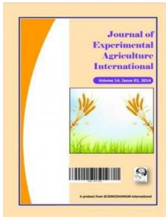

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A Comparative Study between Meteorological Data from Conventional and Automatic Weather Stations in Espírito Santo, Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RAS, WRR and MSG performed the statistical analysis of the data and wrote the first draft of the manuscript. Authors ECO, EMG, JEMP and SSB made the corrections of the draft of the manuscript, contributed significantly to the improvement of the work. All authors read and approved the final manuscript.

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ABSTRACT

Meteorological variables are mainly monitored by conventional and automatic weather stations. Presently, conventional weather stations are now being replaced by automatic weather stations or being installed to complement and improve observations in areas where there is little or no observation. In order for this permanent replacement to take place, it is necessary that the

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exposure conditions of the sensors and the methodologies used to obtain meteorological data remain standardized. This study aims to carry out a comparative study of meteorological data from the conventional and automatic weather stations in two cities, São Mateus and Vitória, located in the State of Espírito Santo, Brazil. Daily meteorological data series of maximum and minimum air temperatures, average relative humidity, rainfall and atmospheric pressure were used simultaneously from 2007 to 2016. The data from the respective stations were compared using frequency histogram, linear regression analysis, a coefficient of determination, Willmott index of agreement, bias (systematic error), relative root mean square error, confidence coefficient, and Pearson correlation coefficient. From the results, it was observed that the best data adjustments were found for maximum and minimum air temperature and atmospheric pressure, as for the other meteorological variables, there was a need for adjustment coefficients so as to ensure that the current historical series continue to exist in order to consequently replace conventional weather stations with automatic ones.

Keywords: Climate; sustainability; agrometeorology; sensors; meteorological elements.

1. INTRODUCTION

It is notable that during the analysis of the history of extreme climatic events, there is mostly some decay, especially in the last few decades [1]; this is mainly due to global warming, which has affected several aspects such as the agriculture, increase migration to urban areas and have caused enormous economic losses in Brazil and some other part of the world.

In the state of Espírito Santo, the agricultural sector has great socioeconomic importance, occupying an area of 2.3 million hectares with annual gross revenues of R$ 8.4 billion in 2014 [2]. However, this sector has suffered several losses since 2014, since high temperatures and below-normal rains have caused damages to agricultural production, even in regions with high technology in irrigation systems. This is due to the high dependence of agricultural activities on meteorological conditions, making it a determining factor agricultural production. Thus, the knowledge and availability of reliable meteorological data are fundamental to quantify the impacts on crop yield, as well as assisting in monitoring and controlling irrigation, frost prediction and for pest and disease control [3,4].

In the past, a large part of the climatic variables was obtained exclusively by conventional weather stations. In recent years, automatic weather stations have replaced the conventional ones, due to the advances in technology [5], what increases the sampling capacity, usage in difficult-to-reach places, and a faster way to monitor atmospheric conditions, which favors the application of agricultural practices with greater efficiency [6,5].

Although automatic stations are calibrated based on a standard station, a comparison of the meteorological elements in fundamental to verify if the new equipment maintain high accuracy while observing the data [7].

According to Ribeiro et al. [8], to replace a conventional weather station by an automatic one, a comparative studies between these two types of weather stations has to be conducted. It ensures the homogeneity of the data and reliably replace the conventional stations by the automatic ones, since the automatic stations are subject to greater deterioration caused by physical damage [9,5].

Researchers like Pereira et al. [4], Oliveira et al. [10], Ribeiro et al. [8] and many others have found a good agreement between meteorological variables during the comparison of data obtained by these two stations. However, as reported by Strassburger et al. [5], it is necessary that the adjustment coefficients are calculated independently in each region in which they are installed. In Espírito Santo research of this nature is still developing, and this justifies this study. Therefore, it is imperative to carry out this study, in order to ascertain the relationship between the meteorological data from conventional and automatic weather stations in the cities, São Mateus and Vitória, located in the state of Espírito Santo, Brazil so as to observe if there are errors that could compromise the permanent replacement of automatic stations by conventional ones.

2. MATERIALS AND METHODS

The study was carried out with the data obtained from two automatic weather stations (AWS) and two conventional weather stations (CWS) in operation, that belong to the network stations of the National Institute of Meteorology [11], located in two cities of the state of Espírito Santo. The geographic location of the stations, the coordinates, and the data collection period are shown in Fig. 1 and Table 1. In São Mateus, the two stations are 3023 m apart and in Vitória they are 5199 m apart. Due to the proximity of the automatic and conventional stations in each city, the influence of the microclimatic conditions for each station can be excluded.

The daily maximum and minimum air temperature (°C), average relative humidity (%), rainfall (mm) and mean atmospheric pressure (hPa) data obtained from the CWS and AWS were compared. The equipment used in the two stations, sensor elements, and their sensitivities and precision are presented in Table 2.

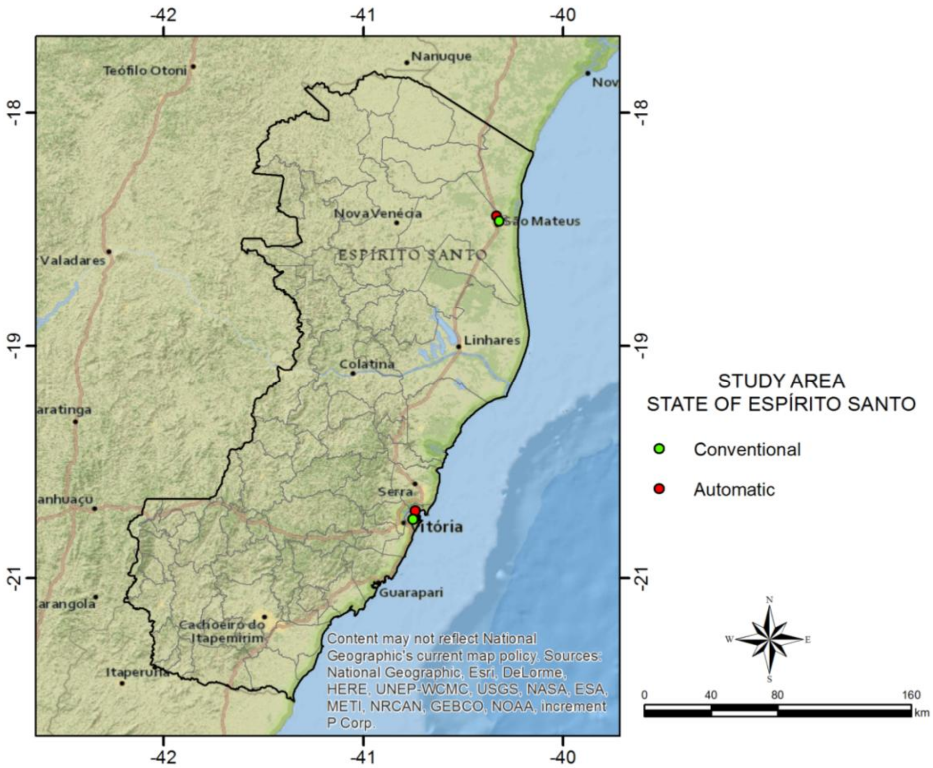

Fig. 1. Map identifying the cities with the INMET automatic and conventional weather stations used in the study

Table 1. Cities, identification of the stations, geographical coordinates and period of analysis of the meteorological data of the automatic and conventional stations of the state of Espírito Santo

City	Station (ID) *	Geographic Coordinates Lat (S)	Long (W)	Alt (m)	Period
São Mateus	A616	18º40'34"	39º51'50"	29.00	2007-2016
	83550	18º41'60"	39º51'00"	25.04	
Vitória	A612	20º16'15"	40º18'21"	9.00	2007-2016
	83648	20º19'00"	40º19'00"	36.20	

** Identification of the station in automatic stations network (upper line) and synoptic number of the conventional station (OMM) (bottom line)*

The collected data went through previous analysis for adequacy and to standardize the dates. This procedure standardized the dates in order to compare them. The days were removed when the data were not collected. Table 2 presents the comparison on the how they data were collected from CWS and AWS.

The data from CWS and AWS were compared using linear regression analysis, coefficient of determination (R²) (Eq. 1), Willmott index of agreement (d) [12] (Eq. 2), bias (systematic error, Eq. 3), relative root mean square error (RRMSE) (Eq. 4), the coefficient of confidence (c) [13] (Eq. 5) and the Pearson correlation coefficient (Eq. 6) in Table 3.

$$R^2 = r.r \tag{1}$$

$$d = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} \left(|\hat{y}_i - \bar{y}_i| + |y_i - \bar{y}_i|\right)^2} \tag{2}$$

$$Bias = n_d^{-1} \sum_{i=1}^{n} (y_i - \hat{y}_i) \tag{3}$$

$$RRMSE = \frac{\sqrt{\frac{1}{n} \times \sum_{i=1}^{n} (\hat{y}_i - y_i)^2}}{\bar{y}_i} \tag{4}$$

$$c = r * d \tag{5}$$

$$r = \frac{\sum_{i=1}^{n} [(\hat{y}_i - \bar{x}_i)(y_i - \bar{y}_i)]}{\sqrt{\sum_{i=1}^{n} (\hat{y}_i - \bar{x}_i)^2 \sum_{i=1}^{n} (y_i - \bar{y}_i)^2}} \tag{6}$$

In which:

y, $\hat{y}$, $\bar{y}$ e $\bar{x}$ *represent respectively the meteorological variable in the CWS and AWS, and the means of the CWS and AWS, n is the number of observations, and nd is the number of data pairs.*

Table 2. The meteorological elements observed in the stations, as well as the sensor element, its sensitivity and manufacturer are presented in Table 2

Station	Climate element	Sensor element	Sensibility	Maker
CWS	MaxT	Mercury	0.2°C	R Fuess
	MinT	Alcohol	0.2°C	R Fuess
	RH	Humanhair	5%	R Fuess
	Precipitation	Pluviometer	0.1 mm	R Fuess
	Atmospheric pressure	Mercury	0.1 hPa	R Fuess
AWS	MaxT	Thermistor	0.1°C	Vaisala
	MinT	Thermistor	0.1°C	Vaisala
	RH	Capacitor	3%	Vaisala
	Precipitation	Tipping bucket	0.1 mm	Vaisala
	Atmospheric pressure	Capacitor	0.1 hPa	Vaisala

**MaxT: maximum air temperature; MinT: minimum air temperature; RH: relative humidity*

Table 3. Comparison of how the meteorological data were collected from the CWS and the AWS, according to INMET

Meteorological Element	CWS	AWS
MaxT	Reading at 09:00 pm	>value of 24:00h
MinT	Reading at 9:00 am	<value of 24:00h
avgRH	$\frac{(RH_{9:00am} + \text{maxRH} + \text{minRH} + 2RH_{9:00})}{5}$	$\frac{\sum RH^*}{24}$
Pp n+1	Reading 9:00 AM	Sum of the rain collected from 9:00am to 9:00 pm+1
atmP	$\frac{(atmP_{9:00} + atmP_{3\ 00pm} + atmP_{9:00pm})}{3}$	$\frac{\sum atmP^*}{24}$

*T: air temperature; RH: relative humidity; Pp: precipitation; Patm: atmospheric pressure of air; 9:00 AM; 3:00 pm and 9:00pm are the times of the data collection in conventional stations; * measurements taken every hour*

The values of the index of performance or confidence (c) were classified according to the classification proposed by [13] (Eq. 5), as shown in Table 4.

Table 4. Values of the coefficients of performance according to Camargo and Sentelhas [13]

Value of "c"	Performance
> 0.85	Great
0.76 a 0.85	Very good
0.66 a 0.75	Good
0.61 a 0.65	Medium
0.51 a 0.60	Tolerable
0.41 a 0.50	Bad
≤ 0.40	Terrible

The relative root mean square error (RRMSE) was calculated according to Loague and Green [14], being considered excellent when RRMSE is less than 10%, good between 10 and 20%, acceptable between 20 and 30% and poor when higher than 30% [15]. Absolute frequency histograms were also performed to verify the distribution of the data between the stations.

3. RESULTS AND DISCUSSION

Fig. 2 shows the distribution of the maximum air temperature data. In the weather stations in Vitória (Fig. 2 (A), (B)), the highest frequency of the data occurred in 28-30°C range, with more than 800 days in this range for both conventional and automatic weather stations. The CWS presented 78.8% of the data in 26-34°C range, while the AWS presented 76.5% in this range.

For the weather stations in São Mateus (Fig. 2 (C), (D)), there was a higher frequency of data in the 28-30°C range, with more than 1000 observations for both type of stations. The CWS presented frequency of 87.2% of the data within the 28-30°C range while the AWS presented 56.8% of the values within the same range. These values indicate a less similar data distribution.

When the statistical values of the maximum air temperature (Table 5) were evaluated, the stations in Vitória presented a high value of the coefficient of determination, with R^2 = 0.92, a positive value for the Bias, indicating that the CWS overestimated the AWS by 0.48°C. There was also a high correlation between the data, with a value of 0.96 and a RRMSE error of 3.45%, presenting low dispersion and being considered excellent.

The maximum temperature had high index of agreement between the weather stations in Vitoria, with d=0.97, as well as a great index of performance. Although the coefficient of determination and index of agreement were below 0.90 for maximum air temperature in São Mateus (Table 5), the performance was very good with a correlation of 0.92, as well as good accuracy between the data, with RRMSE below 8%. This difference might be explained by the difference in the sensors calibration. Several authors found positive results for this meteorological element, with a performance varying from good to excellent. For example, Carvalho [16] in Teresina, Piauí, Almeida and Hermenegildo in Areia, Paraíba [17] and Ribeiro, et al. [8] in Maranhão.

For minimum air temperature (Fig. 3), the weather stations in Vitória had the highest frequency of the data within the 18-26°C range. For the CWS, 3368 days (94.4%) were within this range (Fig. 3 (A)) while for the AWS, 2826 days (79.2% of the days) fell in this range (Fig. 3 (B)). The greatest discrepancy between the data occurred between the class range of 24-26°C, in which the AWS overestimated the CWS in 498 days.

Table 5. Statistical indexes for the concordance analysis of the meteorological element maximum air temperature between the CWS and the AWS

Cities	Maximum air temperature (°C)						
	R^2	d	Bias	RRMSE (%)	r	c	Performance
Vitória	0.92	0.97	0.48	3.47	0.96	0.93	Good
São Mateus	0.84	0.84	1.99	7.46	0.92	0.77	Very Good

R^2 = coefficient of determination; r = Pearson's correlation; Bias = bias; RRMSE = relative root mean square error; d = Willmott index of agreement and c = index of performance

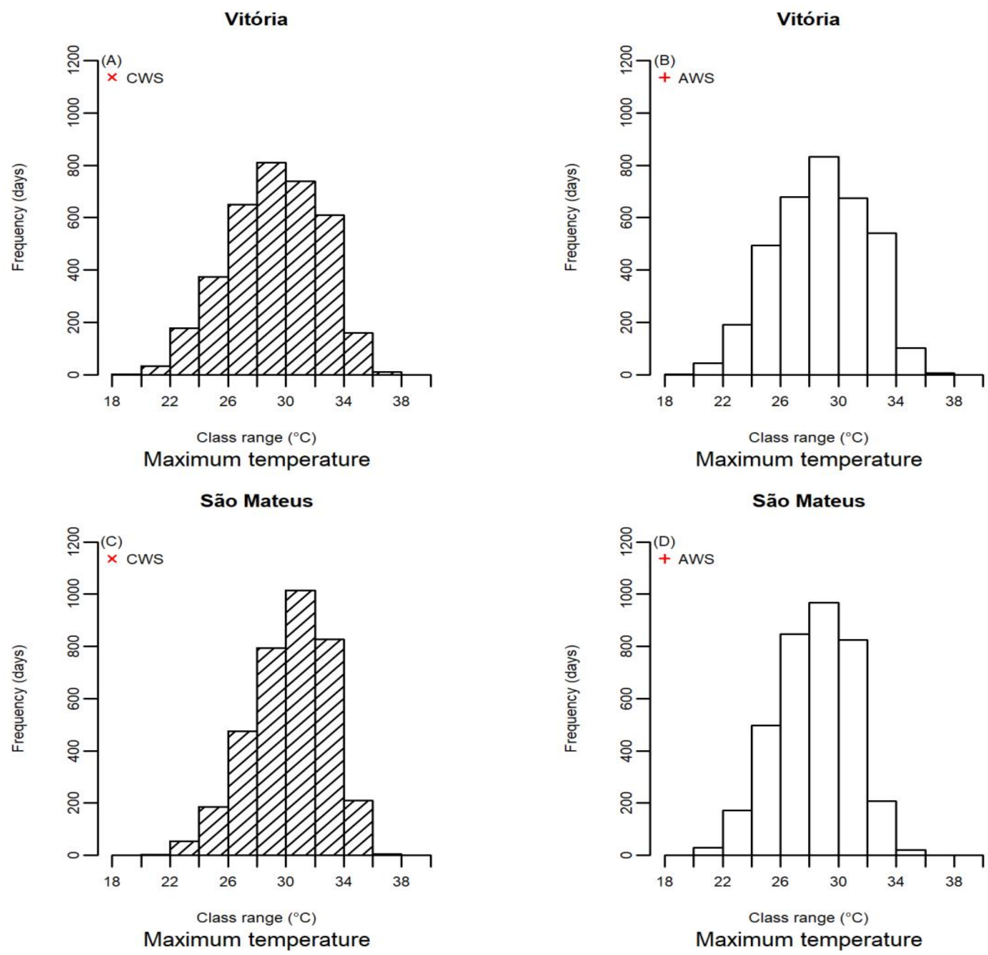

Fig. 2. Absolute frequency histogram of maximum temperature data for conventional (CWS) and automatic (AWS) weather stations for the cities, Vitória (A, B) and São Mateus (C, D)

The stations located in São Mateus presented a homogeneous data distribution, and the CWS presented a frequency of 3086 days in the range of 18-26°C (Fig. 3 (C)), which represents 86.1%, while the AWS in this same class range presented a frequency of 3086 days (Fig. 3 (D)), that is, 81.0% of the data.

Vitória and São Mateus presented overestimated values for the CWS, as observed by the bias (Table 6). The temperatures that were overestimated in the conventional weather stations is also observed by Hermenegidio [17] in Areia, Paraíba, in which the authors state that this is due to the sensitive elements, and the same result was observed for this study.

A high correlation was observed for the minimum air temperature between the weather stations in Vitória, with a coefficient of determination R^2 = 0.79 and index of agreement of 0.87. Although the values of the coefficient of determination and the index of agreement for Vitória were below 0.90, the comparison of the stations obtained a very good performance and an error of 8.36% for the RRMSE.

It is also observed in Table 6 that the weather stations in São Mateus presented a high agreement between the data of minimum temperature, together with the RRMSE below 5%, that is, excellent, and with an optimum performance. The values found for the coefficient of determination and for the correlation were 0.85 and 0.92, respectively.

According to Fig. 4, the relative humidity presented a close distribution between the weather stations. It is observed in the weather stations located in Vitória that between the class range of 65-85% there was an absolute frequency of 1993 days for the CWS (Fig. 4 (A)),

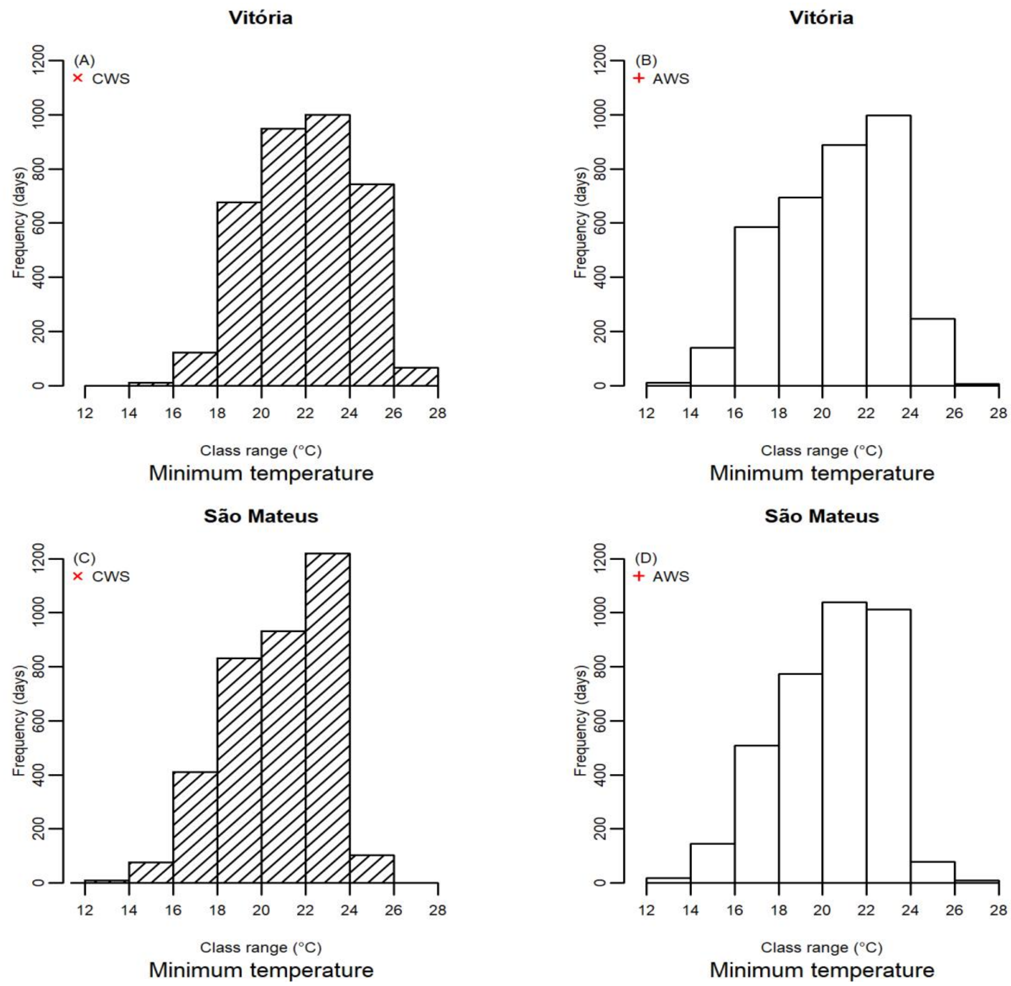

Fig. 3. Absolute frequency histogram of minimum temperature data for conventional (CWS) and automatic (AWS) weather stations for the cities, Vitória (A, B) and São Mateus (C, D)

Table 6. Statistical indexes for the concordance analysis of the meteorological element minimum air temperature between the CWS and AWS

Cities	Minimum air temperature (°C)						
	R^2	d	Bias	RRMSE (%)	r	c	Performance
Vitória	0.79	0.87	1.41	8.36	0.89	0.77	Very Good
São Mateus	0.85	0.96	0.27	4.67	0.92	0.88	Good

R^2 = coefficient of determination; r = Pearson's correlation; Bias = bias; RRMSE = relative root mean square error; d = Willmott index of agreement and c = index of performance

representing 84.7% of the data, whereas in this same range, AWS presented 2009 days (Fig. 4 (B)), that is, 85.4% of the data.

The CWS located in São Mateus presented a frequency of 2460 days in the class range of 65-85% (Fig. 4 (C)), which represents 81.9%, while the AWS in that same class range presented a frequency of 2324 days (Fig. 4 (D)), which represents 77.3%. In spite of this proximity between the data distribution, it can be observed in Table 7 by the statistical indexes, that the R² values for Vitória and São Mateus presented values below of 0.70.

For relative humidity (Table 7), a good agreement was observed in the weather stations located in Vitória, showing a correlation of 0.82 and good performance. Regarding the RRMSE, a value of 5.51% was

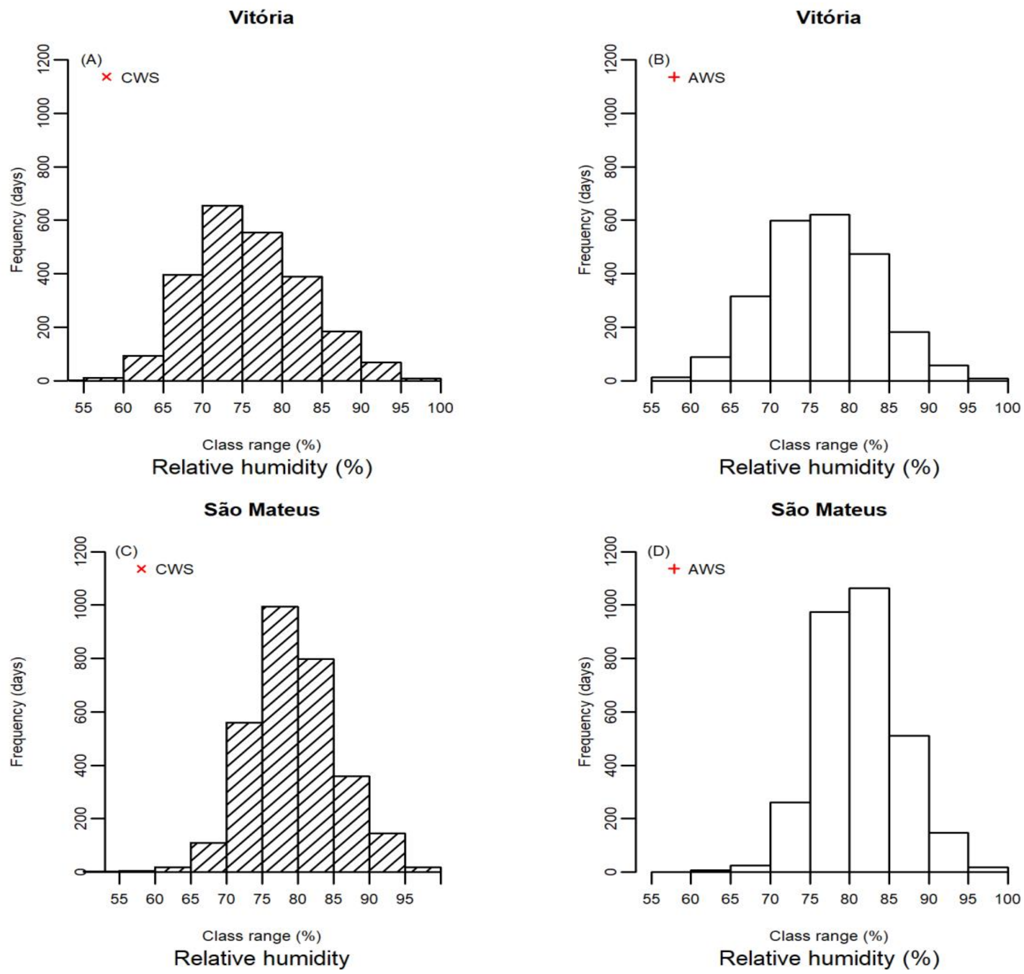

Fig. 4. Absolute frequency histogram of the relative humidity data for the conventional (CWS) and automatic (AWS) weather stations for the cities, Vitória (A, B) and São Mateus (C, D)

observed, which can be classified as excellent, according to Jamieson et al. [15], and with underestimated values at -0.51% when compared to the AWS.

Statistical indexes for the weather stations in São Mateus (Table 7) showed a behavior very close to the weather stations in Vitória for the relative humidity. A high agreement between the data was observed, with correlation values of 0.81, and with good performance. When the RRMSE was evaluated, it had values below 5%, that is, an error considered low, and with underestimated values for the CWS of -1.78%. The differences observed between the CWS and AWS in Vitória and São Mateus may be due to the type of sensitive element of the instruments, which in the automatic weather station is a capacitor and in the conventional, a thermohygrograph.

The atmospheric pressure data distribution is shown in Fig. 5, in which there was an absolute frequency of 2697 days for the CWS (Fig. 3 (A)) for the class range of 010-1020 hPa for the weather stations in Vitória (Fig. 5 (A), (B)), representing 75.7% of the data, whereas in this same range, AWS presented 2807 days (Fig. 5 (B)), 78.8% of the data. Although this class range presented close values, when the range with the highest frequency (1010-1015 hPa) was evaluated, a very large difference was observed, with AWS overestimating in this range when compared to CWS in 639 days.

For the weather stations in São Mateus (Fig. 5 (C), (D)), there was a higher frequency in the range of 1010-1015 hPa, with more than 1600 observations in conventional and automatic weather stations, respectively. AWS showed a

Table 7. Statistical indexes for the analysis of the concordance of the meteorological element relative humidity between the CWS and AWS

Cities	Relative humidity (%)						
	R^2	d	Bias	RRMSE (%)	r	C	Performance
Vitória	0.68	0.90	-0.51	5.51	0.82	0.75	Good
São Mateus	0.66	0.87	-1.78	3.94	0.81	0.71	Good

R^2 = coefficient of determination; r = Pearson's correlation; Bias = bias; RRMSE = relative root mean square error; d = Willmott index of agreement and c = index of performance

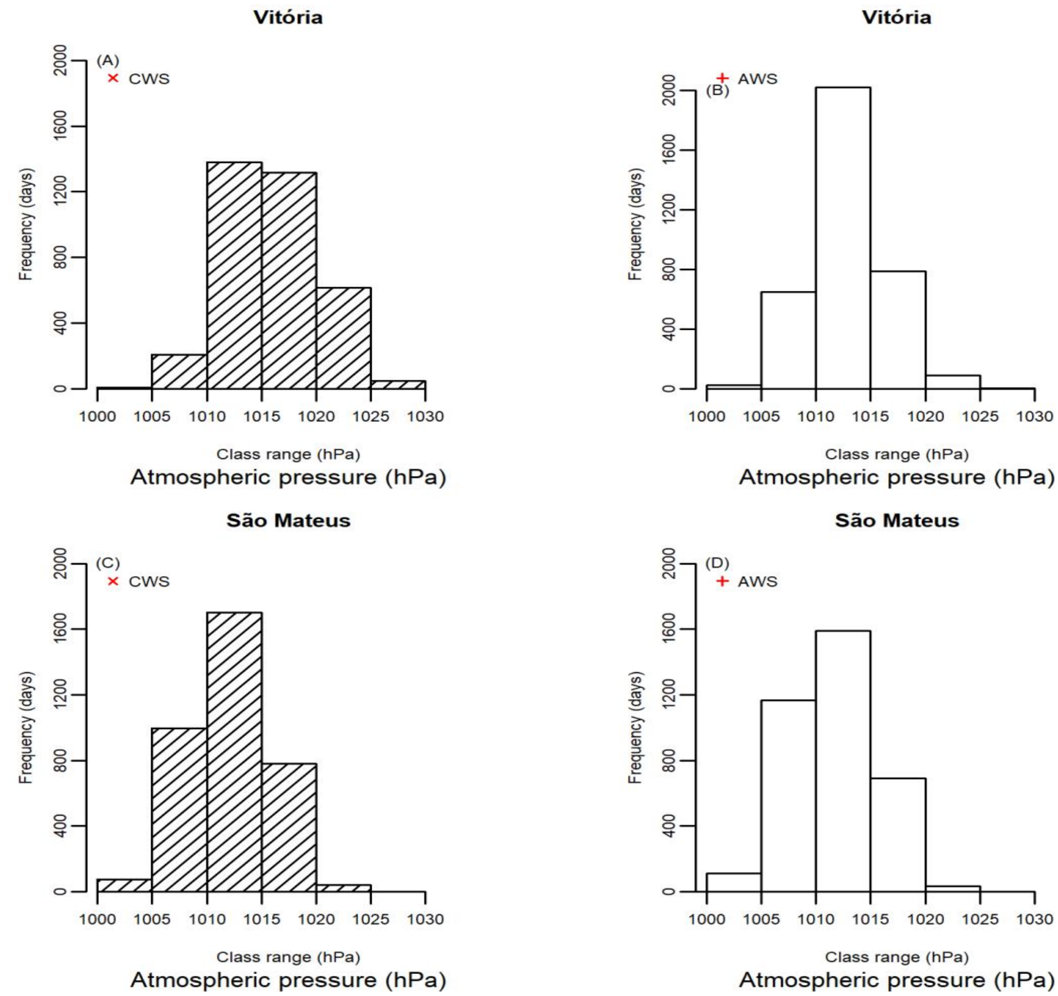

Fig. 5. Absolute frequency histogram of atmospheric pressure data for conventional (CWS) and automatic weather stations (AWS) in Vitória (A, B) and São Mateus (C, D)

frequency of 75.1 and 76.7%, respectively, in the class range of 1005-1010, thus showing a very homogeneous data distribution.

From the statistical indexes in Table 8, there are notable differences in the performance of the stations according to where they are located. The weather stations in Vitória had a low value in the coefficient of determination, with a value of R^2 = 0.65, with a positive value for the Bias, indicating that the CWS overestimated the AWS by 3.09 hPa. The index of agreement presented a value of 0.76 with a correlation of 0.81, and index of performance classified as medium. This greater difference observed in the weather stations in Vitória may be due to the difference in

Table 8. Statistical indexes for the concordance analysis of the meteorological element atmospheric pressure between the CWS and the AWS

Cities	Atmospheric pressure (hPa)						
	R^2	d	Bias	RRMSE (%)	r	c	Performance
Vitória	0.65	0.76	3.09	0.38	0.81	0.61	Medium
São Mateus	0.92	0.97	0.45	0.12	0.96	0.93	Great

R^2 = coefficient of determination; r = Pearson's correlation; Bias = bias; RRMSE = relative root mean square error; d = Willmott index of agreement and c = index of performance

Table 9. Statistical indexes for the concordance analysis of the meteorological element precipitation between the CWS and the AWS

Cities	Precipitation (mm)						
	R^2	d	Bias	RRMSE (%)	r	C	Performance
Vitória	0.51	0.84	-0.23	181.68	0.71	0.60	Tolerable
São Mateus	0.27	0.69	0.17	220.01	0.52	0.36	Terrible

R^2 = coefficient of determination; r = Pearson's correlation; Bias = bias; RRMSE = relative root mean square error; d = Willmott index of agreement and c = index of performance

the altitude between the two weather stations, resulting in lower values of atmospheric pressures in the AWS due to the higher air rarefaction caused by the higher altitude.

In São Mateus, low dispersion of data is observed, with R2 of 0.92 and index of agreement of 0.97. It is also observed overestimated in the conventional weather station of 0.45 hPa, and an error below 1%. The overestimated observed in the conventional weather stations for the atmospheric pressure was also observed by Souza et al. [18], in Maringá, Paraná.

The statistical coefficients for concordance analysis of the precipitation data between the two stations can be observed in Table 9. Both cities presented high errors and low dispersion of data. In Vitória an underestimation of the conventional weather stations is observed, whereas São Mateus presented overestimated values.

The highest difference observed in the weather stations in Vitória and São Mateus is mainly due to the distance between the stations, being 5 and 3 km for Vitória and São Mateus respectively, which was also observed by Sanchez-Moreno et al. [19] in the Island of Santiago, Cape Verde, at nearby stations. According to Mellaart [20], rainfall presents high spatial variability even at relatively small distances (1 km), corroborating with the results found in this study.

Low correlation and poor performance were observed in the weather stations in Vitória, with c = 0.60. While evaluating the weather stations in São Mateus, poor performance was observed, with an RRMSE value of 220%. The high RRMSE values can be due to the outliers, which greatly increase the margin of error of this statistic.

4. CONCLUSION

The best data adjustments were found for maximum and minimum temperatures and atmospheric pressure, in which the atmospheric pressure is only for São Mateus.

The results were intermediate for the relative humidity, and was not good enough for the atmospheric pressure and precipitation for the weather stations in Vitória, with greater differences between the CWS and AWS, due to the difference of the geographic position where the CWS and AWS are located.

Overestimations were observed in the conventional weather stations in all the variables, except for the relative humidity of the two cities and precipitation in Vitória.

The data analysis indicated the need for adjustment coefficients ensure that the existing historical series continues to exist and, consequently, to replace conventional weather station by the automatic weather station in São Mateus and Vitória.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. What is mareng And Fatty Clim The Brasil Revista Usp. To. 2014;103:25-32.
2. Dadalto GG, Silva AES, Costa EB, Galvêas PAO, Loss WR. Transformações da agricultura capixaba: 50 anos Cedagro; Incaper; Seag: Vitória. 2016;128.
3. Fernandes ALT, Silva FC, Folegatti MV. São Paulo in the United States of America for Automated Explosives In: Congresso Brasileiro de Agrometeorologia, Campina Grande. Anais. Campina Grande: Sociedade Brasileira Agrometeorologia / UFPB. 1995;1-3.
4. Pereira LMP, Caramori PH, Ricce WS, Caviglione JH. Analyzing the comparative analysis of meteorological issues, including the conveniences and automatics in Londrina - PR. Semina: Ciências Agrárias. 2008;29(2):299-306.
5. Strassburger AS, Menezes AJEA, Perleberg TD, Eicholz ED, Mendez MEG, Schöffel ER. Compatibility of the meteorological and ecosystems that occur in the temperate region. Revista Brasileira de Meteorologia. 2011;26(2):273-278.
6. Tagliaferre C, Jesus SRA, Rocha FA, Santos LC, Silva CS. Eunápolis, BA in evapotranspiration for the differential metadations of the institute. Revista Caatinga. 2010;23(1):103-111.
7. Teramoto ÉT, Carvalho LGD, Dantas AAA. Comparison between values of air temperature average obtained by conventional station and automatic station and analysis of estimations of air temperature in Lavras, MG, Brazil. Ciência e Agrotecnologia. 2009;33:1798-1803.
8. Ribeiro AA, Andrade Júnior AS, Silva EM, Simeão M, Bastos EA. Comparisons of meteorológicos are compromised by the composition and automation of the Piauí, Brasil. Irriga. 2017;22(2):220-235.
9. Almeida HA, Souza JA, Alcantara HM. Analyzing the comparative analysis of meteorolysis of the metaolorogy, and not the conventional and automated metabolic system. Revista Brasileira de Agrometeorologia. 2008;16(1):58-66.
10. Oliveira AD, Almeida BM, Cavalcante JEG, Espinola JS, Vieira RYM. Comparado de dados meteorológicos are also known as composition and automatics in Jaboticabal-SP. Revista Caatinga. 2010;23(4):108-114.
11. INMET - Instituto Nacional de Meteorologia, Brasília, DF, Brasil. Disponível. Available:http://www.inmet.gov.br/portal/ (Acesso em: 10 de dezembro de 2017)
12. Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink KM, Legates DR, O'donnell J, Rowe CM. Statistics for the evaluation and comparison of models. Journal of Geophysical Research. 1985;90(5):8995-9005.
13. Camargo AD, Sentelhas PC. Evaluation of evapotranspirants from Brazilian states of Sao Paulo, Brazil. Revista Brasileira de Agrometeorologia. 1997;5(1):89-97.
14. Loague K, Green RE. Statistical and graphical methods for evaluating solute transport models: Overview and application. Journal of Contaminant Hydrology. 1991;7:51-73.
15. Jamieson PD, Porter JR, Wilson DR. A test of the computer simulation model ARC-WHEAT on wheat crops grown in New Zeland. Field Crops Research. 1991;27:337-350.
16. Carvalho MWL. The composition of the meteorológicos is also known as the Eclectic and Automated Teresina-PI. 53f Dissertação (Mestrado em Agronomia: Producão Vegetal) - Universidade Federal do Piauí, Teresina; 2014.
17. Almeida HA, Hermenegidio GMS. Metaorológicos of metaorológicos compounds and meteorological events and automations of comparations. Revista Brasileira de Climatologia. 2013;12(9):32-47.
18. Souza IA, Galvani E, Assunção HF. Regions of Maringa in the Establishment of

the Metaorolocic Acta Scientiarum Technology. 2003;25(2):203-207.
19. Sanchez-moreno JF, Mannaerts CM, Jetten V. Influence of topography on rainfall variability in Santiago Island, Cape Verde. International Journal of Climatology. 2014;34(4):1081-1097.
20. Mellaart EAR. Small-scale spatial rain distribution: The effect of temporal and spatial rain distribution on drought and crop yield at village level. Nelspruit: Institute for Soil, Climate and Water. 1999;18.

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