Study of the maximum wind speeds and meteorological characteristics in Paraguay in order to differentiate synoptic and non-synoptic events, for a future update of the NP-196.

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Abstract. The Paraguayan standard NP-196 *Acción del Viento en las Construcciones*, estimates wind action on structures taking into consideration only synoptic events and does not account the effects of thunderstorms (TS). Nonetheless, severe storms usually have higher values of the wind speeds than synoptic events in the region. Currently, the adoption of a vertical profile of wind speeds for TS events is being studied internationally in order to be included in several wind standards. Therefore, there is an urgent need to statistically study these events in order to consider the loads of the TS and EPS winds over structures. The present work aims to classify synoptic (EPS) and non-synoptic winds (TS) of three Paraguayan meteorological stations, looking forward to a future update of the basic wind speeds of the NP-196.

Keywords: Extreme wind, Synoptic and non-synoptic events, Thunderstorm.

1 Introduction

The NP-196 *Acción del Viento en las Construcciones* as most of the wind loading regional standards does not take into consideration actions of downdraft. However, such winds are predominant in the region and are known for having higher values of wind speeds than synoptic events [1]. Given the level of structure collapses (such as telecommunication towers or gas stations) that have caused recent storms in Paraguay, it is vitally important to consider wind action on structures, including the ones caused by downdrafts.

To identify and differentiate the types of events occurred in the country, the present work aims to analyze extreme wind speeds and other meteorological characteristics of three Paraguayan automatic meteorological stations with up to 14 years of records. From this analysis, it is expected to develop a database that will allow to start a statistical study of the maximum wind speeds, looking forward to a future update of the NP-196.

2 Fundamentals

Synoptic winds are those which are represented by models of full-developed atmospheric boundary layers, such as the power or log-law vertical profile of horizontal wind speeds. This type of wind is characterized by having high gusts and a nearly constant mean wind speed over long periods of time. Moreover, wind direction, atmospheric pressure and temperature does not display significant changes over time. The non-synoptic events are represented by downdraft outflow models, with horizontal velocities that diverge from a center. The vertical wind speed profile has a particular shape, in which the maximum wind speed occurs at heights relatively close to the ground and decreases at higher altitudes.

3 Events classifying algorithm

3.1 Peak detection

To detect events associated with severe storms, it is necessary to establish a wind speed threshold value, in which events are considered for further studies. According to Ferreira [2], sustained by Moller [3] and the National Weather Service (NWS), a criteria to define a local convective storm is the record of damages caused by wind and gusts speeds equals to or over 25 m/s. Lower speeds can be chosen in order to obtain a bigger number of events to be classified, in this study a speed of 20 m/s was adopted.

3.2 Changes in temperature, atmospheric pressure and meteorological descriptors

Ferreira [2], studied gust generated by severe storms in the south of Brazil. Within the analyzed variables, the atmospheric pressure and the temperature were the most decisive parameters in the identification of convective storms. To analyze these variables, Vallis [1] used the parameters mentioned below:

- $T_{med,3}$: is a weighted average of the temperature calculated from the observations between 3 and 1 hours (-180 to -60 min) prior to the guts peak., each one of the temperature observations is multiplied by a weight that depends on the validity time, that equals to the difference of time between readings.
- $\Delta T_{min,3}$: in the range of 2 hours before and 1 hour after the gust peak the minimum temperature T_{min} must be determined. Also, in the same range of time, the maximum temperature T_{max} recorded before the minimum must be identified. Then, the parameter $\Delta T_{min,3}$ is calculated as the difference between both temperatures.
- $\Delta P_{max,3}$: in the range of 2 hours before and 1 hour after the gust peak the maximum pressure P_{max} must be determined. Also, in the same range of time, the minimum pressure P_{min} recorded before the maximum must be identified. Then, the parameter $\Delta P_{max,3}$ is calculated as the difference between both pressures.

According to the intensity of the changes in the variables under analysis, Vallis [1] defined the following classification groups for the events:

- Group 1: Severe changes in the magnitudes of the parameters $\Delta T_{min,3}$ and/or $\Delta P_{max,3}$.
- Group 2: Medium changes in the magnitudes of the parameters $\Delta T_{min,3}$ and/or $\Delta P_{max,3}$.
- Group 3: Slight or inverted (increase in temperature or decrease in atmospheric pressure) changes in parameters $\Delta T_{min,3}$ and/or $\Delta P_{max,3}$.

In order to determine the classification groups, the variable ΔT_0 is used, which is calculated from eq. (1). This equation is obtained from a linear regression for Automatic Surface Weather Stations observed by Vallis [1] in Brazil between the parameters $\Delta T_{min,3}$ and $T_{med,3.}$ The values $m_{\Delta T}$ = -0.6611 and $b_{\Delta T}$= 9.0195 are extracted from this regression.

$$\Delta T_0 = max\ (20, min(30, T_{med,3}))\ m_{\Delta T} + b_{\Delta T}. \tag{1}$$

Each event is assigned to group 1(eq. (2)), group 2 (eq. (3)) or group 3 (eq. (4)) depending on what conditions it satisfies.

$$\Delta T_{min,3} \leq 1.25\Delta T_0 - \frac{\Delta P_{max,3}\Delta T_0}{4}. \tag{2}$$

$$1.25\Delta T_0 - \frac{\Delta P_{max,3}\Delta T_0}{4} \leq \Delta T_{min,3} \leq 0.75\Delta T_0 - \frac{\Delta P_{max,3}\Delta T_0}{4}. \tag{3}$$

$$\Delta T_{min,3} \geq 0.75\Delta T_0 - \frac{\Delta P_{max,3}\Delta T_0}{4}. \tag{4}$$

3.3 Changes in gust speed and wind direction

To analyze the behavior of the gust speed and the relationship between the peak gust speed and the readings hours before and after the peak, the parameters Pro_{-6}, $Pro_{-3,}$ $Pro_{+3,}$ Pro_{+3} are introduced. Pro_{-3} and Pro_{+3} are the relationships between the peak gust and the average gust speed in the previous three hours and three hours after the peak gust. Pro_{-6} and Pro_{+6} are calculated for six hour before and six hours after the peak gust.

The wind direction is another parameter to be analyzed, to quantify the maximum variations before and after the maximum gust speed reading, a similar procedure is applied. Regarding the wind direction at the gust speed peak moment DIR (measured in sexagesimal degrees from a reference axis), the absolute maximum variations are found in a range of three hours before $\Delta DIR_{max,-3}$ (eq. (5)) and three hours after $\Delta DIR_{max,+3}$ (eq. (6)).

$$\Delta DIR_{max,+3} = |\, DIR - DIR_{+3} \,| \tag{5}$$

$$\Delta DIR_{max,-3} = |\, DIR - DIR_{-3} \,| \tag{6}$$

To adjust the results of the algorithm to manual classifications made by Ferreira and Nascimento [4], weather descriptors were analyzed by Vallis [1]. In this work the weather descriptors were used as a complement of the parameter previously mentioned. The algorithm proposes a different treatment of the parameters depending on weather it was recorded the presence of thunderstorms near the time of the peak of gust speed.

4 Methodology

4.1 Preparation of time series and data homogenization

The data used for the analysis correspond to three automatic stations of the *Dirección Nacional de Aeronáutica Civil* (DINAC) of Paraguay.

The data processing was performed by matching the observed values of mean wind speed averaged in 10 minutes V_{obs}, gust speed averaged in 3 seconds R_{obs}, temperature, atmospheric pressure, wind Direction and meteorological descriptors according to the station, date and UTC time in which they were recorded.

In order to homogenize, correction factors provided by the NP-196 [5] were applied: the topographic factor S1 that considers the terrain relief variations; and the combined factor S_2, that takes into account the combined effect of the ground roughness and the variation of the wind speed with the height above the ground.

Each of the stations under analysis was divided into 16 sectors of 22.5° to consider the influence of the type and height of obstacles and surface coverage in a radius of 500m. Through eq. (7) and (8) the correction factors for wind speed F_V and gust F_R were calculated. The parameters involved in the equations are the same as those on the calculation of the combined factor S_2, and their values are obtained from NP-196 [5].

$$F_V = \frac{S_{2,600s}}{b_{600s(CAT)} * Fr \left(\frac{Z}{10}\right)^{p_{600s(CAT)}}} \tag{7}$$

$$F_R = \frac{S_{2,3s}}{b_{3s(CAT)} * Fr \left(\frac{Z}{10}\right)^{p_{3s(CAT)}}} \tag{8}$$

All the observed mean wind speed readings V_{obs} and observed gust speed readings R_{obs} were corrected according to the sector of wind direction at the time of the readings through the eq. (9) y (10).

$$R_{cor} = F_R R_{obs} \tag{9}$$

$$V_{cor} = F_v V_{obs} \tag{10}$$

4.2 Classifying events

The classification of synoptic, non-synoptic and suspicious of false readings events has been made according to the algorithm developed by Vallis [1].

The results of the algorithm are verified by analyzing graphics of mean wind speed, gust speed, direction, atmospheric pressure, and temperature over time with a 10-hour time lapse before and after the gust peak. The graphics inspection allows to detect abnormal behavior and/or possible false readings which may interfere with the events classification and also to verify if the graphs correspond to the characteristics of the phenomenon. For more information about this section, consult [6].

5 Results

The present work focused on the analysis of the stations of the three most important airports in Paraguay. All the data was provided by DINAC.

In the case of the automatic station located at Silvio Pettirossi Airport, in the periods with available data, 70 events with gust speed equal to or greater than 20 m/s were detected; no suspicious event was detected, 6 (8.6%) were classified as synoptic, 64 (91.4%) were classified as non-synoptic Fig. 1.

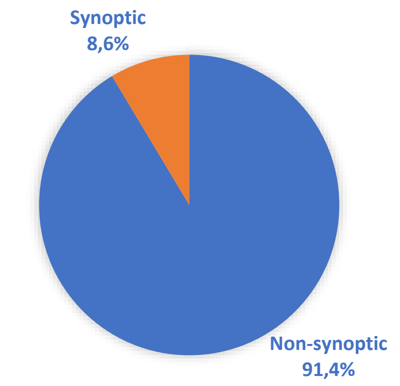

Figure 1. Percentage distribution of classified events at Silvio Pettirossi Airport

For Guaraní Airport, in the period with available data, 20 events with gust speed equal to or greater than 20 m/s were detected; 1 (5.0%) event was classified as suspicious, 2 (10.0%) were classified as synoptic, 17 (85.0%) were classified as non-synoptic Fig. 2.

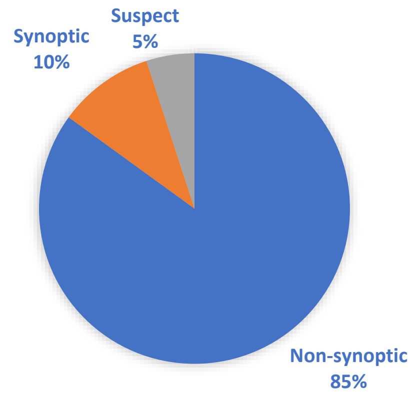

Figure 2. Percentual distribution of classified events at the Guarani Airport

Regarding the records of the automatic station located at Tte. Amín Ayub González Airport, there is an unusual behavior regarding the distribution of the events over the years. In the period between 2012 and 2016, no gust speeds greater than 20 m/s were recorded, although there are journalistic reports of severe storm that occurred in that period. Moreover, in the period between September 2019 and December 2020, more than 50 events were recorded, a similar number of events recorded at the Silvio Pettirossi Airport station in more than 10 years of data.

In addition, most of the maximum gust speed data from the database, do not coincide with those reported on the DINAC website [7], for both intensity and time of the event. For these reasons, the analysis of the Tte. Amín Ayub González Airport station was discarded for further analysis.

6 Conclusions

A large predominance of non-synoptic events over synoptic events was found at the Silvio Pettirossi and Guaraní Airports stations. Anomalies and suspected errors were found in the records of Tte. Amín Ayub González Airport station, and therefore, were not analyzed.

The algorithm used facilitates the process of events classification but may give some wrong results. It may be necessary to apply manual corrections.

The present work aims to prepare the groundwork of future statistical analysis of wind data, to be able to include the effects of non-synoptic winds in the NP-196.

Acknowledgements. To the DINAC for providing the necessary data to perform this study, to *Laboratorio de Mecánica Computacional* of FIUNA (*Facultad de Ingeniería de la Universidad Nacional de Asunción*) and to *Laboratorio de Aerodinâmica das Construçõe*s, UFRGS (*Universidade Federal do Rio Grande do Sul*) for giving special attention and support to this research.

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