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VALIDATION OF AIR TEMPERATURE DATA OBTAINED FROM THE ERA5-LAND REANALYSIS IN THE STATE OF PERNAMBUCO, BRAZIL

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ABSTRACT: This research aimed to validate the estimated monthly air temperature (°C) from the ERA5-Land meteorological reanalysis with the corresponding data registered in 2019 by the automatic weather stations (AWS) belonging to the National Institute of Meteorology. The comparison between the data measured and those estimated was performed using statistical indices of accuracy and precision. The errors on the monthly average air temperature estimates by ERA5-Land showed the greatest precision for the municipality of Garanhuns (R^2=0.99), while the smallest was observed in Cabrobó (R^2=0.79). The highest and lowest RMSE values were found in Caruaru (2.1°C) and Recife (0.3°C), respectively. The MBE showed that the values obtained by ERA5 in the Floresta, Ouricuri, Cabrobó, Salgueiro, and Ibimirim underestimated those of the AWS's (-0.5°C to -1.3°C). On the other hand, in Caruaru, Garanhuns, and Serra Talhada the values of the AWS's were overestimated (MBE = 2.1°C, 0.5°C, and 0.2°C, respectively). In the other municipalities, the data were characterized by relatively greater accuracy. The average temperature estimated by ERA5, on a monthly scale, proves to be feasible to replace the measured registered by the examined AWS's.
KEYWORDS: meteorology, automatic weather stations, ECMWF

VALIDAÇÃO DOS DADOS DE TEMPERATURA DO AROBTIDOS DA REANÁLISE ERA5-LAND NO ESTADO DE PERNAMBUCO

RESUMO: Objetivou-se validar os dados de temperatura do ar (°C) estimados virtualmente pela reanálise meteorológica ERA5-Land com base nos dados medidos em 2019 por estações meteorológicas automáticas (AWS) pertencentes à rede do Instituto Nacional de Meteorologia.

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A comparação entre os dados medidos e os estimados foi realizada com índices estatísticos de exatidão e precisão. Os erros das estimativas média mensal da temperatura do ar pelo ERA5-Land, apresentaram maior precisão para a cidade de Garanhuns (R^2=0,99), enquanto a menor observou-se em Cabrobó (R^2=0,79). O maior e o menor valor de RMSE foram encontrados em Caruaru (2,1°C) e Recife (0,3°C), respectivamente. Os resultados de MBE apontaram que, os valores obtidos pelo ERA5 em Floresta, Ouricuri, Cabrobó, Salgueiro e Ibimirim subestimaram os valores das AWS's (-0,5°C a -1,3°C). Por outro lado, em Caruaru, Garanhuns e Serra Talhada os valores das AWS's foram superestimados (MBE=2,1°C, 0,5°C e 0,2°C, respectivamente). Nas demais cidades, os dados foram caracterizados com elevada precisão. A temperatura média do ar estimada pelo ERA5, numa escala mensal, demonstra ser viável na substituição dos dados registrados nas AWS's analisadas.

PALAVRAS-CHAVE: meteorologia, estações meteorológicas automáticas, ECMWF

INTRODUCTION

The agriculture activities represent one of the main economic gains in the state of Pernambuco, with greater emphasis on the cultivation of sugarcane and irrigated fruit orchards. In this activity, air temperature intervenes directly, and changes in this component can cause economic and social reflexes (LIMA et al., 2001). The impacts of these variations may affect the natural ecosystems and compromise the preservation of agricultural systems.

Orbital remote sensing has the advantage of collecting information from a specific region without physical contact. The applicability of remote data to geographic information systems (GIS) stands out for the ability to monitor the physical-hydric characteristics on the surface. The multitemporal mathematical modeling by satellite aims to supply the absence of information and climatic/environmental data mainly in areas of difficult access without monitoring by surface weather stations neither local measurement equipment. Observations based on atmospheric models and remote processes play a central role due to speed and efficiency at the applications to be carried out on a local, regional, and global scale, mainly in studies related to the effects of climate change, the climate projections, and the management of water resources (ZHANG et al ., 2018; CAO et al., 2020; MARENGO et al., 2020).

Thus, the difficulty of obtaining surface meteorological variables and homogeneous historical series with consistent data in Brazil, the atmospheric reanalysis products such as ERA5-Land stand out, which are widely validated worldwide and used to monitor climatic conditions/environmental and hydrological. For example, research conducted on different

reanalysis products, including temperature, in India (MAHTO & MISHRA, 2020), also the study on the effects of climate change in the incorporation of reanalysis data and MODIS sensor data, observing a warming trend in Antarctica (RETAMALES-MUÑOZ et al., 2019) and in the accuracy analysis of the European Center for Medium-Range Weather Forecast (ECMWF) data set, aiming to evaluate the decennial rainfall estimates and maximum and minimum air temperature for the state of São Paulo, Brazil (MORAES et al., 2012).

Air temperature variations, when measured correctly, can represent a strategic tool, which can reduce the adverse effects of climate change (CARLOS et al., 2019). The use of air temperature data retrieved from global atmospheric models, such as those downloadable from the ECMWF, and derived from various meteorological sources and satellites can be considered a replacement of the ground measurements. Aparecido et al. (2019), evaluating the accuracy of average air temperature (°C) from the ERA-Interim reanalysis in the state of Paranáfor a period often-year (from 1989 to 2014), found under- and over-estimation of the estimated data compared to the corresponding measured on the ground.

Thus, the objective of this study was to evaluate the accuracy of the monthly air temperature data estimated by ERA5-Land in 2019 in the state of Pernambuco, Brazil, when compared to those automatically obtained by weather stations (AWS) installed on the ground, to subsidize evaluations in areas with missing meteorological information and to support researches on crop monitoring and yield forecast.

MATERIAL AND METHODS

The values of average monthly air temperature (°C), from January 1st to December 31st, 2019, were obtained by considering the data registered by thirteen automatic weather stations (AWS) belonging to the network of the National Meteorological Institute (INMET) of the state of Pernambuco. This state, with an area of 98,146 km² in northeast brazil, includes regions characterized by humid and semi-arid tropical climates with six climates classes: Am, Aw, BWh, BSh, Csa, and Csb. The database retrieved from ERA 5-Land was generated for the same locations where the AWS's were installed.

The map of figure 1 shows the spatial distribution of AWS in the municipalities of Arcoverde, Cabrobó, Caruaru, Floresta, Garanhuns, Ibimirim, Ouricuri, Petrolina, Salgueiro, Serra Talhada, Palmares, Recife, and Surubim, with the respective codes following the codification of the World Meteorological Organization. The on-ground weather stations are located in different climatic regions characteristic of the state. The data originated from ERA5-

Land were on a monthly scale, with a spatial resolution of 0.10°, corresponding to a squared grid of about 11 x 11 km, relating to 811 points of virtual stations at the state of Pernambuco.

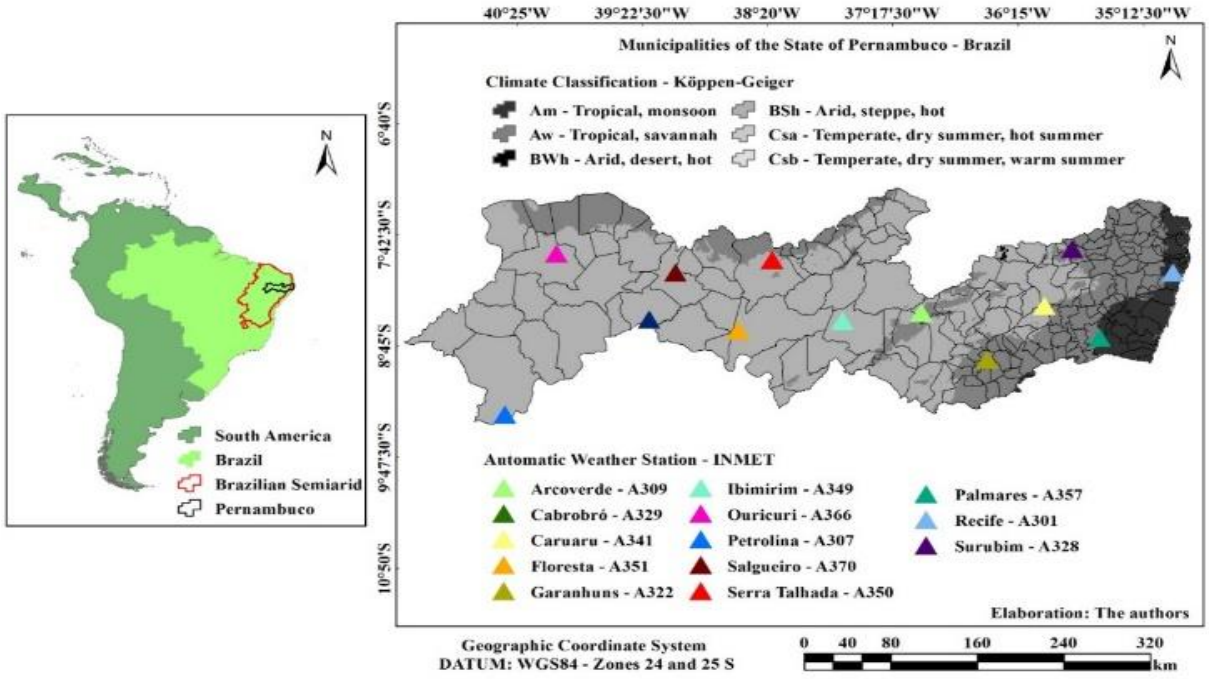

Figure 1. Spatial distribution of automatic weather stations of the National Institute of Meteorology (INMET) in the state of Pernambuco, Brazil.

The ERA5-Land reanalysis monthly air temperatures were converted from Kelvin to degree Celsius. The series temporal of maps with the monthly temperature estimated by ERA5-Land was obtained using GIS techniques by the reading netCDF files (format file of ERA5-Land data) without reclassifying the pixel original value, which allowed to keep the value original pixel. The comparison between the ERA5-Land estimations with those measured by the AWS was performed using the root means square error (RMSE) and the mean bias error (MBE). A graphical analysis of the dispersion around the 1:1 line was then carried out and the determination coefficients (R^2) were generated. For an analysis more accurate and regional, the error between temperature monthly estimated by ERA5-Land and the measured by AWS were stratified by macroregions of the Pernambuco: Coastal/Forest, Agreste, and Semiarid Zone.

RESULTS AND DISCUSSION

The average monthly temperature estimated by ERA5-Land shows a certain spatial and temporal variability in the state of Pernambuco (Figure 2). The pixel color shows that in the coastal and forest regions the temperature is quietly low, in a range of 19.3 to 24.8 °C, in

contrast with the semiarid area where the temperature increases up to 30.2 °C most of the year (Figure 2).

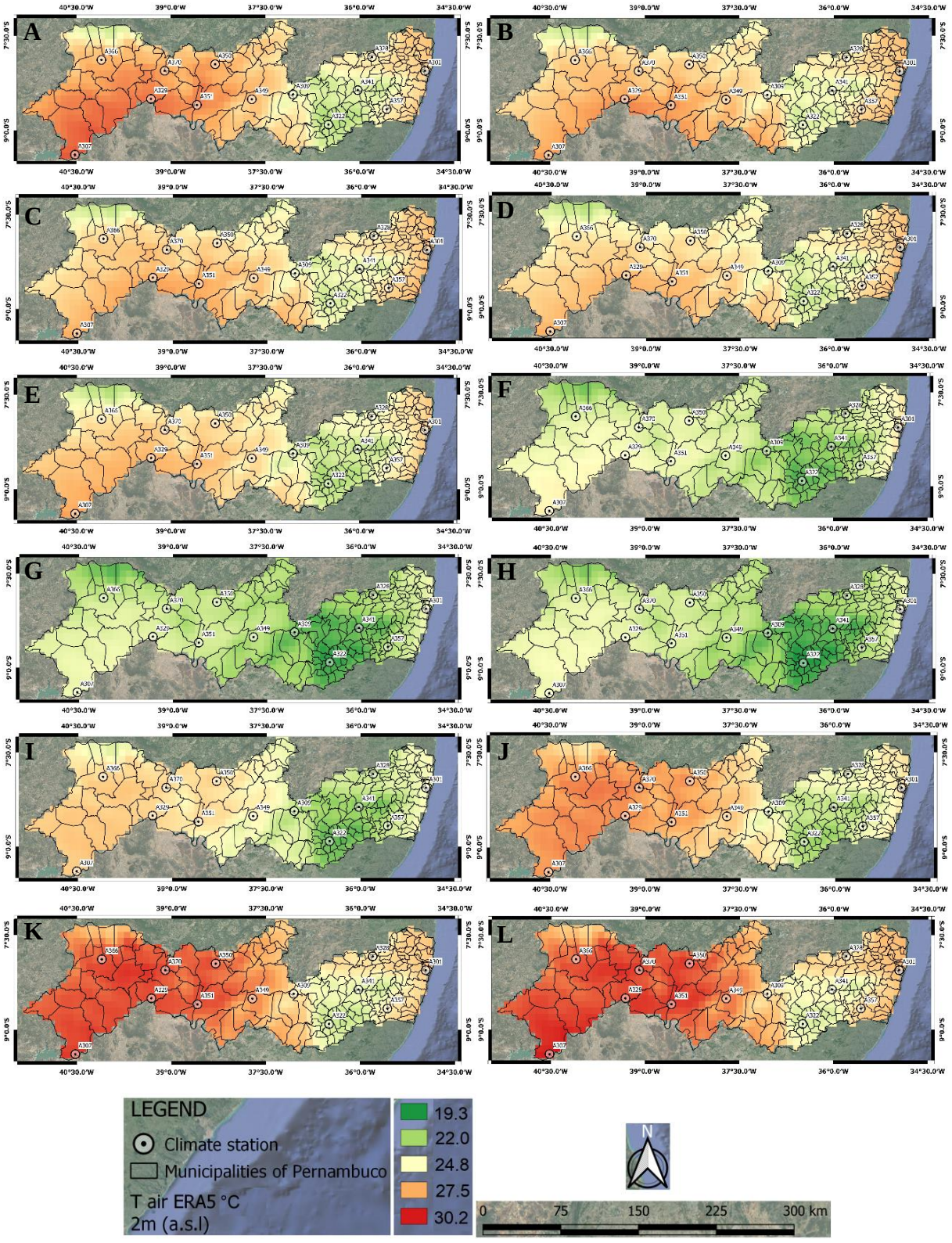

Figure 2. Spatial and temporal variability of the monthly temperature (°C) estimated by ERA5-Land in the state of Pernambuco. January (A); February (B); March (C); April (D); May (E); June (F); July (G); August (H); September (I); October (J); November (K); December (L).

The graphs obtained from the stratification of the error by the macro-regions in Pernambuco show different trends as a function of them (Figure 3). The error of monthly temperature estimated by ERA5-Land associated with the microregion semiarid although lows (<1.0 °C) were higher compared to other macro-regions a long of year, independent of the seasons, with the trend to underestimate the temperature measured by ground stations (Figure 3A). On the other hand, in the Agreste Zone can be noted a light reduction in errors, the exception of Caruaru, and a tendency to overestimate the measured data (Figure 3B). And, finally at the Coastal/Forest Zone the smallest errors were found, in general, < 0.4 °C (Figure 3C).

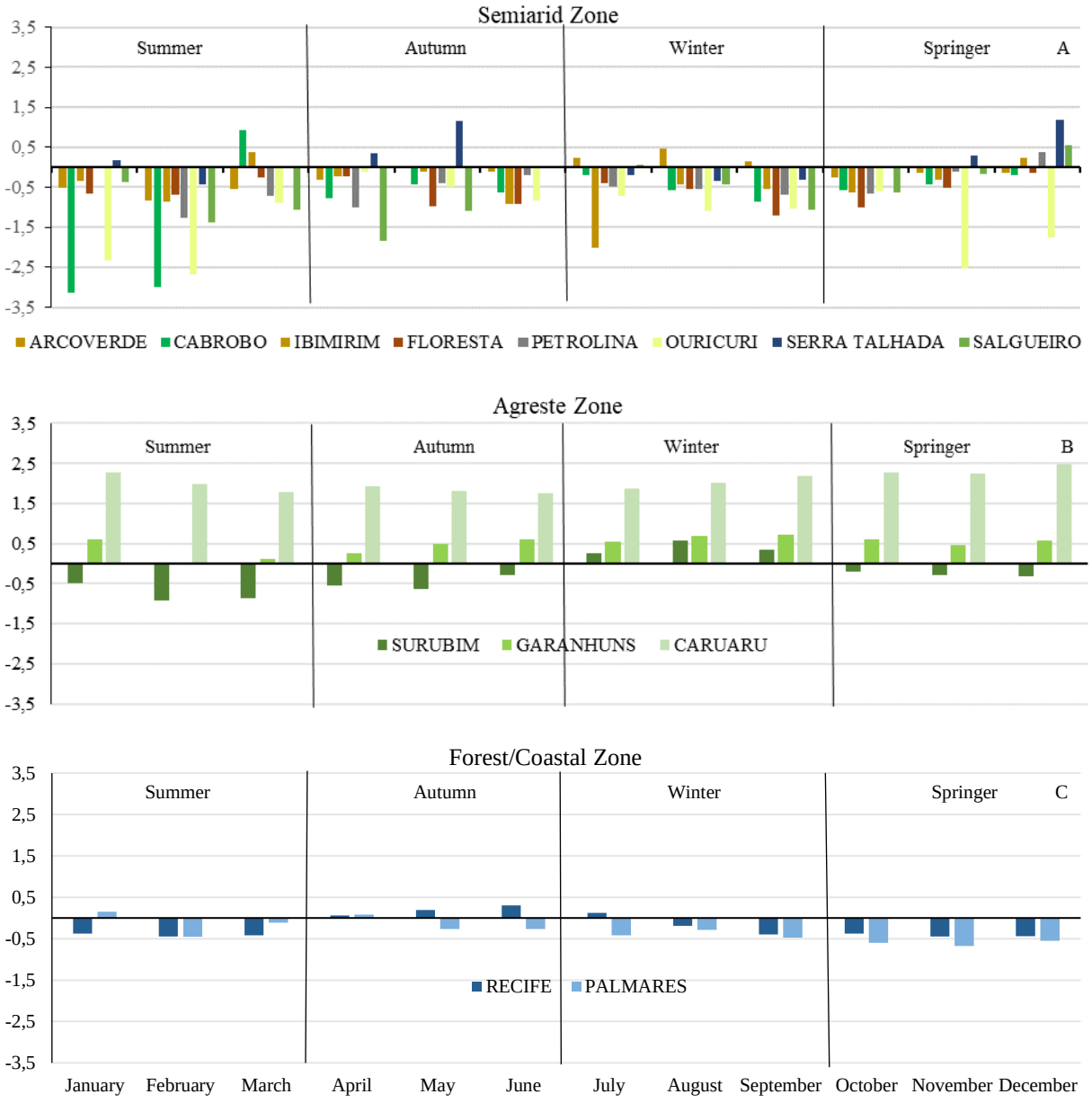

Figure 3. Monthly temperature (°C) estimated by ERA5-Land stratified by macroregions of the Pernambuco: Semiarid (A), Agreste (B), and Coastal/Forest Zone (C).

The estimated monthly average air temperatures (°C) were quite similar to the measured ones. The graphical analysis of figure 4 shows that the ERA5-Land data underestimated the corresponding measured for the municipalities of Floresta, Ouricuri, Cabrobó, Salgueiro, and Ibimirim. On the other hand, it can be noticed that monthly air temperatures retrieved by ERA5-Land overestimated the corresponding values for the municipalities of Caruaru, Garanhuns, and Serra Talhada. For the municipalities of Arcoverde, Recife, Surubim, Palmares, and Petrolina, the points are very close to the 1:1 straight line, confirming the suitability of ERA5-Land to well estimate the monthly average temperature.

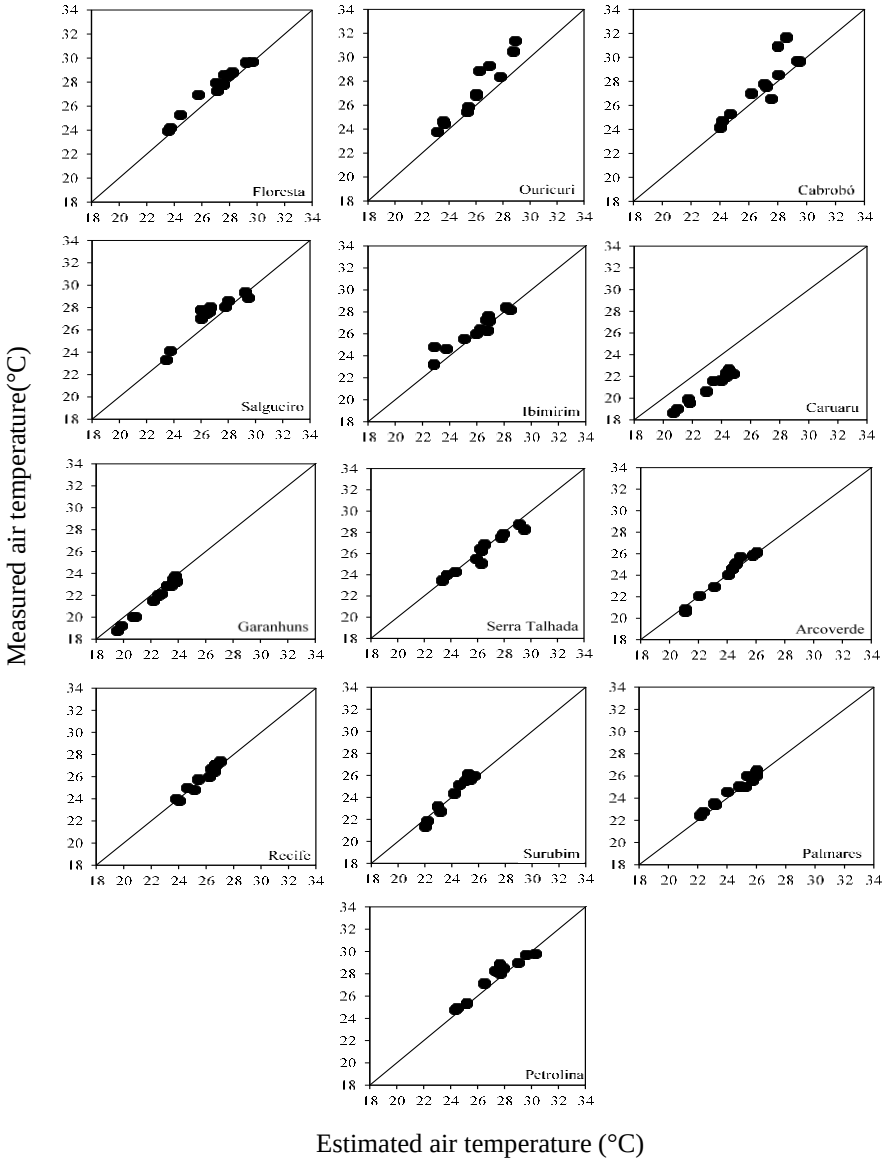

Figure 4. Relationship between monthly air temperature (°C) measured by AWS and the corresponding estimated by ERA5-Land in municipalities of the state of Pernambuco, Brazil.

The results in terms of R^2 showed that the highest precision for the municipality of Garanhuns (R^2=0.99), whereas the lowest was observed in Cabrobó (R^2=0.79) (Table 1). The

highest and lowest RMSE values were found in the municipalities of Caruaru (2.1°C) and Recife (0.3°C), respectively.

Table 1. Statistical indexes for the monthly average air temperature (°C) between ERA5-Land and AWS for the examined municipalities of Pernambuco state, Brazil.

Indices	Municipalities						
	Floresta	Ouricuri	Cabrobó	Salgueiro	Ibimirim	Caruaru	Garanhuns
R^2	0,97	0,91	0,79	0,87	0,91	0,98	0,99
RMSE (°C)	0,7	1,5	1,4	0,9	0,8	2,1	0,5
MBE (°C)	-0,6	-1,3	-0,8	-0,6	-0,5	2,1	0,5
Indices	Municipalities						
	Serra Talhada	Arcoverde	Recife	Surubim	Palmares	Petrolina	
R^2	0,93	0,98	0,95	0,98	0,96	0,95	
RMSE(°C)	0,5	0,4	0,3	0,5	0,4	0,6	
MBE	0,2	-0,2	-0,2	-0,3	-0,3	-0,5	

R^2: Coefficient of determination; RMSE: root mean square error; MBE: Mean bias error.

The results of the systematic error measurement (MBE) confirmed the graphical analysis, regarding the differences between the ERA5-Land estimations and the measured values; in particular, the MBE values for the municipalities Caruaru, Garanhuns, and Serra Talhada overestimated the measured, with deviations of 2.1°C, 0.5°Cand 0.2°C, respectively. On the other hand, in the municipalities of Floresta, Ouricuri, Cabrobó, Salgueiro, and Ibimirim, the ERA5-Land data resulted slightly underestimated, with deviations ranging between -0.5°Cand -1.3°C. In the municipalities of Arcoverde, Recife, Surubim, Palmares, and Petrolina, the data were quite similar and aligned to the 1:1 line.

Similar results were found in studies carried out in other regions of Brazil, where the feasibility of estimating meteorological elements from global atmospheric models, such as the ECMWF, was confirmed with moderate to high accuracy in terms of water deficiency, average, minimum, and maximum air temperature and precipitation (MORAES et al., 2012; APARECIDO et al., 2019; VALERIANO et al., 2019; MORAES et al., 2020).

CONCLUSIONS

The data obtained from the automatic weather stations showed the accuracy of the ERA5-Land reanalysis data in thirteen municipalities of the state of Pernambuco, Brazil. The municipalities that showed the highest and the lowest performance in terms of estimated monthly air temperature were Recife and Caruaru, respectively. The highest and lowest R^2 values were obtained in Garanhuns and Cabrobó, respectively.

The analysis of the error a long of 2019 did not show a clear relationship as a function of months neither seasons. However, this trend was identified by stratifying the state of

Pernambuco in macro-regions, where the semiarid zone showed the highest values of errors (<1.0 °C) and the tropical zone (coastal/forest) generated lower errors (<0.4 °C).

The average air temperature, on a monthly scale, estimated by ERA5-Land, at the standard resolution of 0.1°, proves to be accurate enough and suitable to provide evaluations in areas with missing meteorological information.

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