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A systematic evaluation of NEWA and CERRA wind datasets in the Mediterranean Sea

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Abstract: The Copernicus European Regional Reanalysis (CERRA) has been recently released (August 2022), providing a continental reanalysis with a horizontal resolution of 5.5 km, a vertical one of 106 levels and a time step of 3 hours. On the other hand, the New European Wind Atlas (NEWA) is also a recent reanalysis product to create a high temporal and spatial resolution wind resource atlas of Europe. CERRA and NEWA are two of the finest products as regard spatial resolution and therefore, promising candidates for preliminary wind energy applications in the area of models' definition. In order to demonstrate the suitability of the NEWA and CERRA wind datasets for offshore wind energy applications, the accuracy of these datasets is assessed for the Mediterranean Sea, a basin with a high potential for the development of offshore wind projects. Long-term *in-situ* measurements from thirteen (13) offshore locations along the basin are used in order to assess the performance of the CERRA and NEWA wind speed datasets in the hourly and seasonal time scales by using different evaluation tools. The results reveal that the CERRA dataset outperforms NEWA and is a reliable source for offshore wind energy assessment studies in the examined area, although special attention should be paid as regards extreme value analysis of wind speed.

Keywords: NEWA; CERRA; offshore wind energy; model validation; Mediterranean Sea; atmospheric reanalysis models

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1. Introduction

Accurate and high-resolution wind speed data are essential for a variety of applications that depend on the reliable estimation of the atmospheric state. Taking into consideration the scarcity of wind speed data over sea areas, where the deployment of site-specific instruments (e.g. fixed or floating mast, buoy, LiDAR) is more difficult and cost-intensive than onshore, the use of reanalysis products has gained a lot of attention in wind energy studies [1], [2], [3], amongst related methods such as satellite [4], [5], [6], [7], and gridded products constructed by interpolating observational data [8], [9]. Some of the advantages of the reanalysis data include the long-term time series that allow the estimation of interannual variability, the spatial coverage that extends to remote and offshore locations and their availability and accessibility; however, their coarse spatial resolution poorly captures complicated topographical features, leading to inadequate representation of local climatic conditions, [10].

Wind reanalysis datasets are a combination of atmospheric model and wind observational data spanning back some decades using an assimilation scheme. Specifically, over a long-time span, these reanalysis datasets can provide wind speed estimates for every grid point of the model domain at each assimilation time and level. Thus, the provision of wind information of extended areas at multiple vertical atmospheric levels [11], [12], regardless the coverage of observational networks, is an improved tool for the better understanding of the wind speed patterns.

In order to verify the suitability of reanalysis data for a particular region, the most credible method is to compare them with in situ wind measurements, a data source of high accuracy [13], for at least one year. It should be emphasized that when reanalysis data sets are compared with other model products, this may lead to less robust and safe conclusions regarding the performance of the data set under evaluation. Several studies that deal with the comparison of reanalysis data sets with measured data have used evaluation and correlation metrics as well as probability distributions, e.g. [14], [15]. However, validation across different time scales (e.g., months, seasons) and for various percentiles are rarely provided.

The Copernicus European Regional Reanalysis (CERRA) has been recently released (August 2022), providing a continental reanalysis with very high spatial resolution [16]. Predecessors of CERRA were ERA-Interim [17] and ERA5 [18] produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) with a global coverage.

CERRA dataset has been validated in terms of on-shore air temperature, relative humidity, 10-meter wind speed and global solar radiation in Greece by using up to 11-year-long ground-based observations and has been also compared to the ERA5-Land dataset, [19]. The results of that study revealed that the CERRA dataset outperformed significantly the ERA5-Land reanalysis data with respect to the measured meteorological variables. Hadjipetrou and Kyriakidis [20], reported that CERRA exhibited the strongest agreement with in-situ onshore wind speed measurements in the eastern Mediterranean basin). Rouholahnejad et al. [21], comparatively assessed ERA5, CERRA and WRF based on measured wind data in the North Sea. They concluded that CERRA demonstrated great accuracy in wind speed distribution with low errors in both extreme values (95th percentile) and mean bias. Pelosi [22], evaluated different meteorological variables from CERRA (including wind speed at 10 m), with interpolated ground-based data and found that CERRA wind speed performance showed the least accuracy, in complex terrain areas of Sicily Isl. Jourdier et al. [23], comparatively evaluated the performance of CERRA wind speed at 100 m with ERA5, and COSMO-REA6. CERRA exhibited larger differences in relation to ERA5, with higher wind speeds over most of Europe, while in relation to COSMO-REA6, the differences were smaller. Finally, Spangehl et al. [24], evaluated the performance of CERRA near-surface wind speed based on satellite observations in the North Sea and concluded that it exhibits a systematic overestimation.

The New European Wind Atlas (NEWA) [25], is a recent initiative to create a high resolution wind resource atlas of Europe. One of the most important components of the initiative was conducting extensive sensitivity studies and production runs using the Weather Research and Forecasting (WRF) mesoscale model [26]. The objective was to establish a well-informed model setup, based on scientific evaluation, for the production of the mesoscale wind atlas. The NEWA wind atlas has been evaluated in various publications. For example, Murcia et al. [27], based on onshore wind measurements from 32 tall meteorological masts in Europe, examined three different mesoscale reanalysis models including NEWA and ERA5, and concluded that NEWA performs better than ERA5, although it overestimates wind speed. Kalverla et al. [28] compared the performance of ERA-5, Dutch Offshore Wind Atlas (DOWA), and NEWA wind reanalyses using measurements from the Met Mast IJmuiden in the North Sea. Results showed that NEWA accurately predicted near surface wind speeds, but underestimated wind shear. As mentioned before, Hadjipetrou and Kyriakidis, [20] evaluated five high resolution wind speed reanalyses, CERRA and NEWA included, with coastal (on-shore) in-situ measurements from five meteorological stations in the eastern Mediterranean during the 2009-2018 period. Among the five reanalyses, CERRA and NEWA exhibited the highest alignment with measured wind speeds, though NEWA overestimated mean values, but captured extremes effectively. Meyer et al. [29], compared ERA5 and NEWA datasets for offshore wind resource assessment across multiple North and Central European offshore areas, including the Irish Sea, Baltic Sea, North Sea and English Channel. In their analysis, NEWA exhibited increased accuracy regarding mean wind speed values and better overall wind speed variability assessment due to its higher temporal resolution, but both datasets underestimated extreme wind speeds. The study also examined the effectiveness of the spectral correction method in 50-year return wind speed predictions, finding it adequate for certain sites, yet inadequate for others, something that highlights the need for more localised validation approaches. Araveti et al. [30], examined four different reanalysis products including ERA5 and NEWA at four onshore locations in Ireland. The authors concluded that ERA5 outperforms the other products, while they also emphasized that NEWA exhibited the poorest performance combined with an anomaly at 100 m and 110 m levels above ground wind speed. Jourdier [31], compared five different reanalysis products (ERA5 and NEWA included) using wind measurements from seven onshore meteorological masts and one LIDAR in France. The author concluded that ERA5 performed very good underestimating though wind speeds in mountainous areas, while NEWA presented large biases and overestimate wind speeds especially at night.

The objective of the present study is to assess and compare the accuracy and performance of CERRA and NEWA wind data sets for the Mediterranean Sea in order to be used for preliminary offshore wind energy applications. The economic viability of a wind energy project, and other factors during the design of an offshore wind farm (e.g., wake effects) are highly dependent on the wind regime, especially wind speed, of the location of interest. Thus, the CERRA and NEWA datasets are evaluated for various aspects encountered in wind energy studies. Specifically, *in-situ* measurements from thirteen (13) buoy locations are used along the Mediterranean Sea in order to assess the performance of the CERRA and NEWA wind speed data through evaluation metrics.

The wind data sources used in this paper are described in Section 2. The methodology, including the collocation procedure for reanalysis and *in situ* data and the evaluation metrics used in this work is described in Section 3. The numerical results of the evaluation of the CERRA and NEWA wind datasets at two different temporal scales in order to identify the performance quality of them is presented in Section 4, including extreme values (i.e., values greater than the 90^{th} and 95^{th} percentiles). Finally, in Section 5, the main findings and remarks of this study are summarized.

2. Wind data sources

2.1 Copernicus European Regional ReAnalysis (CERRA)

CERRA has been initially developed through a project led by the Swedish Meteorological and Hydrological Institute (SMHI) in collaboration with Météo-France and the Norwegian Meteorological Institute (MET Norway). The CERRA reanalysis system is based on the “Hirlam Aladin Research Mesoscale Operational NWP In Europe” (HARMONIE) numerical weather prediction (NWP) system with ALADIN (Aire Limitée

Adaptation dynamique Développement InterNational) physics and dynamics, [16], [32]. It improves upon previous European reanalysis databases by adding new advances in modelling and data assimilation techniques. CERRA incorporates a broad range of observational data derived from surface stations, ships, aircraft, drifting buoys and radiosonde/balloon reports to constrain the model state.

For the surface and upper-air analyses, it uses an optimal interpolation assimilation scheme and a three-dimensional variational (3D-VAR) data assimilation scheme, respectively, with a horizontal resolution of 5.5 km and a vertical one of 106 levels. The ERA5 reanalysis is used as input for the lateral boundary conditions of CERRA. Apart from the high spatial resolution, additional improvements of the CERRA system include:

1. The assimilation of additional observations, available from the observing system, throughout the reanalysis period in order to represent more accurately the atmospheric conditions. These observations are obtained from ECMWF's Meteorological Archival and Retrieval System (MARS) and European Centre File Storage system (ECFS), and includes conventional (e.g., synoptic surface observations, drifting buoys, ships) and other observations, such as scatterometer and radiance observations [33].
2. The Ensemble Data Assimilation (EDA) system coupled with the deterministic CERRA system to regularly estimate the background error covariance matrix (B-Matrix) with flow-dependency updates [34] to sufficiently represent errors when changes in weather regime are detected.

The model domain spans in terms of the north-to-south axis from northern Africa beyond the northern tip of Scandinavia and in terms of the west-to-east axis from the Atlantic Ocean up to the Ural Mountains. The model grid is Lambert conformal conic comprising in 1069x1069 grid points corresponding to around 5.5 km x 5.5 km horizontal resolution. CERRA covers a period of 38 years (1984–2021), that will be constantly updated, and assimilates eight times per day (i.e., 3-hour temporal resolution). The dataset can be obtained through the Copernicus Climate Data Store (https://cds.climate.copernicus.eu/#!/home). CERRA dataset has been validated in terms of air temperature, relative humidity, 10-meter wind speed and global solar radiation in Greece by using up to 11-year-long ground-based observations and has been also compared to the ERA5-Land dataset, [19]. The results of that study revealed that the CERRA dataset outperformed significantly the ERA5-Land reanalysis data with respect to the measured meteorological variables.

2.2 New European Wind Atlas (NEWA)

The New European Wind Atlas (NEWA), [35], [36], aims to provide thorough, accurate, and sound information on the European wind resource, necessary for commercial evaluations of wind farms. The reanalysis data were used by the NEWA project to provide the dynamical forcing and initial and boundary conditions for the WRF model simulations, while observational data from meteorological masts across Europe were used to validate the numerical simulations.

Regarding the properties of NEWA model data, sensitivity tests [37], were initially conducted using WRF version 3.6.1, while later tests employed version 3.8.1. The initial sensitivity experiments were performed in five distinguished 3km × 3km domains in Europe, as this resolution seems to be the standard [38], and used three nested grids with horizontal resolutions of 27 km, 9 km, and 3 km, with 61 grid points in each direction for the outer nest. In addition, the model configuration used 61 vertical levels and 30 minutes time resolution, therefore making it an adequate source of data for this particular study. See also [25]. An innovative aspect of NEWA was the use of multi-parameter ensemble simulations in order to address uncertainties in wind resource estimation. The ensembles consisted of WRF runs with different configurations, physical parameterization schemes, initialization, and boundary conditions. The extensive sensitivity studies conducted within the NEWA project helped to identify a well-founded WRF model configuration for the mesoscale wind atlas production runs. The final setup was used to offer a complete wind resource dataset of Europe's wind resource, supplied with insights from the ensemble simulations associated with uncertainty in wind resource assessment. The production and evaluation of the NEWA wind atlas is analytically described in [39].

2.3 In-situ wind measurements

Long-term measured wind speed data were obtained from the Copernicus Marine Service - ocean *in-situ* data (https://marineinsitu.eu/dashboard/). The In Situ Thematic Assembly Centre (TAC) is a component of the Copernicus Marine Service that provides consistent and reliable access to a range of *in-situ* measured data derived from high-frequency radars, moorings, tide gauges, profilers, gliders, drifters, etc. For wind data the main source of information is moorings, i.e., oceanographic buoys equipped with wind measurement devices. Most of the available buoys are located in the western and central-eastern Mediterranean, while for the central and western Mediterranean, no buoys are available. The Greek buoys are part of the POSEIDON network [40] that started operating at 1999, under the responsibility of the Hellenic Centre for Marine Research (HCMR). The majority of the western Mediterranean buoys operate under the responsibility of the Spanish Operational Marine Climate Monitoring and Forecasting System - Spanish Port Authority (Puertos del Estado) and Météo-France / Ifremer. In order to enrich the available information, four additional buoys were considered for the Greek Seas, bringing the total number of buoys to thirteen (13) [1].

The buoy data consist of wind speed time series, which cover large time periods. The wind measurements have different recording intervals ranging from 1 to 3 hours. The locations of the thirteen examined buoys along with their code numbers used in this work and the measurement periods, are listed below in Table 1; see also Figure 1.

Table 1. Buoy locations and measurement period.

Buoy Code	Latitude (°)	Longitude (°)	Measurement Period
6100196	41.9000	3.6500	27/03/2001 - 18/11/2024
6100197	39.7100	4.4200	29/04/1993 - 30/11/2024
6100198	36.5700	−2.3400	27/03/1998 - 30/11/2024
6100280	40.6900	1.4700	20/08/2004 - 30/11/2024
6100281	39.5100	0.2000	15/09/2005 - 13/11/2024
6100417	37.6500	−0.3100	18/07/2006 - 30/11/2024
6100430	39.5600	2.0900	29/11/2006 - 30/11/2024
61277	35.7263	25.1307	28/05/2007 - 21/11/2024
68422	36.8288	21.6068	09/11/2007 - 01/04/2023
ATH	39.9750	24.7294	25/05/2000 - 26/11/2022
HER	35.4342	25.0792	15/07/2016 - 29/10/2024
SAR	37.6099	23.5669	27/08/2007 - 01/08/2019
SKY	39.1130	24.4640	28/08/2007 - 18/07/2012

1. The additional Greek buoys considered are Athos (ATH), Heraklion (HER), Saronikos (SAR) and Skyros (SKY).

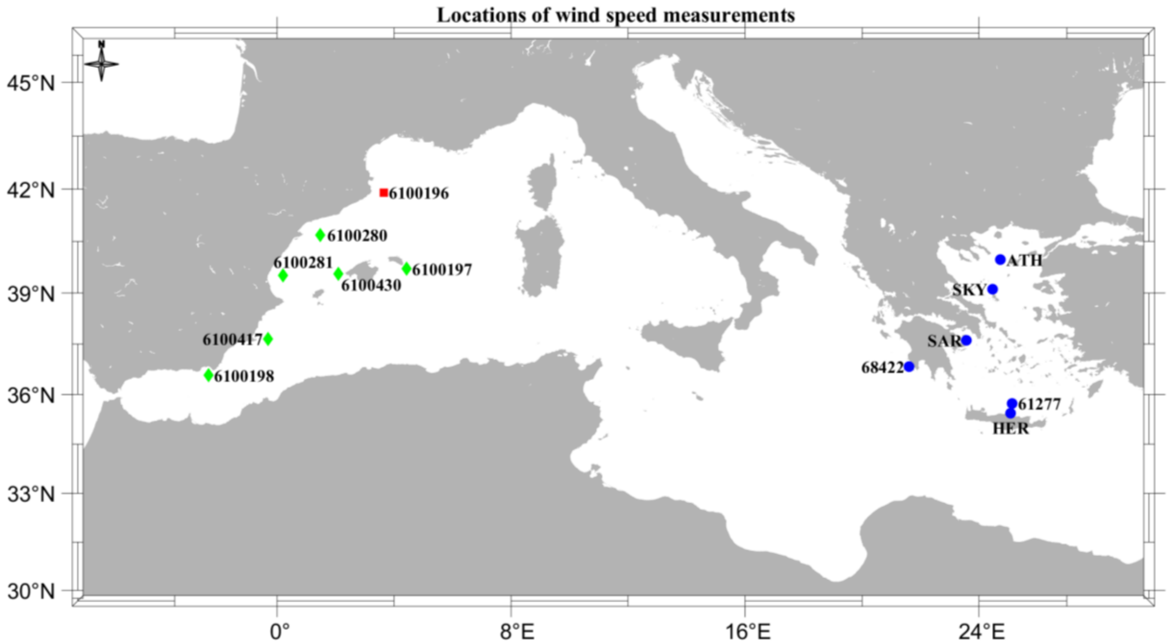


Figure 1: Locations of the examined oceanographic buoys.

3. Methodology

Wind speed modeling is fundamental to atmospheric and oceanographic studies, since high-quality wind data are crucial for applications such as weather forecasting, climate research, and offshore wind energy planning. The Mediterranean Sea presents a demanding landscape for wind resource assessment due to its complex wind regimes and varied topography. *In-situ* buoy measurements represent an ideal data source to consider in these applications, as they record real time wind speed and direction along with other met-ocean parameters. Although surface buoy observations provide reliable data, their spatial coverage is restricted, hence numerical models are required for comprehensive wind resource mapping. On the other hand, reanalysis models provide gridded wind speed data, but their accuracy must be validated against field observations to determine their credibility. This study will assess the ability of two contemporary reanalysis models —CERRA and NEWA— to simulate wind speeds over the Mediterranean Sea region, using buoy measurements as reference. The methodology involves collocating model data to buoy locations, adjusting model measurements in buoy measurement height levels, and performing a comprehensive statistical comparison to quantify each model's accuracy.

The first part of the methodology refers to the collection and preprocessing of buoy and model data. Only buoys with good quality data are utilized in the analysis. On the other hand, model data are extracted from the NEWA and CERRA datasets that provide gridded values of wind speed at 10 m height above sea level (asl).

In order to compare model data and buoy observations, the four nearest model grid points to each buoy location are identified. This is accomplished by calculating the Euclidean distance between the buoy coordinates and all available model grid points. The four nearest grid points to each buoy are selected and the model wind speed at the buoy location is estimated as a weighted average of the wind speeds from these grid points, i.e.,

$$\overline{U_M} = \frac{\sum_{i=1}^{4}\left(\frac{U_{M_i}}{d_i^2}\right)}{\sum_{i=1}^{4}\left(\frac{1}{d_{M_i}^2}\right)}, \quad (1)$$

where $\overline{U_M}$ is the weighted average wind speed, U_{M_i} is the model wind speed at the i-th nearest grid point, and $d_{M_i}^2$ is the squared distance between the buoy and the i-th grid point, $i = 1,2,3,4$, of the model. This process ensures that the model data chosen for the analysis are spatially representative of the buoy' s location.

Temporal alignment is another important aspect of this methodology, as it ensures that the model and buoy data being compared correspond to the same time instants. For this, buoy and model data are filtered to retain only those timesteps present in both datasets. Additionally, missing or invalid values of buoy data are discarded. This filtering process ensures that only high quality, temporally collocated data are used in the assessment process.

As buoy wind speeds are generally recorded at heights different from the 10-meter height above sea level (asl) of the models' datasets, the buoy wind speeds are adjusted to 10 meters asl using the logarithmic wind profile equation, i.e.,

$$U_{B_{10}} = U_{B_h} \frac{\ln(10/z_0)}{\ln(h/z_0)}, \quad (2)$$

where $U_{B_{10}}$ is the wind speed of the buoy at 10 m, U_{B_h} is the wind speed of the buoy at the measurement height h, and z_0 is the roughness length, assumed to be 0.0001 meters for open water.

The final step in the methodology is to compare the adjusted buoy wind speeds with the models' weighted average wind speeds, by using statistical metrics. The particular metrics used are the Root Mean Squared Error ($RMSE$), bias (b), Pearson correlation coefficient (r), Mean Absolute Error (MAE), scatter index (SI), and the Hanna-Heinhold indicator (HH).

$RMSE$ is defined as:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(U_{B_i} - U_{M_i})^2}, \quad (3)$$

where U_{B_i} is the measured wind speed obtained from the buoy and U_{M_i} is the corresponding wind speed obtained from the model dataset. The $RMSE$ provides a measure of the spread of the errors between the observed and modeled values.

Bias is calculated as:

$$b = \frac{1}{n}\sum_{i=1}^{n}(U_{B_i} - U_{M_i}), \quad (4)$$

and represents the mean error between the observed and modeled values. A positive value of b indicates that the model tends to overestimate in the mean the observed values, while a negative value indicates underestimation.

The Pearson correlation coefficient (r) is given by:

$$r = \frac{\sum_{i=1}^{n}(U_{B_i} - \overline{U_B})(U_{M_i} - \overline{U_M})}{\sqrt{\sum_{i=1}^{n}(U_{B_i} - \overline{U_B})^2 \sum_{i=1}^{n}(U_{M_i} - \overline{U_M})^2}}, \quad (5)$$

where $\overline{U_B}$ and $\overline{U_M}$ are the mean values of the observed and modeled data, respectively. The correlation coefficient ranges from –1 to 1, with values close to 1 indicating a strong positive correlation.

MAE is defined as:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|U_{B_i} - U_{M_i}\right|, \quad (6)$$

and provides the average absolute difference between the observed and model data. The scatter index (SI) is given by:

$$SI = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(U_{B_i} - U_{M_i} - b)^2}}{\overline{U_B}}. \tag{7}$$

SI provides a normalized measure of the variability of the errors relative to the mean observed value.

According to [41], it is not always valid that lower values of $RMSE$, and SI imply a better performance. Therefore, an additional indicator introduced by Hanna and Heinhlod [42] will be used, which is defined as follows:

$$HH = \frac{\sqrt{\sum_{i=1}^{n}(U_{B_i} - U_{M_i})^2}}{\sum_{i=1}^{n} U_{B_i} U_{M_i}}. \tag{8}$$

3. Numerical results

3.1 Overall evaluation

In this section, we present the numerical results obtained from the analysis of the CERRA and NEWA reanalysis datasets and the *in-situ* measurements derived from 16 buoys across the Mediterranean Sea.

The buoy distribution (see Figure 1) indicates a lack of *in-situ* measurements in the area surrounding Italy. Most of the buoys used in this study are positioned in the geographic locations of the above-mentioned Greek and Spanish offshore areas, ensuring that the recorded measurements provide a comprehensive representation of wind conditions across a wide range of locations in the Mediterranean. As a result, the findings should be generally reflective of the broader wind patterns in the region and the aforementioned lack of *in-situ* measurements is not expected to compromise the validity of this study.

In Table 2 and Table 3, the main statistical parameters of the collocated data from buoy and CERRA and NEWA are respectively shown. Specifically, the following parameters are shown: common sample size of buoy and model measurements N, mean value m_U, median med_U, coefficient of variation CV_U, maximum value max_U, and the 95[th] and 99[th] percentiles U_{95} and U_{99}, respectively. The subscript "B" denotes data from buoy, the subscript "C" denotes data from CERRA and the subscript "N" denotes data from NEWA. The buoy statistics reflect the observed reality, while the model statistics represent the simulated counterparts, enabling a general understanding of how well the model performs for different wind regimes.

The model with the highest data availability is NEWA since it has temporal resolution of 30 minutes, but has a shorter timeframe ranging from 2005 to 2018. In contrast, CERRA has reduced data availability with observations at 3-hour intervals, but with a larger timeframe from 1993 to 2020. Despite these differences in temporal coverage and resolution, the total number of eligible data points across all models is high enough to ensure the statistical robustness and validity of the results.

Table 2**.** Statistical parameters of collocated *in-situ* measurements and CERRA.

#	N	m_{U_B} (m/s)	m_{U_C} (m/s)	med_{U_B} (m/s)	med_{U_C} (m/s)	CV_{U_B} (%)	CV_{U_C} (%)	max_{U_B} (m/s)	max_{U_C} (m/s)	$U_{B,95}$ (m/s)	$U_{C,95}$ (m/s)	$U_{B,99}$ (m/s)	$U_{C,99}$ (m/s)
6100196	33782	6.91	7.69	5.70	6.46	70.0	62.7	27.9	28.8	16.5	17.0	19.9	20.4
6100197	50912	6.04	6.05	5.47	5.44	59.8	56.0	24.5	22.7	13.1	12.6	16.3	15.8
6100198	48341	6.03	6.56	5.47	6.14	62.1	59.2	22.2	24.3	12.8	13.4	15.9	16.7

6100280	43592	5.04	5.40	4.36	4.62	67.0	62.7	21.4	22.5	11.7	12.1	14.9	15.2
6100281	38111	5.02	5.09	4.36	4.36	64.2	61.7	21.1	20.6	11.2	11.3	14.1	13.8
6100417	37063	5.41	5.73	4.97	5.31	57.4	53.6	19.9	19.7	11.2	11.5	13.8	14.0
6100430	36647	5.30	5.33	4.70	4.69	61.7	60.1	23.0	22.1	11.7	11.6	14.7	14.9
61277	24523	6.14	5.99	5.89	5.72	50.9	47.9	20.9	19.1	11.8	11.2	14.6	13.8
68422	24375	5.36	5.49	4.97	5.12	58.1	55.6	20.7	20.6	11.2	11.1	14.1	14.3
ATH	44736	5.30	5.94	4.54	5.18	69.5	61.7	24.5	21.9	12.4	13.0	16.2	16.1
HER	8734	6.12	5.33	6.09	5.39	49.3	50.4	20.1	18.2	10.9	9.5	14.1	12.9
SAR	21407	5.15	4.90	4.81	4.62	60.1	56.5	19.3	19.0	10.7	9.7	13.1	12.5
SKY	10676	5.63	6.26	5.10	5.87	62.3	55.5	20.9	21.3	12.1	12.6	15.2	15.6

Table 3**.** Statistical parameters of collocated *in-situ* measurements and NEWA.

#	N	m_{U_B} (m/s)	m_{U_N} (m/s)	med_{U_B} (m/s)	med_{U_N} (m/s)	CV_{U_B} (%)	CV_{U_N} (%)	max_{U_B} (m/s)	max_{U_N} (m/s)	$U_{B,95}$ (m/s)	$U_{N,95}$ (m/s)	$U_{B,99}$ (m/s)	$U_{N,99}$ (m/s)
6100196	76427	6.94	7.65	5.70	6.43	69.6	64.6	26.7	27.4	16.4	17.7	19.9	21.8
6100197	98096	6.08	6.51	5.47	6.03	59.8	55.1	24.8	25.3	13.1	13.3	16.4	16.9
6100198	89363	6.11	7.36	5.70	7.22	61.6	54.5	23.0	25.1	12.8	14.2	15.9	17.6
6100280	113775	5.02	5.53	4.36	4.73	66.9	63.5	21.9	24.7	11.7	12.8	14.7	16.6
6100281	99809	5.02	5.26	4.36	4.53	63.8	62.4	21.1	24.3	11.2	11.7	13.9	15.1
6100417	92900	5.40	6.15	4.97	5.86	57.9	52.1	19.9	22.4	11.2	11.9	13.8	14.8
6100430	94425	5.32	5.81	4.91	5.28	61.4	58.5	24.8	22.4	11.7	12.3	14.7	15.8
1277	20009	6.05	6.62	5.84	6.50	51.4	47.4	20.9	21.6	11.8	12.3	14.4	15.2
8422	22851	5.37	6.22	4.97	6.02	58.4	53.3	20.7	25.6	11.2	12.1	14.1	15.4
ATH	31509	5.50	5.92	4.71	5.31	65.7	60.6	22.5	23.7	12.6	12.7	16.0	16.0
HER	6102	6.07	6.69	5.96	6.86	51.1	49.7	20.1	24.0	11.2	12.1	14.4	15.3
SAR	21048	5.15	5.34	4.79	4.94	60.3	59.5	19.3	21.4	10.7	11.2	13.1	14.4
SKY	10455	5.62	6.35	5.09	6.01	62.4	55.9	20.9	22.4	12.1	12.8	15.2	16.4

As can be seen from Table 2 and Table 3, NEWA systematically overestimates the mean wind speed, while CERRA overestimates it for the majority of the examined locations (10 out of 13). As regards the median values, NEWA systematically overestimates, while CERRA overestimates the median at 7 locations. CERRA overestimates the maximum wind speed for 4 locations, while NEWA overestimates it for all locations (except from 6100430). In addition, NEWA overestimates the extreme percentiles U_{95} and U_{99} at 13 and 11 locations respectively, while CERRA overestimates the extreme percentiles at 7 locations for both percentiles.

In Table 4 the statistical metrics for both reanalysis datasets are summarized.

Table 4**.** Statistical metrics for CERRA (C) and NEWA (N) models' performance.

Buoy	$RMSE$ **(m/s)**		b **(m/s)**		r		MAE **(m/s)**		SI		HH	
	C	N	C	N	C	N	C	N	C	N	C	N
6100196	2.172	2.827	−0.780	−0.713	0.912	0.844	1.604	2.120	0.293	0.394	0.252	0.330
6100197	1.781	2.391	−0.009	−0.435	0.872	0.788	1.292	1.779	0.295	0.387	0.259	0.339
6100198	1.971	2.856	−0.534	−1.250	0.877	0.784	1.461	2.203	0.315	0.420	0.273	0.379
6100280	1.895	2.534	−0.360	−0.515	0.849	0.740	1.410	1.920	0.369	0.495	0.312	0.420
6100281	1.794	2.462	−0.072	−0.241	0.841	0.714	1.315	1.850	0.357	0.489	0.307	0.423
6100417	1.618	2.354	−0.324	−0.755	0.868	0.752	1.197	1.789	0.293	0.413	0.258	0.369
6100430	1.840	2.533	−0.024	−0.486	0.839	0.723	1.361	1.901	0.347	0.467	0.302	0.406
61277	1.791	2.334	0.151	−0.575	0.826	0.738	1.303	1.688	0.291	0.374	0.270	0.339
68422	1.829	2.461	−0.129	−0.847	0.826	0.744	1.362	1.868	0.340	0.430	0.299	0.384
ATH	2.245	2.451	−0.643	−0.423	0.829	0.775	1.592	1.830	0.406	0.439	0.344	0.375
HER	1.855	2.477	0.796	−0.623	0.834	0.723	1.450	1.792	0.274	0.395	0.296	0.357
SAR	2.001	2.517	0.254	−0.192	0.777	0.681	1.524	1.921	0.385	0.488	0.354	0.430

SKY	2.536	2.828	–0.636	–0.721	0.753	0.700	1.623	1.926	0.436	0.486	0.380	0.424

Regarding $RMSE$, r, MAE, SI and HH, CERRA outperforms overall NEWA. Specifically, $RMSE$ values for CERRA are smaller than the corresponding values for NEWA for all locations. The CERRA values of $RMSE$ range between 1.618 m/s (for 6100417) and 2.536 m/s (for SKY), while the corresponding values for NEWA range between 2.334 m/s (for 61277) and 2.856 m/s (for 6100198). The values of r for CERRA are uniformly higher (0.753 – 0.912) than the corresponding values for NEWA (0.681 – 0.844), and the values of MAE for CERRA (1.292 m/s – 1.623 m/s) are always smaller than the corresponding values for NEWA (1.688 m/s – 2.203 m/s).

The values of SI for CERRA (0.274 – 0.436) are always smaller than the corresponding values for NEWA (0.374 – 0.495). Moreover, CERRA also outperforms NEWA with regards to b, since the corresponding values are smaller in the absolute sense than the values for NEWA for 9 out of 13 locations. NEWA exhibits consistent negative biases across all buoys with values between –1.250 m/s and –0.192 m/s, while CERRA's biases are ranging between –0.780 m/s to 0.796 m/s. The values of HH for CERRA (0.252 – 0.380) are always smaller than the corresponding values for NEWA (0.330 – 0.430). See also Figure 2.

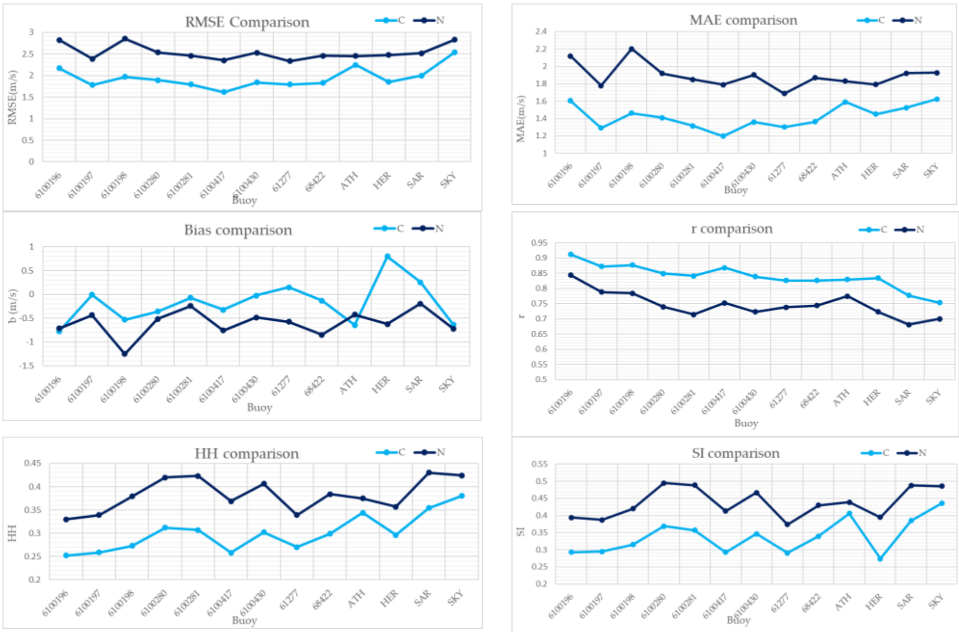


Figure 2: Statistical metrics for all examined locations.

In an attempt to derive statistical metrics for the entire basin (for all examined locations), the weighted averages of the $RMSE$, b, MAE, and SI values are calculated (with weights the available sample sizes). For CERRA it was found that $\overline{RMSE_{W,C}} = 1.922\ m/s$, $\overline{b_{W,C}} = -0.252$ m/s, $\overline{MAE_{W,C}} = 1.408\ m/s$, $\overline{SI_{W,C}} = 0.336$, $\overline{r_{W,C}} = 0.849$, while for NEWA, the corresponding values are: $\overline{RMSE_{W,N}} = 2.543\ m/s$, $\overline{b_{W,N}} = -0.601$ m/s, $\overline{MAE_{W,N}} = 1.915\ m/s$, $\overline{SI_{W,N}} = 0.440$, $\overline{r_{W,N}} = 0.757$. The overall superiority of CERRA across all examined locations is evident. Specifically, $\overline{RMSE_W}$, $\overline{b_W}$, $\overline{MAE_W}$ and $\overline{SI_W}$ for CERRA are ~138%, ~32%, ~36% and ~31% smaller and $\overline{r_W}$ is ~11% greater than the corresponding values for NEWA.

The assessment of the CERRA and NEWA datasets has been also performed with respect to the 90th and 95th percentiles of the buoys' wind speed. Specifically, the collocated datasets with $U_B \geq U_{B,0.90}$ and $U_B \geq U_{B,0.95}$ have been examined and the corresponding results are summarized in Table 5 and Table 6, respectively. Evidently, the quality of the CERRA and NEWA extreme wind speeds is poorer than in the case of the entire samples.

Table 5. Statistical metrics for CERRA (C) and NEWA (N) models' performance for $U_B \geq U_{B,0.90}$.

Buoy	$RMSE$ (m/s)		b (m/s)		r		MAE (m/s)		SI		HH	
	C	N	C	N	C	N	C	N	C	N	C	N
6100196	1.880	2.748	-0.049	-0.332	0.707	0.619	1.420	2.067	0.209	0.441	0.012	0.026
6100197	2.333	2.640	1.102	0.812	0.642	0.587	1.715	1.931	0.315	0.467	0.032	0.040
6100198	1.819	2.533	-0.026	-0.270	0.695	0.570	1.327	1.851	0.249	0.473	0.018	0.034
6100280	2.162	3.144	0.450	0.432	0.635	0.543	1.604	2.417	0.369	0.802	0.032	0.068
6100281	2.080	3.155	0.802	1.004	0.608	0.458	1.524	2.420	0.316	0.776	0.033	0.080
6100417	1.778	2.590	0.381	0.442	0.643	0.487	1.319	1.931	0.261	0.562	0.024	0.051
6100430	2.238	2.923	0.705	0.667	0.634	0.496	1.625	2.146	0.374	0.672	0.036	0.061
61277	2.227	2.456	1.368	0.646	0.613	0.545	1.697	1.770	0.252	0.464	0.037	0.043
68422	2.066	2.368	0.698	0.140	0.650	0.586	1.483	1.727	0.328	0.484	0.033	0.042
ATH	1.974	2.806	0.377	1.004	0.692	0.546	1.437	2.036	0.290	0.527	0.023	0.049
HER	2.667	2.494	1.995	0.448	0.656	0.576	2.166	1.771	0.272	0.509	0.063	0.045
SAR	2.810	2.995	1.936	1.061	0.511	0.463	2.292	2.347	0.374	0.707	0.076	0.079
SKY	1.949	2.520	0.611	0.741	0.663	0.570	1.355	1.848	0.274	0.463	0.025	0.042

Specifically, for CERRA and for $U_{B,0.90} \geq U_{B,0.90}$, r reduces significantly for all locations ranging between 0.511 (for SAR) and 0.707 (for 6100196), while for NEWA r is ranging between 0.458 (for 6100281) and 0.619 (for 6100196). The values of r for CERRA still remain greater than the corresponding values for NEWA for all locations. Regarding the $RMSE$ values of CERRA, they are increasing for the majority of the examined locations (except from 6100196, 6100198, ATH and SKY), while for NEWA they are also increasing (except from 6100196, 6100198, 68422 and SKY). In any case, the $RMSE$ values of CERRA are still lower than the corresponding values of NEWA for all locations except from HER. Regarding b for CERRA, it increases in the absolute sense except from 6100196, 6100198, ATH and SKY, while for NEWA it increases for 6100197, 6100281, 6100430, 61277, ATH, SAR and SKY.

Table 6. Statistical metrics for CERRA (C) and NEWA (N) models' performance for $U_B \geq U_{B,0.95}$.

Buoy	$RMSE$ (m/s)		b (m/s)		r		MAE (m/s)		SI		HH	
	C	N	C	N	C	N	C	N	C	N	C	N
6100196	1.892	2.617	0.174	-0.443	0.613	0.524	1.436	1.987	0.190	0.360	0.010	0.019
6100197	2.501	2.712	1.301	0.907	0.533	0.502	1.845	1.985	0.303	0.437	0.030	0.035
6100198	1.923	2.615	-0.038	-0.238	0.618	0.520	1.426	1.890	0.252	0.459	0.017	0.031
6100280	2.180	3.099	0.557	0.282	0.568	0.457	1.586	2.328	0.328	0.704	0.027	0.053
6100281	2.110	3.298	0.946	1.119	0.564	0.405	1.537	2.505	0.275	0.752	0.028	0.072
6100417	1.812	2.738	0.468	0.530	0.582	0.415	1.335	2.023	0.241	0.568	0.021	0.048
6100430	2.390	3.080	0.828	0.852	0.558	0.407	1.715	2.233	0.372	0.647	0.033	0.055
61277	2.429	2.580	1.577	0.777	0.563	0.510	1.874	1.880	0.255	0.453	0.037	0.039
68422	2.141	2.371	0.737	0.168	0.605	0.561	1.534	1.749	0.314	0.434	0.029	0.034
ATH	1.974	3.011	0.612	1.255	0.648	0.479	1.428	2.165	0.240	0.515	0.019	0.046
HER	2.964	2.772	2.135	0.436	0.620	0.492	2.344	2.046	0.333	0.570	0.064	0.045
SAR	3.085	3.056	2.180	1.028	0.461	0.396	2.516	2.374	0.390	0.679	0.077	0.068
SKY	2.082	2.683	0.820	0.959	0.616	0.543	1.416	1.961	0.261	0.447	0.023	0.039

For wind speeds above $U_{B,0.95}$, r reduces significantly for both models and for all locations. Specifically, r for CERRA ranges between 0.461 (for SAR) and 0.620 (for HER), and for NEWA it ranges between 0.396 (for SAR) and 0.561 (for 68422). The values of r for CERRA still remain greater than the corresponding values for NEWA for all locations. Regarding the $RMSE$ values of CERRA, they are increasing for the majority of the examined locations (except from 6100196, 6100198, ATH and SKY), while for NEWA they are also increasing (except from 6100196, 6100198, 68422 and SKY). In any case, the $RMSE$ values of CERRA are still lower than the corresponding values of NEWA for all locations except from HER. Regarding b for CERRA, it increases in the absolute sense for all locations (except from 6100196, 6100198, and ATH), while for NEWA it also increases (except from 6100196, 6100198, 6100280, 6100417, 68422 and HER).

3.2 Seasonal evaluation

In this section the seasonal evaluation results of the CERRA and NEWA wind datasets are presented for winter (DJF), spring (MAM), summer (JJA) and autumn (SON) in

Table 7, Table 8, Table 9, and Table 10, , respectively for all examined buoys.

Buoy	$RMSE$ (m/s)		b (m/s)		r		MAE (m/s)		SI		HH	
	C	N	C	N	C	N	C	N	C	N	C	N
6100196	2.252	3.104	-0.639	-0.898	0.921	0.853	1.630	2.314	0.252	0.346	0.219	0.300
6100197	1.838	2.560	0.005	-0.469	0.893	0.806	1.363	1.881	0.249	0.341	0.222	0.304
6100198	1.987	2.734	-0.265	-0.768	0.887	0.805	1.439	2.060	0.313	0.420	0.265	0.360
6100280	2.068	2.786	-0.482	-0.652	0.861	0.763	1.564	2.141	0.323	0.441	0.281	0.381
6100281	1.844	2.702	0.001	-0.188	0.877	0.756	1.370	2.047	0.315	0.459	0.271	0.396
6100417	1.774	2.463	-0.345	-0.619	0.867	0.764	1.321	1.865	0.290	0.391	0.256	0.348
6100430	1.981	2.673	-0.264	-0.741	0.865	0.781	1.459	1.987	0.317	0.411	0.274	0.359
61277	2.108	2.822	0.099	-0.674	0.838	0.749	1.542	2.069	0.301	0.398	0.273	0.355
68422	1.956	2.696	0.142	-0.680	0.847	0.756	1.475	2.020	0.302	0.404	0.273	0.359
ATH	3.002	2.714	-1.058	-0.517	0.790	0.796	2.004	2.039	0.450	0.409	0.386	0.352
HER	2.111	2.991	0.639	-0.723	0.829	0.726	1.593	2.236	0.308	0.438	0.304	0.387
SAR	2.158	2.720	0.449	-0.375	0.816	0.737	1.644	2.087	0.350	0.447	0.328	0.390
SKY	3.223	3.475	-0.949	-1.066	0.697	0.657	2.105	2.368	0.452	0.486	0.404	0.434

For the winter season, CERRA outperforms NEWA as regards all the examined statistical measures. For MAE, CERRA outperforms for all locations, while for $RMSE$, r, HH, SI, and b CERRA outperforms for 12 out of 13 locations.

Table 7. Seasonal statistical results between collocated CERRA (C) and NEWA (N) model for winter.

Buoy	$RMSE$ (m/s)		b (m/s)		r		MAE (m/s)		SI		HH	
	C	N	C	N	C	N	C	N	C	N	C	N
6100196	2.252	3.104	-0.639	-0.898	0.921	0.853	1.630	2.314	0.252	0.346	0.219	0.300
6100197	1.838	2.560	0.005	-0.469	0.893	0.806	1.363	1.881	0.249	0.341	0.222	0.304
6100198	1.987	2.734	-0.265	-0.768	0.887	0.805	1.439	2.060	0.313	0.420	0.265	0.360
6100280	2.068	2.786	-0.482	-0.652	0.861	0.763	1.564	2.141	0.323	0.441	0.281	0.381
6100281	1.844	2.702	0.001	-0.188	0.877	0.756	1.370	2.047	0.315	0.459	0.271	0.396
6100417	1.774	2.463	-0.345	-0.619	0.867	0.764	1.321	1.865	0.290	0.391	0.256	0.348
6100430	1.981	2.673	-0.264	-0.741	0.865	0.781	1.459	1.987	0.317	0.411	0.274	0.359
61277	2.108	2.822	0.099	-0.674	0.838	0.749	1.542	2.069	0.301	0.398	0.273	0.355
68422	1.956	2.696	0.142	-0.680	0.847	0.756	1.475	2.020	0.302	0.404	0.273	0.359
ATH	3.002	2.714	-1.058	-0.517	0.790	0.796	2.004	2.039	0.450	0.409	0.386	0.352
HER	2.111	2.991	0.639	-0.723	0.829	0.726	1.593	2.236	0.308	0.438	0.304	0.387
SAR	2.158	2.720	0.449	-0.375	0.816	0.737	1.644	2.087	0.350	0.447	0.328	0.390
SKY	3.223	3.475	-0.949	-1.066	0.697	0.657	2.105	2.368	0.452	0.486	0.404	0.434

Table 8. Seasonal statistical results between collocated CERRA (C) and NEWA (N) model for spring.

Buoy	$RMSE$ (m/s)		b (m/s)		r		MAE (m/s)		SI		HH	
	C	N	C	N	C	N	C	N	C	N	C	N
6100196	2.155	2.912	-0.748	-0.694	0.911	0.830	1.583	2.181	0.295	0.412	0.252	0.345
6100197	1.799	2.520	-0.278	-0.768	0.864	0.769	1.330	1.927	0.304	0.404	0.266	0.358
6100198	2.006	3.053	-0.672	-1.521	0.890	0.792	1.471	2.370	0.290	0.406	0.257	0.377
6100280	1.937	2.562	-0.482	-0.628	0.848	0.734	1.438	1.942	0.375	0.498	0.317	0.424
6100281	1.846	2.491	-0.220	-0.421	0.824	0.687	1.364	1.892	0.371	0.499	0.320	0.434
6100417	1.715	2.556	-0.503	-1.038	0.869	0.739	1.278	1.956	0.292	0.420	0.261	0.384
6100430	1.883	2.599	-0.164	-0.671	0.826	0.696	1.400	1.982	0.358	0.478	0.311	0.420
61277	1.888	2.422	0.068	-0.536	0.834	0.751	1.380	1.795	0.321	0.411	0.288	0.363
68422	1.773	2.378	-0.129	-0.837	0.839	0.751	1.304	1.798	0.323	0.407	0.285	0.367
ATH	2.264	2.601	-0.696	-0.615	0.823	0.722	1.657	1.969	0.424	0.502	0.357	0.429
HER	1.950	2.600	0.544	-0.699	0.808	0.725	1.501	1.980	0.352	0.475	0.341	0.414
SAR	1.994	2.520	0.071	-0.432	0.748	0.639	1.512	1.917	0.436	0.543	0.388	0.474
SKY	2.644	2.875	-0.806	-0.864	0.722	0.669	1.793	2.088	0.520	0.566	0.443	0.484

For the spring season, CERRA outperforms NEWA with respect to all the examined statistical measures. For $RMSE$, r, SI, HH, and MAE, CERRA outperforms for all locations, and for b CERRA outperforms for 11 locations.

Table 9. Seasonal statistical results between collocated CERRA (C) and NEWA (N) model for summer season.

Buoy	$RMSE$ (m/s)		b (m/s)		r		MAE (m/s)		SI		HH	
	C	N	C	N	C	N	C	N	C	N	C	N
6100196	2.189	2.630	-1.017	-0.697	0.878	0.792	1.633	1.999	0.351	0.448	0.311	0.379
6100197	1.562	2.058	0.078	-0.288	0.833	0.708	1.152	1.558	0.321	0.429	0.290	0.382
6100198	2.069	2.982	-0.809	-1.763	0.839	0.751	1.578	2.347	0.361	0.439	0.322	0.429
6100280	1.618	2.137	-0.152	-0.214	0.777	0.613	1.197	1.614	0.412	0.542	0.359	0.480

6100281	1.616	2.017	-0.033	-0.082	0.767	0.630	1.182	1.519	0.382	0.474	0.342	0.431
6100417	1.470	2.043	-0.326	-0.803	0.835	0.722	1.094	1.585	0.306	0.407	0.274	0.375
6100430	1.686	2.253	0.222	-0.083	0.741	0.553	1.261	1.709	0.387	0.520	0.363	0.478
61277	1.358	1.754	0.135	-0.787	0.787	0.708	1.058	1.327	0.225	0.264	0.218	0.268
68422	1.726	2.328	-0.465	-1.203	0.774	0.692	1.310	1.836	0.371	0.445	0.333	0.426
ATH	1.855	2.174	-0.460	-0.350	0.790	0.705	1.396	1.658	0.408	0.468	0.353	0.410
HER	1.715	2.146	1.075	-0.864	0.856	0.701	1.422	1.505	0.190	0.290	0.251	0.286
SAR	1.873	2.348	-0.071	-0.157	0.732	0.605	1.415	1.803	0.399	0.500	0.360	0.453
SKY	1.593	1.869	-0.321	-0.398	0.839	0.796	1.136	1.373	0.312	0.362	0.278	0.321

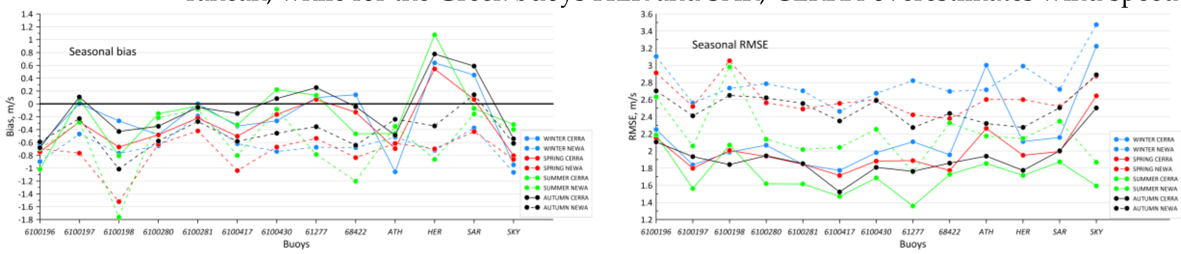
For the summer season, CERRA outperforms NEWA as follows: For $RMSE$, r, MAE, SI and HH, CERRA outperforms NEWA for all locations, while for b CERRA outperforms for 9 locations.

Table 10. Seasonal statistical results between collocated CERRA (C) and NEWA (N) model for autumn.

Buoy	$RMSE$ (m/s)		b (m/s)		r		MAE (m/s)		SI		HH	
	C	N	C	N	C	N	C	N	C	N	C	N
6100196	2.106	2.703	-0.682	-0.592	0.914	0.853	1.574	2.031	0.283	0.380	0.242	0.318
6100197	1.934	2.411	0.107	-0.229	0.848	0.770	1.349	1.764	0.308	0.383	0.278	0.340
6100198	1.842	2.649	-0.430	-1.014	0.875	0.780	1.382	2.051	0.304	0.405	0.265	0.364
6100280	1.944	2.621	-0.347	-0.577	0.834	0.718	1.454	1.995	0.374	0.508	0.319	0.433
6100281	1.853	2.555	-0.053	-0.274	0.831	0.690	1.343	1.917	0.368	0.511	0.318	0.443
6100417	1.522	2.351	-0.149	-0.582	0.881	0.751	1.117	1.773	0.280	0.422	0.246	0.371
6100430	1.809	2.589	0.083	-0.456	0.841	0.703	1.334	1.930	0.329	0.465	0.292	0.408
61277	1.763	2.274	0.253	-0.354	0.803	0.702	1.265	1.621	0.303	0.395	0.287	0.358
68422	1.859	2.439	-0.043	-0.644	0.801	0.726	1.368	1.825	0.362	0.459	0.321	0.402
ATH	1.940	2.321	-0.487	-0.239	0.874	0.802	1.442	1.688	0.328	0.389	0.281	0.337
HER	1.774	2.276	0.776	-0.342	0.819	0.693	1.377	1.632	0.285	0.405	0.312	0.367
SAR	2.002	2.505	0.588	0.143	0.781	0.670	1.549	1.905	0.353	0.464	0.351	0.425
SKY	2.503	2.890	-0.544	-0.615	0.745	0.659	1.546	1.928	0.425	0.496	0.373	0.438

For the autumn season, regarding $RMSE$, r, MAE, SI, and HH, CERRA outperforms NEWA for all locations, while for b, it outperforms for 9 locations.

In Figure 3, b, r, $RMSE$ and HH are depicted for each season and buoy location. Overall, it seems that $RMSE$ and r take lower values during summer and higher values during winter for both CERRA and NEWA. For HH, the higher values are overall encountered for summer and the lower values for winter at the buoys of the western Mediterranean. It is also evident that NEWA systematically underestimates wind speed for all seasons and locations (except from SAR for autumn). Also, for the majority of the cases, CERRA underestimates wind speed for all seasons for the buoys of the western Mediterranean, while for the Greek buoys HER and SAR, CERRA overestimates wind speed.



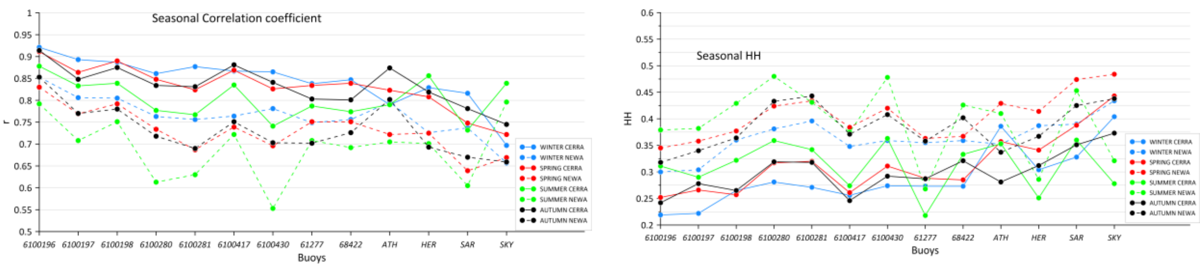


Figure 3: Seasonal statistical metrics for all examined locations

5. Conclusions

In this work, the wind speeds obtained from the CERRA and NEWA datasets have been evaluated for offshore Mediterranean locations at 10 m above sea level, using long-term wind data from 13 oceanographic buoys. Most of the available buoys are located in the western and central-eastern Mediterranean and the quality of the wind speed data were obtained from the Copernicus Marine Service.

The evaluation procedure was extensive. First, the evaluation at the hourly scale has been performed and then the same process has been followed for the seasonal scale. In addition, the evaluation of the collocated data samples with $U_B \geq U_{B,0.90}$ and $U_B \geq U_{B,0.95}$ has been also performed in order to assess the quality of CERRA and NEWA at extreme wind speeds.

The statistical evaluation of the collocated wind speed data from buoys and CERRA has revealed that bias takes relatively low values ranging between –0.780 m/s and 0.796 m/s for CERRA, and relatively high (in the absolute sense) values for NEWA ranging between –1.250 m/s and –0.192 m/s. CERRA outperforms NEWA in this respect for 9 out of 13 locations. For CERRA, all $RMSE$ values are below 2.5 m/s, while for NEWA all $RMSE$ values are greater than 2.3 m/s. CERRA outperforms NEWA by providing smaller $RMSE$ values for all locations. r takes systematically medium to high values for CERRA ranging from 0.753 up to 0.912, while for NEWA it takes medium values with the corresponding range 0.681 to 0.844. CERRA also outperforms NEWA with respect to MAE, SI and HH since it provides smaller values for all examined locations. Moreover, at the basin scale, the weighted averages of all the examined statistics clearly suggest the superiority of the CERRA wind data set.

The same qualitative characteristics have been also observed at the seasonal time scale. For winter, CERRA outperforms NEWA with respect to MAE for all examined locations and, with respect to the rest statistics, CERRA outperforms NEWA for 12 out of 13 locations. For spring, CERRA outperforms NEWA with respect to all statistics for all examined locations (except from bias, where CERRA outperforms NEWA for 11 out of 13 locations). For summer, CERRA outperforms NEWA with respect to all statistics for all examined locations (except from bias, where CERRA outperforms NEWA for 11 out of 13 locations). For autumn, CERRA outperforms NEWA with respect to all statistics for all examined locations (except from bias, where CERRA outperforms NEWA for 9 out of 13 locations).

Regarding the evaluation of the wind speeds greater than the 90th and 95th percentile points, the values of all the evaluation parameters are clearly increased and r clearly decreases. For $U_B \geq U_{B,0.95}$, CERRA outperforms NEWA with respect to r, MAE and SI for all locations, while with respect to $RMSE$ and HH, CERRA outperforms NEWA for 12 out of 13 locations. For b, CERRA outperforms NEWA for 7 locations. For $U_B \geq U_{B,0.95}$, CERRA outperforms NEWA with respect to r and SI for all locations, with respect to HH CERRA outperforms NEWA for 12 locations, with respect to MAE and $RMSE$ it outperforms NEWA for 11 out of 13 locations, and with respect to b, CERRA outperforms NEWA for 8 locations.

The results of this analysis establish CERRA as the more reliable model for replicating buoy measured winds in the Mediterranean Sea and guide practitioners toward CERRA for baseline wind resource assessment.

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