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Climatological standard of the CDTN weather station as a resource for environmental studies in nuclear research centers

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ABSTRACT

In air quality studies, atmospheric models are widely used in order to estimate the concentration and behavior of the spatial distribution of pollutants released into the atmosphere originated from point sources. The data derived from the Climatological Norms constitute an important reference for these studies, as they provide understandings for phenomena and events related to meteorological and climatic parameters, such as rainfall variability, deviations and temperature anomalies, dispersion of airborne pollutants, etc. In this article, the main objective is to validate the data of the meteorological station of the Center for the Development of Nuclear Technology (CDTN) for the time period of 1997-2017, comparing it to the normal climatology of INMET (National Institute of Meteorology) for the period 1981-2010. Based on the results, the variables humidity, wind, temperature and precipitation, obtained from the provisional climatological normals of the (CDTN), were assessed, in order to highlight the practical importance of local climatology for nuclear research centers.

Keywords: **Climatology, Local climatology, Normal climatological**

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1. INTRODUCTION

Nuclear research reactors are complex installations that involve risks and impacts related to safety and to the environment. It is known that nuclear research centers, in their normal operation, do not release sufficient quantities of pollutants into the atmosphere to the point of significantly altering the environment. However, accidents cannot be ruled out. The effluents they emit have a high degree of danger due to the fact that they are radioactive material and can cause harmful consequences to the surrounding areas and population. These releases and their risks depend on the type of the involved processing, safety conditions, transport mechanisms and weather conditions, a dynamic condition that cannot be controlled, but must be known [1].

To assess the consequences of a release of radioactive material into the atmosphere, the destination of effluents in space and time must be predicted.

The concentration of a given substance in the atmosphere varies in time and space due to chemical and/or photochemical reactions, transport phenomena, meteorological factors (winds, air turbulence, thermal inversion, etc.) and local topography. Therefore, meteorological conditions play a determining role in the transport of pollutants between the source and the receiver, and by means of these conditions on a local scale, one can subtract influences directly and indirectly when compared to studies subsidized by data on more comprehensive scales.

According to the World Meteorological Organization (WMO) [2], the climatological normals correspond to the average values of the meteorological variables equivalent to the minimum period of 30 years, aiming at the identification of representative values of characteristic patterns of the climate in the considered place. And all the information related to the climate is better used if compared to a reference, otherwise it will be only values without representativeness. If a normal pattern of these values is established, analyzes of the momentary atmospheric conditions, of future forecasts can be generated and characterize the climate of a particular place or region.

The National Institute of Meteorology (INMET) [3] point out that these variables describe the physical behavior of the atmosphere, while the climatological normals present information on the average behavior, using long-term data, to define the representative climate of a given location.

Recommendations and guidance on how to meet safety requirements are provides by the International Atomic Energy Agency (IAEA) Safety Guide [4], which is jointly sponsored by (WMO), when assessing hazards associated with meteorological phenomena. Accordingly, much attention should be paid to implications of climate variability and, in particular, the possible consequences and hazards that must be considered for the operational lifetime of nuclear installations.

Nuclear safety criteria are different from the industries considered "conventional". Nuclear safety analysis has methods and techniques to guarantee the project feasibility, differentiating between danger and risk, where danger is defined as any potential source of damage regardless of the degree of possibility of that damage coming to fruition, and risk is the probability or expected frequency of the occurrence of an event with its predictable consequences. Following the concept of "defense in depth", their emergency plans, there must be several redundant security systems that prevent the release of radioactive material into the environment.

It is known that Climatological Norms, beginning in the first year of each decade, refer to a 30-year interval of data, however it is possible to calculate and use climatological normals in the unconventional interim periods. This is the scenario of the climatic series of the station at the Center for the Development of Nuclear Technology (CDTN), which is a period of more than 10 years and less than 30 years, so that these data are treated as provisional climatological normals WMO[5].

This work aims therefore to analyze the climatic variability, from the provisional climatological normal of the CDTN meteorological station data in the period 1997-2017. Meteorological and climatological aspects of the site (location) for the analysis reports of safety and comparison of values with regional INMET standards are provided. These procedures facilitate the identification of significant variations and supplies a comparative reference the data presented by the INMET climatological standard of 1981-2010. Focusing on such variations as a means to understand the influences in quantitative terms in relation to nuclear safety, it is expected to generate consistent information to guide, subsidize and complement more comprehensive studies by planning agencies, financiers, licensors, researchers, academics, and other agents involved with the security.

2. MATERIALS AND METHODS

The considered dataset included 20 years of observations of the main climatological variables at the Center (CDTN) station (EMET) located in the campus of the Federal University of Minas Gerais (UFMG), in Belo Horizonte, with Universal Transverse Mercator (UTM) coordinates of 608,050 E and 7,802,451 N (23S) and altitude of 857 meters. In order to understand the climatic variability related to the EMET/CDTN, it was decided to work with a meteorological series standardized according to the WMO of the INMET Belo Horizonte station (609,675 E and 7,795,427 N - 23S; Altitude: 915.47 m).

Data on temperature, wind, humidity and precipitation were made available, collected and treated at CDTN´s offices. Data tabulation and graphing were performed using Microsoft Office Excel software.

2.1. Procedures for calculating averages

According to Sugahara [6] and e INMET [7], there are some procedures for determining the Provisional Climatological Norms and Climatological Norms. These are described below:

A. The 3/5 rule states that if more than 3 consecutive daily values are missing or if the missing data exceeds 5 within the same month, the monthly average will not be calculated.

B. Based on (A), the number of N days in calculating the monthly average can vary between 23 and 31.

C. For precipitation, evaporation and hours of sunshine, monthly totals will be calculated instead of averages, without allowing any missing data.

D. The daily total of precipitation is calculated by the equation:

$$P_d = P_{18} + P_{24} + P_{12} \tag{1}$$

Where P_d is the daily total of precipitation, P_{18} is the precipitation measured at 18 Coordinated Universal Time (UTC) the previous day, P_{24} is the precipitation measured at 24 UTC and P_{12} is the precipitation at 12 UTC of the day on which the measurement was taken.

E. The compensated average daily temperature was calculated using the equation:

$$T_d = \frac{T_{max} + T_{min} + T_{12} + 2T_{24}}{5} \quad (2)$$

Where T_d is the average daily temperature, T_{max} is the maximum temperature, T_{min} is the minimum temperature, T_{12} is the air temperature at 12 UTC and T_{24} is the air temperature at 24 UTC.

F. The average daily relative humidity was calculated using the equation:

$$UR_d = \frac{UR_{12} + UR_{18} + 2UR_{24}}{4} \quad (3)$$

Where UR_d is the daily relative humidity and UR_{12}, UR_{18} and UR_{24} correspond to the relative humidity measured at 12, 18 and 24 UTC.

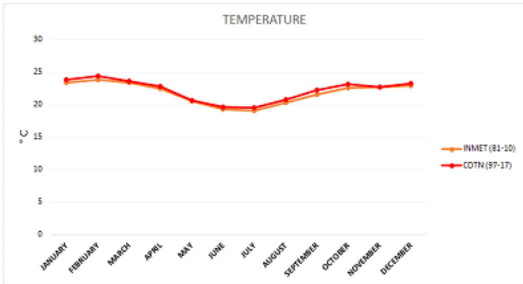
For the predominant wind direction, a monthly survey was carried out for each year. Then, the relative frequency of wind occurrence from eight main directions was raised, namely: North (N), Northeast (NE), East (E), Southeast (SE), South (S), Southwest (SW), West (W) and Northwest (NW). For this purpose, all hourly wind direction measurements for the considered month and already available at the station for the period were classified according to the eight direction ranges specified above. Subsequently, the range (direction) with the highest relative frequency was determined, subject to the restriction that this frequency was higher than 20%. When this condition was not met, the predominant direction was considered undefined. For the speed calculation, the average of the values was extracted.

3. RESULTS AND DISCUSSION

The normals data discussed here are historical averages from the period from January 1, 1997 to December 31, 2017, corresponding to a single weather station. They are, in general, Provisional Norms to standardize the local climate, according to WMO concepts and procedures. The scenarios presented here represent preliminary results of the integration of meteorological information from the EMET / CDTN meteorological station, and environmental data from the study area are available. The analysis of the provisional climatological normal for CDTN (1997-2017) in comparison with the climatological normal for Belo Horizonte (1981-2010) for INMET, with the purpose of identifying the variability of climatic attributes in this period and variations of these values, can be observed in Figure1.

Figure 1: *Analysis of EMET / CDTN compensated average temperature.*

MÊS	NORMAL INMET INMET (81-10)	ADVICE CDTN CDTN (97-17)
JANUARY	23,40	23,85
FEBRUARY	23,80	24,41
MARCH	23,40	23,60
APRIL	22,50	22,78
MAY	20,50	20,63
JUNE	19,30	19,70
JULY	19,10	19,52
AUGUST	20,30	20,83
SEPTEMBER	21,60	22,24
OCTOBER	22,60	23,13
NOVEMBER	22,70	22,72
DECEMBER	22,90	23,28



Source: Data: EMET / CDTN, prepared by the authors

Based on the average temperatures at CDTN, a variation of 1.1 ºC could be observed for the city of Belo Horizonte when compared to INMET station´s data (Figure 1). This can be assigned basically to three factors:

I. Use of measurement devices for different climatic variables in both seasons, that is, these devices operate from similar but not identical physical principles and parameters;

II. The periods compared are different, that is, they show partial temporal overlap.

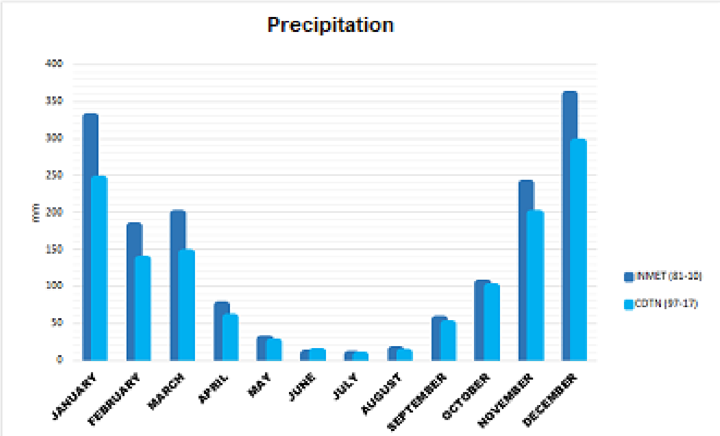
III. The stations are located in different places, with a slightly different altitude value.

Along with the factors related above to the temperature variation, geographic issues of the location of the towers, urban verticalization in the vicinity and the flow of people and vehicles can be attributed as factors that alter the thermal characteristics of the air. Topography (higher elevations) and vegetation contribute to reduce thermal contrasts (difference between maximum and minimum). In addition to these factors of local scale, other effects of atmospheric dynamics, relative to the changes of air masses (regional and zonal) play an important role in temperature variation.

The assessment of the precipitation accumulation for both periods (1981-2010 and 1997-2017), can be seen in Figure 2 According to the presented values, and comparing the periods of these two “normals”, it appears that a variation of 15.34 mm in the pluviometric regime, for example, is perfectly normal when considering that this variable (discrete variable) has no uniform distribution along space and is influenced by the relief. The behavior of this weather conditions for the observation period, indicates a natural climate variability, being more evident for the rainy seasons and presenting irregularities in their distribution over the months. Figure 2 illustrates the monthly average rainfall for the CDTN station (1997-2017) and INMET (1981-2010), as well the difference between both. It seems that general characteristics are reproduced in both stations, although in December there appear to be a large volume of rain, making up the rainiest quarter of the year in November and January.

Figure 2: *Analysis of cumulative mean precipitation EMET / CDTN.*

PRECIPITATION	NORMAL INMET INMET (81-10)	ADVICE CDTN CDTN (97-17)
JANUARY	329,10	244,69
FEBRUARY	181,40	136,34
MARCH	198,00	146,16
APRIL	74,70	58,18
MAY	28,10	24,33
JUNE	9,70	11,94
JULY	7,90	6,52
AUGUST	14,80	10,37
SEPTEMBER	55,50	48,50
OCTOBER	104,70	99,54
NOVEMBER	239,80	198,72
DECEMBER	358,90	294,45



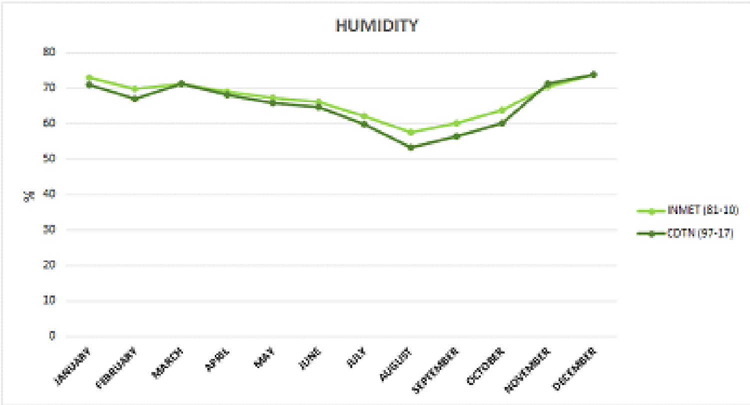
Source: Data: EMET / CDTN, prepared by the authors

It can be observed that the precipitation volume is higher on the INMET station records, which confirms the influence of geographic factors already mentioned (relief, topography, vegetation, etc.), driving a local variability in climate.

Precipitation is associated with the availability of moisture in the air Figure 3 The air humidity, in turn, can be altered by several factors such as maritimity, continentality, dynamics of air masses, the type of vegetation, among others.

Figure 3: *Analysis of compensated mean humidity INMET and EMET / CDTN.*

MÊS	NORMAL INMET INMET (81-10)	ADVICE CDTN CDTN (97-17)
JANUARY	73,00	71,10
FEBRUARY	70,00	67,00
MARCH	71,40	71,46
APRIL	69,20	68,35
MAY	67,40	65,98
JUNE	66,20	64,77
JULY	62,40	59,95
AUGUST	57,80	53,52
SEPTEMBER	60,40	56,60
OCTOBER	64,10	60,33
NOVEMBER	70,50	71,35
DECEMBER	74,00	74,03

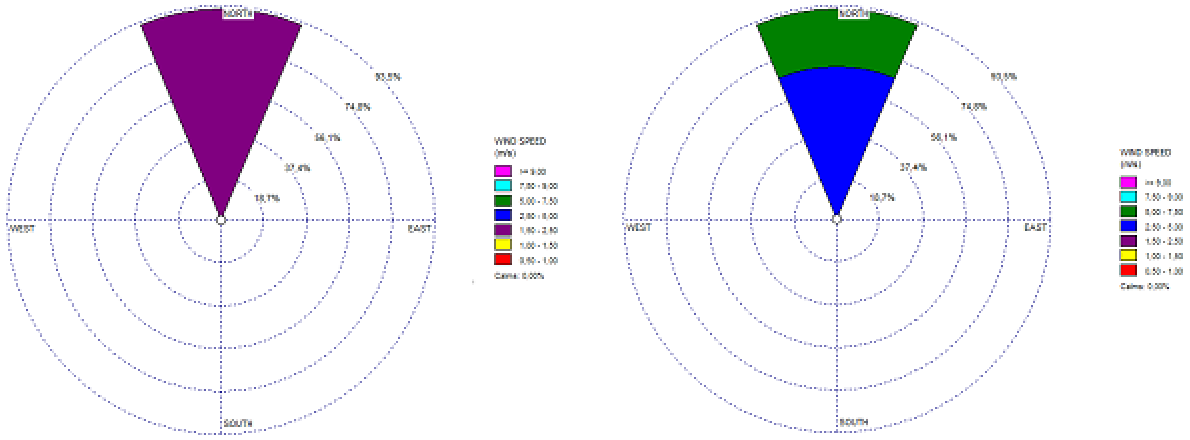


Source: Data: EMET / CDTN, prepared by the authors

Regarding the direction of the winds, predominant winds are observed from the northern quadrants preferably (and northeast and northwest, secondarily) in both seasons. This predominant direction is due to the influence of the South Atlantic Subtropical Anticyclone (ASAS) and is due to the component resulting from the counterclockwise rotation of the downward air whirlwind positioned in the center of the South Atlantic Figure 4.

The climatological normals of 1961-1990 and 1981-2010 present the north / east quadrant as predominant, using two methodologies (a zonal/meridional formula, and a direction one more frequently). However, this work used only one of methodologies (direction of higher frequency) applied to the data of both stations presenting a coherent result, but not exactly identical to that done through two methodologies.

Figure 4: *Analysis of wind direction and intensity INMET and EMET / CDTN.*



Source: Data: EMET / CDTN, prepared by the authors

Precipitation also has an intrinsic relationship with winds, as heavy rains tend to follow the occurrence of strong winds.

4. CONCLUSION

By validating the data from the meteorological station of the Nuclear Technology Development Center (CDTN), it is possible to observe that its data tend to follow the INMET climatological normal, so that it is therefore defensible to consider the EMET/CDTN data as a representative local climatological pattern. The efficiency of the meteorological institutional program can also be confirmed, so that the accuracy for the risk management, mitigation and monitoring studies based on data from the meteorological station at CDTN can be considered fully trustworthy.

The reported treated and standardized data will now more efficiently subsidize environmental monitoring and modeling of radionuclide dispersion by the Atmospheric Radionuclide Transport Model (ARTM) software. The group of assessed variables confirmed codependency, as the compensated average temperature varies between the maximum and minimum temperatures and both are dictated by the behavior of the heating and cooling of the surface. These factors appear to influence the available humidity, which affects the pattern and volume of precipitation. It is known that the amount of pollutants depends not only on the emitting source, but also on the way the atmosphere acts by concentrating or dispersing them. Such scenarios are governed by atmospheric conditions, such as wind speed and direction and precipitation, mainly, and complementary by local aspects of the source's surroundings.

Therefore, the results presented, integrated with the information available at the INMET meteorological station, corroborate for models and studies closer to real cases, since the "normalized" meteorological data are peculiar to the location of the source.

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