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Microscale Wind Assessment, Comparing Mesoscale Information and Observed Wind Data

José Rafael Dorrego Portela [1,2], Geovanni Hernández Galvez [3,*], Quetzalcoatl Hernandez-Escobedo [4,*], Ricardo Saldaña Flores [5], Omar Sarracino Martínez [3], Orlando Lastres Danguillecourt [2], Pascual López de Paz [2] and Alberto-Jesus Perea-Moreno [6,*]

[1] Wind Energy Department, Campus Tehuantepec, Universidad del Istmo, Ciudad Universitaria S/N, Barrio Santa Cruz, 4a. Sección Sto. Domingo Tehuantepec, Tehuantepec 70760, Oaxaca, Mexico
[2] Universidad de Ciencias y Artes de Chiapas, Libramiento Norte Poniente 1150, Lajas Maciel, Tuxtla Gutiérrez 29035, Chiapas, Mexico
[3] Universidad Popular de la Chontalpa, Carretera Cárdenas-Huimanguillo km 2. Ranchería Paso y Playa, Cárdenas 86556, Tabasco, Mexico
[4] Escuela Nacional de Estudios Superiores Unidad Juriquilla, Universidad Nacional Autónoma de Mexico, Juriquilla 76230, Queretaro, Mexico
[5] Instituto Nacional de Electricidad y Energías Limpias, Calle Reforma #113, Col. Palmira Cuernavaca, Cuernavaca 62490, Morelos, Mexico
[6] Departamento de Física Aplicada, Universidad de Córdoba, ceiA3, Campus de Rabanales, 14071 Córdoba, Spain
* Correspondence: geovanni.hdez@upch.mx (G.H.G.); qhernandez@unam.mx (Q.H.-E.); aperea@uco.es (A.-J.P.-M.)

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Abstract: One of the most common problems in wind resource assessment is that measured data are not always available at the site of interest. That is why, in several studies, reanalysis data have been used as an alternative, which, in some cases, have been validated by measured data. Mexico is no exception, since there are not many measurement towers in the country that provide valid records throughout the country. In view of the above, in this study a comparison was made between the measurements observed in six anemometric towers, located in different locations in the United Mexican States; data from the MERRA-2 and ERA-5 reanalysis; and data from the generalized wind climates (GWC), available in the Global Wind Atlas. The study was conducted at 80 m, which is the highest height at which data were recorded on the measurement towers at each site. In the case of the MERRA-2 and ERA-5 data, extrapolation of the data series to 80 m was required. In the case of the towers, a comparison of the two data sets measured at 80 m and the height at which two anemometers were available, was performed. This analysis was supported by Windographer version 4 software designed by the company UL solutions, from which *.tab files were exported at 80 m, which were then imported from the WAsP 10.0 program to perform the microscale modeling. The comparison variable was the mean power density, for which the relative deviations between the measured values and those obtained from the reanalysis data and the GWCs were determined. For a better interpretation of the relative errors calculated, an analysis of the orographic characteristics of all the sites was performed using the roughness index (RIX). The results obtained showed that the behavior of the reanalysis and the GWC data was not homogeneous in the sites studied; therefore, an adequate relationship between the magnitudes of the ΔRIX and the relative deviations was not observed, especially for the ERA5 and GWC. The ERA5 data were the furthest from the measured data, with relative deviations greater than 50% at five of the six sites; however, the MERRA-2 and GWC data were the closest to the measured data. The MERRA-2 data showed deviations of less than 11%, except at the La Venta site, where it was 29.5%—a site where the GWC also had a high deviation of 139.4%. The latter is attributable to the effects caused by the nearby wind farms on the wind flow measured by the La Venta station. In general, the MERRA-2 data are an alternative to performing a pre-analysis of the wind resource in Mexico.

Keywords: wind energy; reanalysis data; resource assessment; generalized wind climate

1. Introduction

The implementation of wind technologies for electricity generation requires a precise knowledge of the potential of this resource at the site of interest. For this purpose, it is necessary to have reliable information to evaluate the characteristics of the wind and its spatial and temporal variations [1]. However, this information is not always available, since it requires expensive anemometric stations, with instruments such as anemometers, wind vanes, atmospheric pressure, and temperature sensors, which also have high installation and maintenance costs [2].

With this in mind, we intended to use reanalysis data to obtain an idea of the wind and atmospheric conditions at the sites. This led to the search for new, alternative sources of information that allowed for a preliminary evaluation of the wind resource, in order to reduce uncertainty in the selection of sites and avoid incurring unrecoverable costs [3]. An alternative is the use of reanalysis meteorological data, which are generated from models that take into account the specific characteristics of the atmosphere and the surface, in terms of orography and roughness. Reanalysis is a process, which uses a data assimilation system to provide a consistent reprocessing of meteorological observations [4].

Two of the most prominent global reanalysis models are MERRA-2 [5], from the National Aeronautics and Space Administration (NASA), and the more recent ERA5, which is provided by the European Center for Medium-Range Weather Forecasts (ECMWF) [6]. Both have been widely used to estimate wind energy potentials in different parts of the world. However, the modeled data do not always adequately replicate wind power production conditions and, therefore, can introduce variable errors, depending on where they are used globally and for what purpose [7]. Gruber et al. [8] stated that reanalysis data should not be relied upon without adequate validation.

In particular, in wind energy, several papers have been published that use this information to make a preliminary assessment of the wind resource in different locations [5,8–13]. Gruber et al. [7] developed an interpolation model, which included MERRA-2 data and Global Wind Atlas (GWA) data to analyze a wind farm, obtaining, as a result, that the bias of GWA and MERRA-2 data improves the estimation of the energy production of a wind farm. Rabbani et al. [5] made a correlation between the wind power density measured and the MERRA-2 data, the result was that, between them, there was up to a 75% correlation. Miao et al. [14] found that in central North America, the MERRA-2 model best reproduced the surface wind. Ayik et al. [15] used MERRA-2 time series to preliminarily evaluate the wind resource in Sudan, while Ren et al. [16] constructed the vertical wind profile in China at 80 m, 100 m, and 150 m and compared the results with those measured at two wind farms and 213 meteorological stations. This study concluded that MERRA-2 data can be used by decision makers to make preliminary planning and select candidate regions for wind farm development. Similarly, De Aquino et al. [17] evaluated the representativeness of MERRA-2 reanalysis data for the Brazilian territory using different interpolation, extrapolation, and bias correction strategies.

Regarding ERA5 data, some authors, such as Patel et al. [10], who used ERA5 data to evaluate the wind resource and wind climate in India, had good results and decided to identify hotspots in an offshore farm. Hayes et al. [11] used ERA5 data to model over 40 years of wind and calculate the power generated from wind farms and found that these data resembled the data produced by 57 wind farms and reduced the root error squared. Gil Ruiz et al. [12] compared the measurements from 13 AWS with ERA5 data and found correlations suitable for the use of reanalysis data. Soukissian et al. [7] performed an analysis of the wind resource in the Mediterranean Sea, where they could observe the wind potential of the Alboran Sea.

Some authors have conducted studies in which measured data are compared with reanalysis data, both MERRA-2 and ERA5. Olauson [18], for example, conducted a comparative study between MERRA-2 and ERA5 data, and found that ERA5 data are more accurate than MERRA-2 data. Zhang et al. [19], in an analysis of meteorological variables, found that wind speed data are overestimated by MERRA-2, while ERA5 data correlate positively with measured data. Samal [4] compared the data measured from an anemometer tower and reanalysis data, such as MERRA-2, and found large variations in wind power density and hourly data, although he recorded good correlations between the mean and variance. In addition, Jourdier [20] evaluated the validity of both models in France, finding that ERA5 underestimates wind speed, especially in mountainous areas, and that MERRA-2 overestimates it, especially at night. However, overall, ERA5 outperformed MERRA-2, showing lower biases, higher correlations, and better diurnal variability.

On the other hand, Gualtieri [21] made a critical review of the uncertainties associated with the use of reanalysis data for wind resource assessment. Based on several reported studies, he analyzed the performance of 15 reanalysis products at 322 locations worldwide, grouping them by location type (offshore, coastal, inland, and mountainous). The results revealed that ERA5 data can adequately reproduce the wind resource offshore and in flat terrain, but that the uncertainties are higher in mountainous and coastal sites.

In Mexico, few investigations have used reanalysis data to evaluate the wind resource. Morales et al. [22] analyzed the ability of MERRA-2 data to represent wind characteristics at 24 anemometric stations in the country. It was observed that the performance of the data is not uniform across sites and depends on factors such as temporal resolution, orographic conditions, and the relationship between local flow and large-scale circulation. In addition, Canul et al. [23] used MERRA-2 and ERA5 data to identify areas with exploitable wind potential in the Gulf of Mexico, proposing the validation of the results obtained as a focus for future work. Similarly, Arenas et al. [9] used 40 years of MERRA-2 data to preliminarily evaluate the wind potential in two marine areas of the country, located in the Gulf of Mexico and in the Mexican Pacific.

On the other hand, the Mexican Wind Atlas project was initiated in cooperation with the National Autonomous University of Mexico (UNAM), the Federal Electricity Commission (CFE), the Technological University of Denmark (TUD), and the National Institute of Electricity and Clean Energy (INEEL), with the INEEL as the leader. Seven anemometric stations were installed in different locations around Mexico, these stations generate data on wind speed and direction, temperature, and atmospheric pressure. Considering the availability of such measured data and the need to evaluate the performance of the reanalysis data in the country, the main objective of this work was to analyze the data measured at the studied site and compare them with the MERRA-2 and ERA5 reanalysis data, to determine how accurate they are to perform the wind resource assessment with confidence.

2. Materials and Methods

Study Sites and Data Used

The study was conducted at six sites, in different locations across the United Mexican States (Figure 1).

Data recorded by anemometric towers at each of the sites were used, with a sampling rate of one second, and averaged every ten minutes for one year. The measurements were carried out as part of the "Atlas Eólico Mexicano" project, coordinated by the National Institute of Electricity and Clean Energy (INEEL), with the support of the General Directorate of Clean Energy of the Ministry of Energy (SENER) and the participation of the Civil Engineering Project Management (GEIC) of the Federal Electricity Commission (CFE), the Institute of Geography of the National Autonomous University of Mexico, and the Technical University of Denmark.

Each tower was equipped with wind speed sensors (model Wind-Sensor P2546A), located at 20 m, 40 m, 60 m, and 80 m height and with wind direction sensors (model Thies TFC 4.3151.00.012), located at 58 m and 78 m. At 80 m height there were two speed sensors, located at 180° from each other and perpendicular to the prevailing wind direction. The instruments were calibrated by Svend Ole Hansen ApS, following the wind tunnel procedures and requirements set forth in IEC 61400-12-1:2017. Table 1 shows the names and the state of the Republic of Mexico where each of the measurement sites were located, as well as their geographic coordinates and altitudes.

Figure 1. Location of studied sites. The figure was prepared with data from the Mexican Wind Atlas.

Table 1. General information on anemometer towers.

ID	Name	State	x (m)	y (m)	Altitude (m)	UTM
M1	La Rumorosa	Baja California	583,346.93	3,594,064.62	1343	11
M2	Mérida	Yucatán	210,699.14	2,339,900.02	4	16
M3	Ciudad Cuauhtémoc	Chihuahua	309,873.90	3,211,836.87	2128	13
M4	La Venta	Oaxaca	291,291.99	1,830,459.9	31	15
M5	Ojuelos	Jalisco	218,970.85	2,397,286.88	2420	14
M6	San Fernando	Tamaulipas	592,077.89	2,767,714.01	33	14

In addition to the data recorded at the anemometer towers (observed data), MERRA-2 and ERA-5 reanalysis data series were used, as well as GWC (Generalized Wind Climate) files generated by the Global Wind Atlas at each of the selected sites.

The coordinates of the closest points and their distances to each measurement tower for which MERRA-2, ERA-5, and GWC data were available, are shown in Table 2.

Table 2. Location of reanalysis and GWC data points closest to the measurement towers.

ID Site	MERRA-2			ERA-5			GWC		
	x (m)	y (m)	d (km)	x (m)	y (m)	d (km)	x (m)	y (m)	d (km)
M1	570,455.2	3596,106.9	13.10	570,455.2	3,596,106.9	13.10	580,832.8	3,602,393.7	8.7
M2	188,106.9	2,325,075.7	27.00	214,593.0	2,352,299.9	13.00	211,469.7	2,340,055.2	0.8
M3	317,357.7	3,209,434.8	7.90	305,179.0	3,209,634.5	5.20	310,686.2	3,212,646.6	1.1
M4	286,520.5	1,825,302.4	7.00	286,520.5	1,825,302.4	7.00	292,559.7	1,831,441.7	1.6
M5	202,119.0	2,380,226.3	24.00	215,568.0	2,407,686.6	10.90	218,304.0	2,398,441.1	1.3
M6	588,298.2	2,765,232.7	4.50	600,913.0	2,765,319.9	9.20	592,515.8	2,768,361.4	0.8

MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications) is a model produced by NASA's Global Modeling and Assimilation Office (GMAO) that provides reanalysis data. Reanalysis is a process that uses a data assimilation system to provide a coherent reprocessing of meteorological observations. MERRA-2 uses version 5.12.4 of the Goddard Earth Observing System (GEOS-5.12.4), which generates data on a latitude and longitude grid with a resolution of 0.50 X 0.6250, at 72 levels from the surface down to 0.01 hPa [24–26].

The ERA 5 reanalysis model, developed by the European Centre for Medium-Range Weather Forecasts (ECMWF), was released in July 2017 and includes data dating from 1950; with a horizontal resolution of 0.250 × 0.250, and 137 levels from the surface down to 0.01 hPa [27].

The GWC files were downloaded free of charge from the Global Wind Atlas 3.0 (GWA) [28]. The GWA is a freely available, web-based application that helps to identify windy sites and perform preliminary energy production calculations anywhere in the world. It provides GWC files of any location at the following five heights: 10 m, 50 m, 100 m, 150 m, and 200 m, which contain wind climate information once the effects of orography and surface roughness have been removed; therefore, they are said to be site-independent, i.e., generalized.

The study was carried out at 80 m, which is the highest height at which data were recorded on the measuring towers at each site. As each tower had two velocity sensors at that height, a combination of both data sets was made using the "combine anemometers" tool of the Windographer program.

A flow chart shows the process followed in this study, see Figure 2.

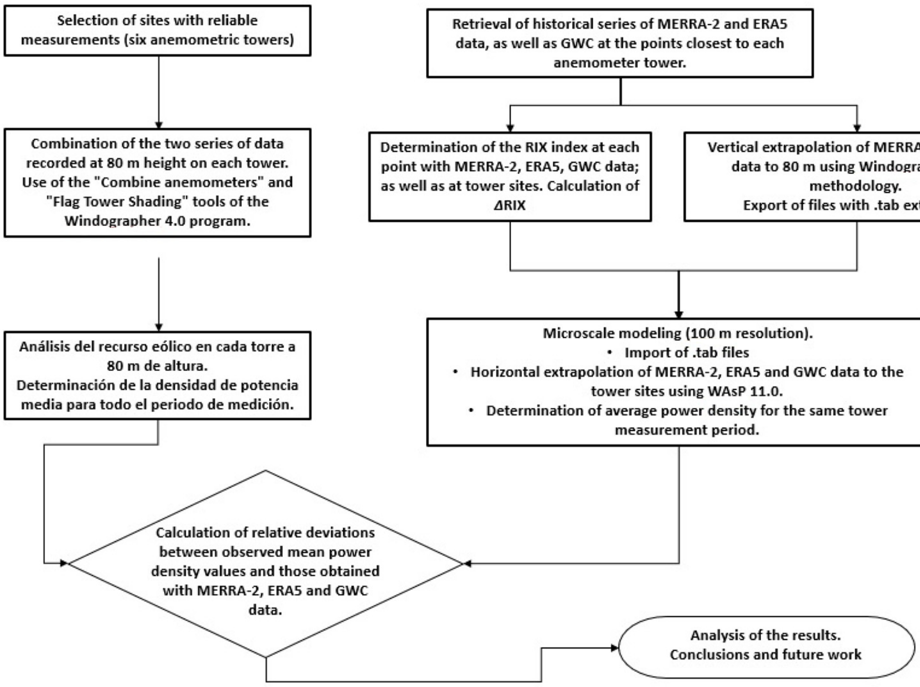

Figure 2. Flow chart of the process applied in the study.

The average option was used to perform the combination. This option gives a combined value equal to the average of the two original values, if both are valid. While it gives a value equal to the valid value when only one of them is valid, it leaves a gap in each time interval in which neither of the two original values are valid [27].

In turn, the determination of invalid (shaded) values was performed with the "Flag Tower Shading" tool, which allows flagging for those values that match certain flagging criteria, to identify shading effects. Windographer automatically infers the shaded sectors, according to the following procedure [29]:

- For each pair of speed sensors, calculate the ratio between the wind speeds at each interval.
- Next, find the median of these relationships in 72 bearing sectors. The highest and lowest values of the median coincide with the centers of the shaded sectors.
- Wind speeds within each of these sectors that are assigned an amplitude (30° in our case, i.e., 15° to both sides of the center of the sector) are considered invalid values.

Once the new data column was generated with the combined values of the two anemometers, the resource analysis was performed in each of the measurement towers.

For the case of the MERRA 2 and ERA 5 data series, as they are reported at 50 m and 100 m heights, respectively, it was required that we extrapolate both series to 80 m. For this purpose, the power law (Equation (1)) was used, taking as exponent α the value calculated by Windgrapher from measurements at various heights on each of the measuring towers [30].

$$U(z) = \beta z^{\alpha} \tag{1}$$

where z is the effective height above ground level, $U(z)$ is the wind speed at height z, β is a constant y, and α is the exponent.

The effective height is the subtraction of the height at which the sensor is in the measuring tower (z_{actual}) and the displacement height (D) (Equation (2)). In turn, the displacement height is the height above ground level at which the wind speed becomes zero. It can be constant or vary by month and by direction sectors [31]. In our calculations, D was considered constant and equal to zero, as follows:

$$z = z_{actual} - D \tag{2}$$

Next, the procedure followed by Windographer for the calculation of the exponent α, consisted of taking natural logarithm on both sides of Equation (1), thus obtaining the equation of a straight line (Equation (3)), as follows:

$$\ln(U(z)) = \alpha \ln(z) + \ln(\beta) \tag{3}$$

where the exponent α is its slope.

If the ln(U(z)) is plotted versus ln(z) for all effective heights at which wind speed measurements are available, the slope of the line that best fits the point arrangement can be found. Windographer uses the least squares method to determine this slope, which will be the value of the exponent α. This procedure can be used to determine the exponent of the whole measurement period, as well as to determine its values for hours and months.

Once the vertical extrapolations of the MERRA-2 and ERA-5 data at 80 m height were performed, the corresponding *.tab files were exported for later use in the microscale modeling. The *.tab files used corresponded only to the measurement period in each of the towers.

The next step was to carry out the microscale modeling using the WAsP 11 software, using the *.tab files mentioned above, and the GWCs generated in the Global Wind Atlas. The wind resource modeling was performed at a height of 80 m above ground level, in areas of 50 km × 50 km, with a resolution of 100 m. Digital topography and roughness data were imported from the Global Wind Atlas.

The deviations between the results obtained with the reanalysis data and the GWCs with respect to the observed data were determined using the relative percentage error, (Equation (4)), as follows:

$$ER = 100\left(\frac{P_{average} - P_{estimated}}{P_{average}}\right) \tag{4}$$

where $P_{average}$ represents the average power density values derived from the measurements at each tower, and $P_{estimated}$ are the values estimated from the reanalysis data and the GWC.

For a better interpretation of the relative errors calculated, an analysis of the orographic characteristics of all the sites was carried out—that is, both the sites where the towers were located and the sites with MERRA-2, ERA-5, and GWC data. For this purpose, the roughness index (RIX) was used.

According to Bowen and Mortensen [32], the RIX of a given site can be defined as the fraction of the surrounding land area that is steeper than a given critical slope. Berge et al. [33] stated that the RIX describes the fraction of the area within a radius of 2 km, with slopes greater than 30%. In research conducted by Gao et al. [34], they used the RIX to compare three wind turbines on different types of terrain, using the WAsP software.

The configuration adopted by WAsP for the RIX calculation is, by default, the one that considers the values used by Bowen and Mortensen [35], in terms of calculation radius (3500 m), critical slope (0.3), number of sectors (16), and number of subsectors (6). Although, these terms can be changed in the terrain analysis option within the software.

The prediction errors of the WAsP program depend on the RIX values at both reference sites and those where wind climate prediction is required. The best performance of WAsP takes place at sites with a RIX $\approx$ 0%, which indicates that all slopes of the terrain surrounding the site are less than 0.3. Otherwise, one should expect prediction errors, the sign and magnitude of which depend on the differences (ΔRIX) between the RIX at the site to be predicted ($RIX_{predicted}$) and that of the reference site ($RIX_{reference}$).

$$\Delta RIX = RIX_{predicted} - RIX_{reference} \tag{5}$$

According to Mortensen and Petersen [36], if the reference and predicted sites have similar RIX, then the ΔRIX will be very small, and so will the prediction error. On the other hand, if the RIX of the reference site is greater than that of the predicted site, then the $\Delta RIX < 0$ and the expected prediction error will also be less than zero. Otherwise, the error will be positive.

In this study, the reference sites corresponded to the MERRA-2, ERA-5, and GWC points, since from them the wind climate values at the measurement tower sites (which were our predicted sites) were estimated.

3. Analysis and Discussion of Results

Table 3 shows the mean power density values at 80 m above ground level, obtained both for the data measured at the stations and for the reanalysis and GWC data.

Table 3. Average power density and relative deviations from measured values.

ID Sites	Measured Values (W/m^2)	MERRA-2		ERA-5		GWC	
		W/m^2	ER(%)	W/m^2	ER(%)	W/m^2	ER(%)
M1	306	273	10.8	138	54.9	319	−4.2
M2	193	212	−9.8	90	53.4	185	4.1
M3	238	256	−7.6	104	56.3	194	18.5
M4	888	626	29.5	430	51.6	2126	−139.4
M5	172	183	−6.4	242	−87.0	199	−15.7
M6	347	385	−11	248	28.5	227	34.6

As can be seen, the best approximations of the wind power density were obtained from the modeling results with the WAsP program, using the MERRA2 data at 50 m height. In this case, the relative deviations were between 29.5% and −11%. In the case of station M4, La Ventosa, the highest relative deviation was observed, which was 29.5%. This could be because the station is strongly influenced by the wind turbine fields very close to the anemometric tower, which is in the trajectory of the wind turbines (Figure 3).

Figure 3. Top view of the CERTE anemometric station oriented to the north.

However, it can be noted that the behavior of the models was not homogeneous in all sites. Although the results obtained with the MERRA-2 model were the best, in general, in two of the sites studied (La Rumorosa and Mérida) the GWC showed lower relative deviations (Figure 4). For the ERA5 data, relative deviations greater than 50% were obtained in five of the six sites studied. The lowest value was 28.5% in the San Fernando site.

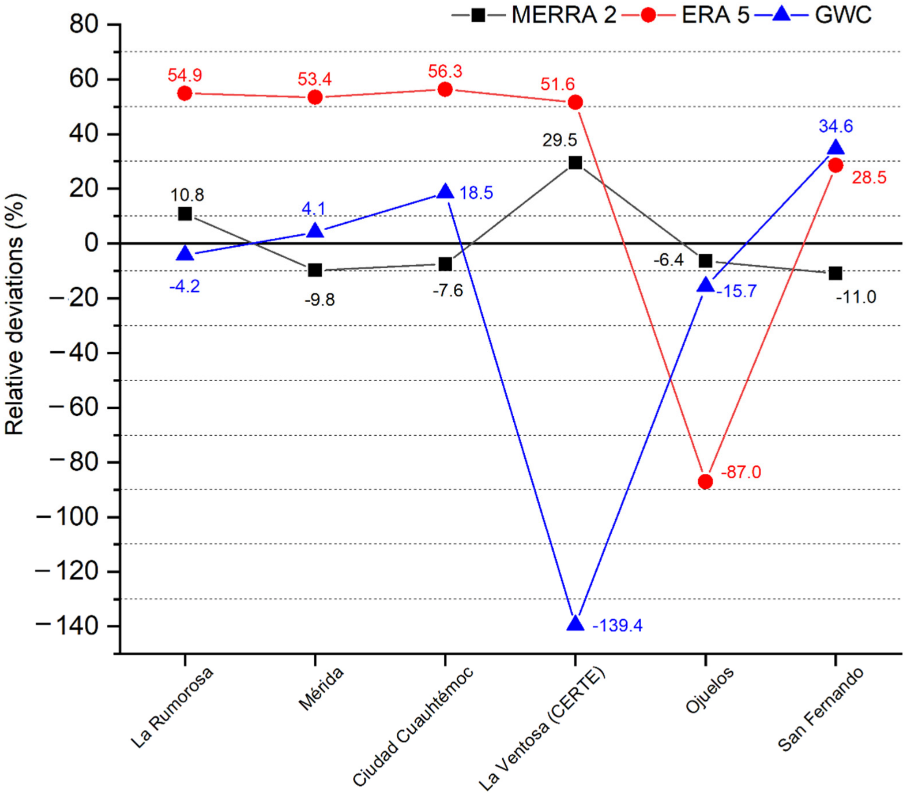

Figure 4. Relative deviations obtained at each site in relation to the values measured at the towers.

Table 4 shows the values of RIX, Δ*RIX*, and the prediction errors. For the case of the sites with MERRA-2 data, an adequate correspondence with that proposed by Mortensen and Petersen [36] was observed, since the Δ*RIX* were close or equal to zero and the deviations in the mean predicted power density were relatively small, although not always of the same sign—except for La Ventosa, where the deviation was much larger (29.5%). For the case of the ERA-5 data, the deviations were large, even though the Δ*RIX* was small—except for Ojuelos, where the Δ*RIX* was −8.6%. Finally, the GWCs showed correspondence between the signs of Δ*RIX* and *ER*, but the values of the latter were elevated at four of the six sites.

Table 4. Values of RIX, Δ*RIX*, and prediction errors at study sites.

Sites	**Towers**		**MERRA-2**			**ERA-5**			**GWC**	
	RIX (%)	**RIX (%)**	**Δ*RIX* (%)**	***ER* (%)**	**RIX (%)**	**Δ*RIX* (%)**	***ER* (%)**	**RIX (%)**	**Δ*RIX* (%)**	***ER* (%)**
M1	0.3	0.1	0.2	10.8	0.1	0.2	54.9	2.5	−2.2	−4.2
M2	0	0	0	−9.8	0	0	53.4	0	0	4.1
M3	0	0.1	−0.1	−7.6	0	0	56.3	0	0	18.5
M4	0	0	0	29.5	0	0	51.6	0.1	−0.1	−139.4
M5	0	0	0	−6.4	8.6	−8.6	−87.0	0.3	−0.3	−15.7
M6	0	0	0	−11	0	0	28.5	0	0	34.6

In the case of Mexico, the MERRA-2 information could also be useful when the measurement-correlation-prediction process (MCP) is carried out with the data from the measurement stations. Its specifically used to determine the characteristics of the wind resource but it should be used carefully, since, in most cases, the point to which the MERRA-2 information corresponds does not coincide with the target site under analysis.

As established by Gruber et al. [8], the reanalysis data must be validated. In this case they were validated with data measured with 80 m-high towers. These data presented good results in certain places, which can be interpreted as the reanalysis data possibly having some relationship with sites where both the orography and roughness do not have so much influence. The results of this work coincide with those found by Rabbani et al. [5]—that MERRA-2 fits better than ERA5 in particular sites. The RIX index was very helpful in clarifying the problems with topography (orography and roughness), because it showed that in places with more irregular topography, the reanalysis data no longer fitted the measured data, as mentioned by Mortensen [32].

4. Conclusions

The opportunity to have reliable data to model or predetermine the selection of a site with wind potential is undoubtedly a point in favor of wind resource developers or researchers. In this work, we compared the measurements made by the six anemometric stations installed in different states of the Mexican Republic, which are in the north (La Rumorosa, Ciudad Cuauhtemoc, and San Fernando); in the center (Ojuelos); in the south (La Ventosa); and in the south-east (Mérida). The closest reanalysis data (MERRA-2, ERA-5, and GWC), from a total of six points found for each data source, were used for comparisons. The site with more slopes above the threshold is La Rumorosa, with a RIX = 0.3, while the other five stations are installed in less complex areas (RIX = 0). Three of the sites studied (Mérida, La Venta, and San Fernando) are near the coast, while the others are located in mountainous areas.

The results showed that the performance of reanalysis and GWC data is not homogeneous. The MERRA-2 data matched best with the data measured at the La Rumorosa, Mérida, Ciudad Cuauhtemoc, and Ojuelos stations, while the ERA-5 data was a better fit with the La Ventosa data, and the GWC data also matched well with La Rumorosa, Mérida, Ciudad Cuauhtemoc, and Ojuelos. The ERA-5 data were the furthest from the measured data, with relative deviations greater than 50% in five of the six locations.

As for the magnitudes of the ΔRIX and the relative deviations, no adequate relationship between them was observed, especially for ERA5 and GWC. That is, small values in the ΔRIX did not necessarily lead to small relative errors in the prediction. This could indicate that the main cause of the errors was not associated with orographic factors, but rather with the spatial resolution of the models and their limited ability to reproduce the relationships between local wind and general circulation fluxes. This aspect was particularly evident in the case of the MERRA-2 data, where the largest errors occurred at the three coastal sites.

In general, it can be observed that the MERRA-2 data were better approximated to the measured data, showing deviations of less than 11%—except at the La Venta site, where it was 29.5%. The latter is attributable to the effects caused by the nearby wind farms on the wind flow measured at that station, so they could be used to make a pre-analysis of the wind resource in Mexico. However, it will be necessary to continue investigating the validity of the reanalysis models in the Mexican territory, which will require a greater number of in situ measurements that meet the criteria, not only of quality but also of heterogeneity in the selection of candidate sites.

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Abbreviations

CFE	Federal Electricity Commission
ERA-5	Reanalysis dataset, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF)
GEIC	Civil Engineering Project Management, of the CFE
GEOS	Goddard Earth Observing System
GWA	Global Wind Atlas
GWC	Generalized Wind Climates
IEC	International Electrotechnical Commission
INEEL	National Institute of Electricity and Clean Energy
MERRA-2	Modern-Era Retrospective Analysis for Research and Applications. Version 2. Produced by NASA's Global Modeling and Assimilation Office (GMAO)
NASA	National Aeronautics and Space Administration
SENER	Secretary of Energy. Government of the United Mexican States
TUD	Technological University of Denmark
UTM	Universal Transversal Mercator
WAsP	Wind Atlas Analysis and Application Program

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