTC, July 3rd, 2016

In the next observation at 2140 UTC, the red echoes were moving away from the aerodrome, and the wind speed at it was decreasing gradually. According with the proposed method, the alarm could be canceled at that moment.

If the method had been applied that day, an alert could have been emitted 20 minutes before the aerodrome had been stricken by the first microburst.

5. Conclusions

A nowcast method using the Casablanca's Weather Radar images capable of emitting an alert of low-level wind shear produced by microbursts for the José Martí International Airport was created.

The use of the nowcast method in the study cases exposed that an alert for low-level wind shear produced by microbursts could be emitted with an anticipation mean time of 10 minutes.

As a necessary condition for microburst to occur, was established the presence of echoes with a reflectivity value of 50 dBZ or more located at heights of 5 km or more.

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Conflicts of Interest: The authors declare no conflict of interest.

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