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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Evaluation of NASA POWER Climatic Data against Ground-Based Observations in The Mediterranean and Continental Regions of Turkey

Türkiye'nin Akdeniz ve Karasal İklim Bölgelerinde NASA POWER İklim Verilerinin Yerden Yapılan Gözlemlere Karşı Değerlendirilmesi

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Abstract

The weather reanalysis datasets are very advantageous data types worldwide that fill the gaps of missed measuring data and are alternatives that compensate for the scarcity of observed climate data. The main purpose of this study was to evaluate the effect of horizontal distance, altitude, and climatic regions compared to sea level on NASA POWER reanalysis data for daily temperature variables, relative humidity, and wind speed observed in meteorology stations in the Mediterranean and Continental regions of Turkey. For this purpose, three different meteorology stations (Antalya airport, Elmalı, Teffenni) from the Mediterranean region with different distances and elevations compared to sea level and one station (Ankara) far from the Mediterranean region with continental climate were selected. The statistical approach used to compare observed and estimated values in this study was determination coefficient (R^2), Nash-Sutcliffe Efficiency (NSE), Root Mean Square Error (RMSE), Normalized Root Mean Square Error (NRMSE), and Mean Bias Error (MBE). The results showed a high relation between the POWER reanalysis dataset and observed data for all parameters except wind speed. For daily maximum, minimum and mean temperature, the R^2 and NSE achieved higher than 0.91 and 0.88 respectively, while the mean bias error MBE ranged between -3 °C up to +2 °C and the RMSE was less than 4 °C in all stations. Additionally, POWER estimated data correlation accuracy for temperature variables increased toward higher altitudes in the study area. Similarly, this performance was followed by relative humidity, increasing relation accuracy toward higher elevated regions. The R^2 was higher than 0.69 in higher altitudes and less than 0.4 in lower elevations. The MBE for relative humidity ranges -2% in Antalya to +9% in Ankara, and the RMSE attained less than 13.81% in all regions. The POWER daily wind speed did not show relation with observed data without adjusting for elevation and seasonal bias correction. Overall, it was concluded that the NASA POWER dataset could predict temperature and relative humidity over study area and give a promising result if used in research, water, and agricultural decision-making where observation data are not available.

Keywords: Decision-making, Estimation, Global atmospheric models, Meteorological data, Reanalysis data

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Öz

İklimsel parametreler için yeniden analiz veri kümeleri, dünya çapında ölçülemeyen ya da eksik verilere alternatifler olan çok avantajlı veri türleridir. Bu çalışmanın temel amacı, ülkemizin Akdeniz ve karasal iklime sahip bölgelerindeki meteoroloji istasyonlarında ölçülen ve NASA POWER yeniden analiz yöntemiyle tahmin edilen günlük sıcaklık, bağıl nem ve rüzgâr hızı parametrelerine ait verilerin deniz seviyesine göre yatay mesafe, yükseklik ve iklim bölgelerinin etkisine bağlı olarak değerlendirmektir. Bu amaçla, Akdeniz bölgesinden deniz seviyesine göre farklı yatay uzaklıkta ve kotlarda üç farklı meteoroloji istasyonu (Antalya havalimanı, Elmalı, Teffenni) ile Akdeniz bölgesine uzak karasal iklime sahip bir istasyon (Ankara) seçilmiştir. Bu çalışmada ölçülen ve tahmin edilen değerleri karşılaştırmak için, determinasyon katsayısı (R^2), Nash-Sutcliffe Verimliliği (NSE), Ortalama Kareler Hatasının Karekökü (RMSE), Normalleştirilmiş Ortalama Kareler Hatasının Karekökü (NRMSE) ve Ortalama Yanlı Hatası (MBE) performans kriterleri kullanılmıştır. Sonuçlar, rüzgâr hızı dışındaki tüm parametreler için POWER yeniden analiz veri seti ile gözlemlenen veriler arasında yüksek bir ilişki göstermiştir. Günlük maksimum, minimum ve ortalama sıcaklık için, R^2 ve NSE sırasıyla 0.91 ve 0.88'den daha yüksek bir değere ulaşırken, MBE -3 °C ile +2 °C arasında değişkenlik gösterdi. İstasyonların tamamında RMSE'nin 4 °C az olduğu belirlenmiştir. Ayrıca, sıcaklık değişkenleri için POWER tahmininin veri doğruluğu, yükselen irtifaya bağlı olarak artış göstermiştir. Ortalama bağıl nem için de benzer sonuçlar elde edilmiştir. R^2, yüksek irtifalarda 0,69'dan fazla ve alçak irtifalarda 0,4'ten düşük olarak elde edilmiştir. Tüm bölgelerde RMSE değerinin %13.81'den daha az olduğu saptanmıştır. POWER günlük rüzgâr hızı, farklı yükseklik ve iklim tiplerinde gözlemlenen verilerle iyi bir ilişki göstermemiştir. Sonuç olarak, NASA POWER veri setinin çalışma alanı üzerindeki sıcaklık ve bağıl nemi tahmin edebileceği ve gözlem verilerinin bulunmadığı araştırma, su ve tarımsal karar verme süreçlerinde kullanılması durumunda umut verici sonuçlar verebileceği sonucuna ulaşılmıştır.

Anahtar Kelimeler: Karar verme, Tahmin, Küresel atmosferik modeller, Meteorolojik veriler, Yeniden analiz verileri

1. Introduction

Climate information is considered vital in the decision-making of the environmental, agricultural, and industrial services. Empirical models are widely applied for decision making of crop water requirement and irrigation scheduling which is highly dependent to weather information data (Konukcu et al., 2020; Sener et al., 2007). Spatially surveying and figuring out promising areas for particular cultivars and tracking of local water use are the maximum sizable targets withinside the agricultural sector (White et al., 2008). Spatially monitoring of specific traits of a crop in a region with different characteristics, requires long-term daily weather records well covering the targeted area (Daly, 2006). Although satellite and measuring station-based meteorological has advanced in many nations, however, in many growing countries either measuring stations are missed, measuring meteorological station records are low in quality, or observing weather information is not available for free (Rodrigues and Braga, 2021). Therefore, the NASA POWER reanalysis meteorological data from a mix of observation, satellites, and global atmospheric models is considered as one of the most crucial climate data sources, which can be used to fill the gaps and compensate for the shortage of measured weather data (Aboelkhair et al., 2019). There are many reanalysis datasets available around the world (CFSR, ERA, JRA-55, MERRA, NCEP/NCAR, and POWER) and these datasets has given acceptable results in many regions around the globe (Chen et al., 2019; Chen et al., 2014; Bao and Zhang 2013). However, these reanalysis datasets are either not globally, lack some of weather parameters, or need specific data processing skills. Therefore, the NASA POWER reanalysis meteorological data from a mix of observation, satellites, and global atmospheric models is considered as one of the most crucial climate data sources, which is a single point and global coverage with hourly, daily, annually temporal average, and its user-friendly interface that helps any user to access near-real-time climatic data for any part of the world. These can be used to fill the gaps and compensate for the shortage of measured weather records (Aboelkhair et al., 2019). Furthermore, many studies (Schneider et al., 2013; Dee et al., 2011; Kobayashi et al., 2015; Kanamitsu et al., 2002; Rienecker et al., 2011; Chandler et al., 2013) evaluated most of the parameters from various mentioned reanalysis datasets against different sources of observation around the globe, and the majority of these investigations showed a close agreement of reanalysis data with the ground-based observation datasets. On the other hand, there are a small number of studies that investigated the performance of POWER datasets.

Rodrigues and Braga (2021) investigated the applicability of POWER maximum and minimum air temperature, wind speed, relative humidity, and solar radiation in Portugal. The result of this study recommended the accuracy of POWER variables with observation data for all parameters except wind speed. Similarly, Aboelkhair et al. (2019) assessed POWER satellite and model datasets for minimum, average, maximum temperature, dew point, and relative humidity in Egypt. This study concluded that a good relationship existed between POWER and observed data for all temperature variables demonstrating an RMSE of 5 °C but the estimated relative humidity was not predicted correctly with the RMSE of 11.6%. Bai et al. (2010) evaluated the POWER model-derived and observation weather dataset for daily maximum and minimum temperatures and total solar radiation, resulting agreement of POWER and the monitored data with acceptable accuracy in China. POWER daily temperature variables tested by White et al. (2008) in the continental climate of the USA showed a good fit with observed data demonstrating 4.1 °C and 3.7 °C differences for maximum and minimum temperatures, respectively. Moreover, this investigation suggested the possibility of data improvement by correcting seasonal bias and ground elevation effect. Likewise, an assessment was conducted in Italy by Negm et al. (2017) to validate the suitability of POWER data in the prediction of reference evapotranspiration through daily total solar radiation, wind speed, relative humidity, minimum, average, and maximum air temperatures. This investigation proved the accuracy of the NASA POWER dataset. However relative humidity was not accurately estimated in comparison to coastal weather stations. Another study has been carried out by Monteiro et al. (2018) in Brazil, concluding similar results for the coastal relative air humidity. There are some studies using satellite and model-derived datasets evaluating watershed runoff, land and sea surface temperature, and climate change projections in Turkey. These studies have claimed satisfaction and the accuracy of satellite and model-based meteorological parameters in modeling of hydrology and agro-climatology (Alramlawi and Fistikoglu, 2022; Kuzay et al., 2022; Tuzcu Kokal and Musaoğlu, 2021; Bicer, 2020; Irvem and Ozbuldu 2019; Tan, 2019; Demircan et al., 2017). However, the NASA POWER reanalysis dataset for different weather variables over Turkey has not been assessed yet. So, The main aim of the study was to evaluate the accuracy of daily measured meteorological variables with daily POWER Dataset (daily maximum, minimum, and mean air temperature, relative humidity, and wind speed) in the lower elevation of the coastal area to the higher elevation of the inland area in Turkey.

2. Materials and Methods

2.1. Study Area

This study took place in two different climatic zones of the study area located in specific geographical coordination datum shown in *Table 1*. Due to the geographical location of Antalya, the meteorology stations vary in terms of their distance from the sea and their altitudes Since this condition is directly related to the purpose of the study, meteorological stations located in Antalya in the Mediterranean region were selected. The altitude ranges are between zero meters in the Mediterranean Sea to 1142 meters in the Elmalı district *(Figure 1).* The Mediterranean zone, specifically Antalya province has cool, rainy winters and hot, moderately dry summers. Higher altitudes across the Mediterranean zone block the Mediterranean effects to increases inland, giving the Central Anatolia (Ankara) area a continental climate. The Ankara region is high exposure to extremes than are the coastal areas. Despite intense extreme winters at the plateau, the summers are warm and dry (MGM, 2022).

Table 1. Geographic information of the study area

Station	Longitude	Latitude	Climate type	Altitude (m)	Distance from sea (km)	Ranges of data
Antalya-(Airport)	30.7990	36.9076	Mediterranean	64	8	Jan/2016-Dec/2020
Elmalı	29.9121	36.7372	Mediterranean	1142	55	Jan/2016-Dec/2020
Teffenni	29.7794	37.3161	Mediterranean	1095	90	Jan/2016-Dec/2020
Ankara	32.8637	39.9727	Continental	891	185	Jan/2016-Dec/2020

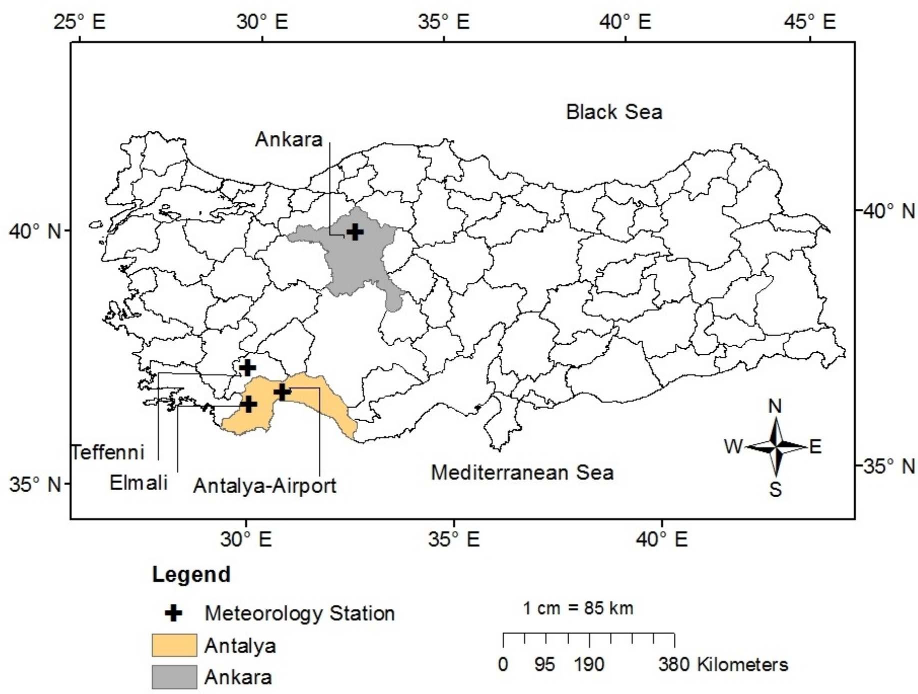

Figure 1. Climatic stations in the study area

2.2. Data

The observed daily meteorological data for the period of five years (from the start of January 2016 up to the end of December 2020) were obtained from the Turkish General Department of Meteorology which had recorded by automated meteorological ground stations located in the Antalya airport, Elmalı, Teffenni, and Ankara. The height of the wind speed sensor in these measuring stations is 10 meters from the ground surface while the temperature and relative humidity, and sunshine duration sensors are installed two meters high from the surface, respectively (MGM, 2022). The daily weather data for the same period and sensor were downloaded from the NASA POWER website (NASA POWER, 2022) for each station based on their geographic coordination points (*Table 1*).

2.3 Method

We selected Antalya airport, Elmalı, and Teffenni stations in the Mediterranean, and the Ankara station in the continental climate region of Turkey. Since the elevation of these measuring stations varies from each other, therefore, we expected to test NASA POWER weather variables in different elevation and climatic regions. All observed daily weather parameters (average temperature (°C), maximum temperature (°C), minimum temperature (°C), relative humidity (%), and wind speed (m s^{-1}) have been processed for quality check by R-Instat software. One-day missed measuring data were interpolated from one day before and after the missing day based on the linear regression method. The continued missed values for more than a day were deleted from the database. Furthermore, we used a total number of (1827) clear values for all variables in the measuring stations of Antalya airport, Ankara, and Elmalı while the total number of clear daily values used for temperature variables, relative humidity, and wind speed in Teffenni station was 1823, 1793, and 1823, respectively. The measured and estimated datasets were evaluated based on determination coefficient (R^2), Nash-Sutcliffe Efficiency (NSE), Root Mean Square Error (RMSE), Normalized Root Mean Square Error (NRMSE), and Mean Bias Error (MBE) that were listed in equations (1-5) given below:

$$R^2 = \frac{[\sum_{i=1}^{n}(X_i - \overline{X_i})(Y_i - \overline{Y_i})]}{\sum_{i=1}^{n}(X_i - \overline{X_i})^2 \sum_{i=1}^{n}(Y_i - \overline{Y_i})^2} \quad \text{(Eq.1)}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_i - Y_i)^2}{n}} \quad \text{(Eq.2)}$$

$$NRMSE = \frac{RMSE}{X_i}100 \quad \text{(Eq.3)}$$

$$MBE = \frac{\sum_{i=1}^{n}(X_i - Y_i)}{n} \quad \text{(Eq.4)}$$

$$NSE = 1 - \frac{\sum_{i=1}^{n}(X_i - Y_i)^2}{\sum_{i=1}^{n}(X_i - \overline{X_i})^2} \quad \text{(Eq.5)}$$

where Xi, Yi, X̄i, and Ȳi represents observed, estimated values, mean observed, and mean estimated values, respectively. Each sample is demonstrated by (i) and the number of samples pinpointed as (n) in the equations. The best and worst determination coefficient values for R^2 and NSE presented more than 0.75 up to 1 and less than 0.25 respectively (Henseler et al., 2009). The smaller value, the better accuracy defines RMSE, and the goodness of fit is below than 15% shown by NRMSE. The MBE measures the over or underestimation of predicted data through its positive and negative values (Willmott and Matsuura, 2006).

3. Results and Discussion

3.1. Evaluation of NASA POWER daily mean, maximum and minimum temperature

The NASA POWER successfully proved the estimation of daily mean, minimum and maximum temperature in all stations indicating a relation coefficient value of higher than 0.9, showing an excellent accuracy when compared with five years of daily observed data in different altitudes of the study area *(Figure 2-4).* These results were obtained by adopting the determination coefficient and other statistical calculations performed in *Table 2.*

The POWER mean temperature indicators demonstrated a maximum RMSE of 3.05 °C day^{-1} and MBE of -2.74 °C day^{-1} for Ankara station followed by Antalya and Teffenni stations recording MBE and RMSE of -1.62°C day^{-1}, 2.45°C day^{-1} and -0.09, 1.37, respectively, while Elmalı station kept its positive MBE of 1.13°C day^{-1}. The POWER mean temperature's underestimation slightly increased in Antalya and Ankara regions. According to mentioned statistical criteria illustrated in *Table 2*, the POWER mean temperature estimation was successful in Elmalı and Teffenni regions but there was a slight underestimation in Ankara and Antalya stations (*Figure 2*). Similarly, the relation of simulated maximum temperature was sufficiently high in the Teffenni region (*Figure 3*) having the RMSE, MBE, and NSE of 1.69 °C day^{-1}, -0.84°C day^{-1}, and 0.96 respectively. Additionally, maximum RMSE was calculated in Antalya 2.78°C day^{-1} followed by Ankara 2.46 °C day^{-1} and Elmalı 2.39 °C day^{-1} (*Table 2*). The maximum MBE -1.95 °C day^{-1} determined in Ankara; describing an underestimation of about 2°C in the region. Despite, representing a high determination coefficient of NASA POWER minimum temperature

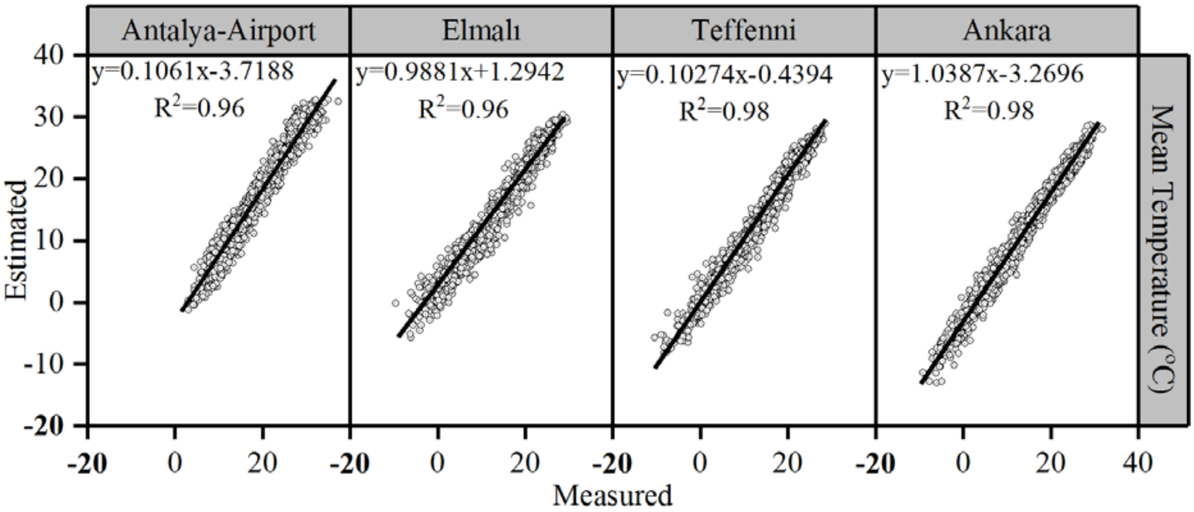

Figure 2. The relation of NASA POWER daily estimated and measured mean temperature

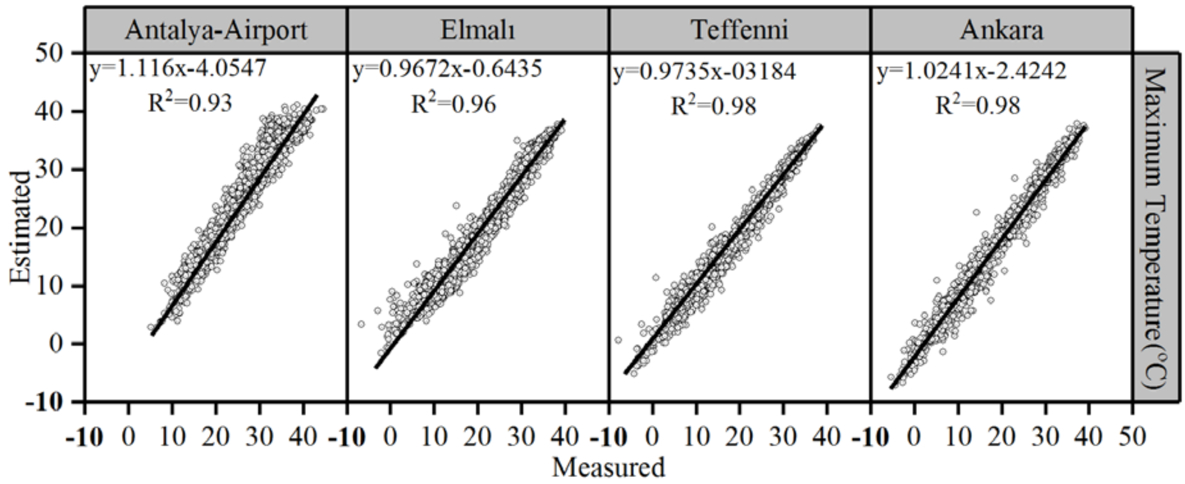

Figure 3. The relation of NASA POWER daily estimated and measured maximum temperature

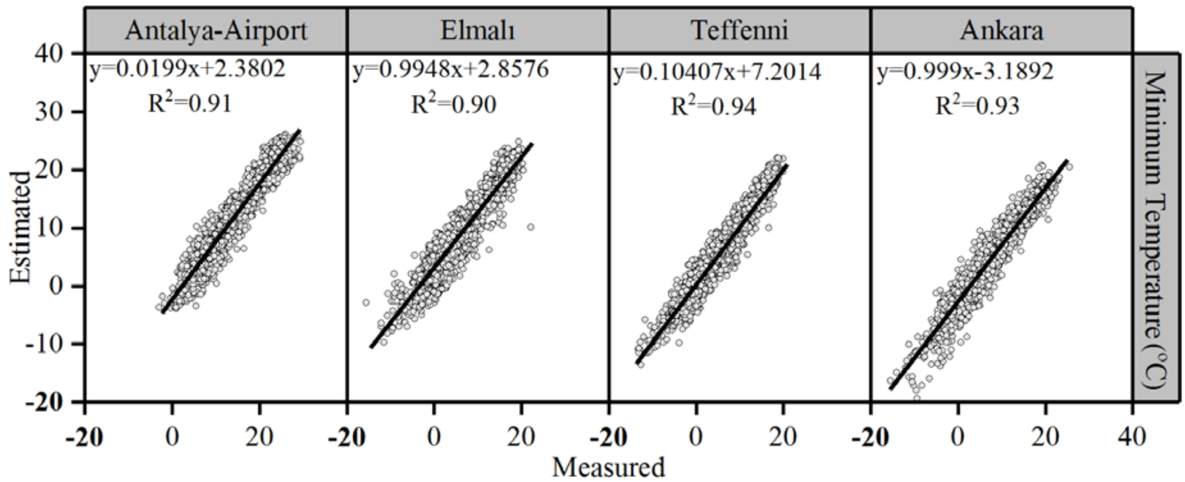

Figure 4. The relation of NASA POWER daily estimated and measured minimum temperature

Table 2. Statistical evaluation of observed and NASA POWER predicted daily temperature parameters

Parameter	Station	R^2	RMSE	NRMSE	MBE	NSE
Mean Temperature (°C)	Antalya airport	0.96	2.45	0.12	-1.62	0.88
	Elmalı	0.96	1.95	0.14	1.13	0.94
	Teffenni	0.98	1.37	0.10	-0.09	0.97
	Ankara	0.98	3.05	0.22	-2.74	0.87
Maximum Temperature (°C)	Antalya airport	0.93	2.78	0.11	-1.13	0.87
	Elmalı	0.96	2.39	0.11	-1.35	0.93
	Teffenni	0.98	1.69	0.08	-0.84	0.96
	Ankara	0.98	2.46	0.12	-1.95	0.93
Minimum Temperature (°C)	Antalya airport	0.91	3.02	0.20	-2.08	0.8
	Elmalı	0.90	3.62	0.49	2.82	0.73
	Teffenni	0.94	1.93	0.28	0.47	0.92
	Ankara	0.93	3.8	0.46	-3.19	0.74

with the ground-based measured minimum temperature in the study area, The POWER data had underestimated minimum temperature by 3°C in Ankara regions, showing the effect of continental climate in this region (*Figure 4*). Ankara station has shown a negative MBE -3.19°C day^{-1} followed by Antalya station having a daily -2°C of underestimation, while Elmalı showed a positive MBE 2.82°C day^{-1} value pinpointing a slight overestimation. This variable was normally estimated in the Teffenni station showing a daily MBE of 0.47°C day^{-1} (*Table 2*).

The comparison of temperature data showed good agreement with POWER temperature variables in the Mediterranean region of Turkey. There was a high relation ($R^2 \geq 0.9$) of NASA POWER temperature variables in the study area with different elevations while White et al. (2008) reported a relationship of less than ($R^2 \leq 0.88$) in major parts of the USA. They concluded that temperature has highly affected by elevation in the mountainous and coastal area while our results showed that elevation and coastal regions do not affect temperature variables. We assume that this variability might be due to other sources of errors such as industrialization, land-use intensity, and land cover variability, which can affect temperature variables, specifically the maximum temperature. Furthermore, temperature variables might be affected by point-based and regional-based correlations since regional-based temperature might be higher in residential areas, industrialized regions, and rock lands in comparison to the dense vegetation and well-covered grasslands. On the contrary, the minimum temperature might fall much more down during the night throughout the winter season. These factors could be sensed in regional-based POWER temperature variables pixel by pixel while point-based POWER temperature variables are not exposed to mentioned factors. Additionally, a good correlation of point-based POWER temperature variables was proved in various regions including the Mediterranean, desert lands, and the mountainous area when they reported a good correlation of point-based POWER temperature variables in Egypt and Oman (Aboelkhair et al.,2019, and Marzouk, 2021). The NASA POWER temperature data at the two-meter above surface is implying the reliability and accuracy of these datasets around the globe. Hence, we can strongly suggest the applicability of NASA POWER temperature variables as the complement of missing data or applying instead of measured low-quality temperature parameters in the study area.

3.2. Evaluation of NASA POWER daily relative humidity

Based on the data shown in *Table 3* and *Figure 5*, the estimated daily relative humidity from the POWER reanalysis dataset was shown a good relationship with the observation data except for the Antalya airport station, showing the R^2 of 0.4 and MBE of -2.33%. The maximum R^2 value (0.77) and MBE (9.13%) were recorded in the Ankara-based station followed by the Teffenni (R^2=0.72) and Elmalı (R^2=0.70) stations with the MBE of 2.27% and 5.32% respectively.

Table 3. Statistical evaluation of observed and NASA POWER predicted daily relative humidity (%) parameter

Station	R^2	RMSE	NRMSE	MBE	NSE
Antalya airport	0.41	13.81	0.22	-2.33	0.26
Elmalı	0.69	12.24	0.21	5.32	0.59
Teffenni	0.72	9.72	0.16	2.27	0.64
Ankara	0.77	12.48	0.22	9.13	0.48

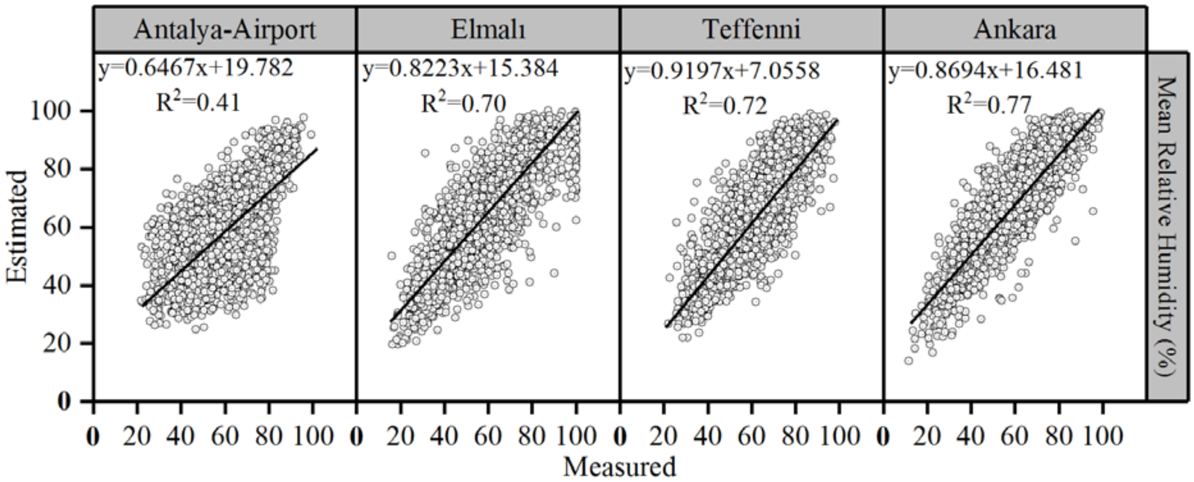

Figure 5. The relation of NASA POWER daily estimated and measured mean relative humidity

Based on the literature review, NASA POWER has estimated a slightly lower percentage of relative humidity in lower altitudes. However, a higher relation between POWER estimated relative humidity was recorded in higher elevation (*Table 3).* This little uncertainty could be obvious for estimating RMSE 13.81% and 12.48% for Antalya and Ankara stations respectively. The RMSE and R^2 for Elmalı and Teffenni Stations were 12.24%, 0.69 and 9.72%, 0.72 respectively. Generally, the estimated relative humidity showed an acceptable relationship in different part of the Mediterranean region and a good correlation to regions with a stable climate and higher elevation. The previous study carried out in Brazil by Monteiro et al. (2018) also reached the same conclusion regarding the effect of elevation and Mediterranean on the estimation of relative humidity by NASA POWER. However, Aboelkhair et al. (2019) stated disagreement of NASA POWER-based estimation of monthly relative humidity with a relationship of ($R^2 \leq 0.1$) in coastal weather stations but our result for daily relative humidity shows a relationship range of ($R^2=0.7$ or ≥ 0.5) in the Mediterranean and continental regions. Therefore, we can conclude that distance from the sea might affect the correlation of POWER relative humidity.

3.3. Evaluation of NASA POWER daily wind speed

NASA POWER estimated wind speed showed the lowest relation with the observation variable among all parameters *(Table 4).* The maximum R^2 (0.45) of estimated wind speed was shown in the Antalya station describing disagreement of estimated wind speed values with the observed data *(Figure 6).*

These values gradually decreased for Teffenni, Elmalı, and Ankara stations with a much lower determination coefficient of (0.45), (0.35), and (0.18), respectively. Furthermore, the lowest RMSE and MBE were recorded 0.33 m s^{-1} and -0.47 m s^{-1} for Antalya airport followed by Elmalı station with an RMSE and MBE of 1.23 m s^{-1} and 1.01 m s^{-1} respectively. The higher RMSE (2.07 m s^{-1}) and MBE (1.74 m s^{-1}) was found in Teffenni station followed by Ankara which represented 1.68 m s^{-1} of RMSE and 1.13 m $s^{-1}$of MBE in the study area (*Table 4*).

Table 4. Statistical evaluation of observed and NASA POWER predicted daily relative humidity parameter

Station	R^2	RMSE	NRMSE	MBE	NSE
Antalya airport	0.45	0.33	0.33	-0.47	0.32
Elmalı	0.35	1.23	0.94	1.01	-6.93
Teffenni	0.45	2.07	2.05	1.74	-36.46
Ankara	0.18	1.68	0.82	1.13	-1.81

Wind circulations prevalence remained challengeable in the territory of Turkey due to its being surrounded on three sides by the sea and varied topography. Rapid changes of pressure and availability of high-altitude mountains across the study area interrupt wind speed and its direction to the region (Malanotte-Rizzoli and Bergamasco, 1989). This could be very apparent withinside the Ankara area with its surrounding high mountains that decrease the influence of the Mediterranean weather and create a different microclimate in central Anatolia. The rugged topography and surrounding oceans are the main reasons that affect wind speed and its direction and are tough to be estimated by weather global models before adjusting for elevation and seasonal bias correction.

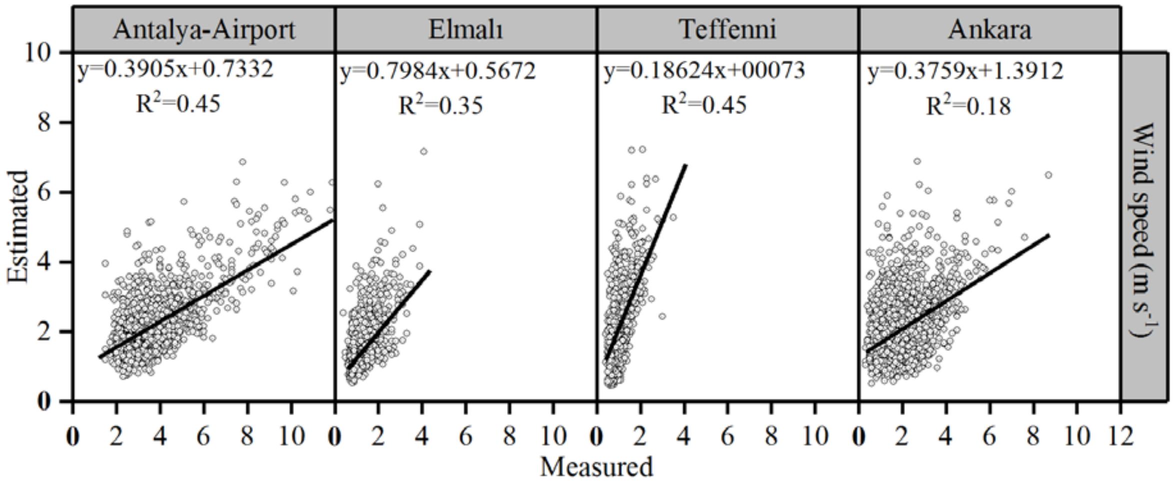

Figure 6. The relation of NASA POWER daily estimated and measured mean wind speed

4. Conclusions

Weather data is a notable factor for water resource management. However, data availability with good quality is still a significant challenge in the majority of the regions around the world. Therefore, assessing the usefulness of applying daily reanalysis data like NASA POWER as an alternative to ground observations is highly required. The results showed a high relation between the POWER reanalysis dataset and observed data for all parameters except wind speed. For maximum, minimum, and mean temperature, the coefficient of determination (R^2) and Nash Sutcliff model efficiency (NSE) achieved higher than 0.91 and 0.88, respectively. The mean bias error (MBE) ranged between -3 °C to +2 °C, and the root mean square error (RMSE) reached less than 4°C in all stations. Additionally, POWER estimated data correlation accuracy for temperature variables increase toward higher altitudes in the study area. Similarly, this performance was followed by relative humidity, increasing correlation accuracy toward higher elevated regions. The R^2 was higher than 0.69 in higher altitudes and less than 0.4 in lower elevations. The MBE for relative humidity ranged from -2 % in Antalya to +9% in Ankara, and RMSE attained less than 13.81% in all regions. Our assessment's findings demonstrated that POWER-based data can estimate most of the climatic data such as maximum, minimum, and mean temperature, and relative humidity with high accuracy. However, wind speed and precipitation of NASA POWER simulated data estimations still need improvements. To sum up, NASA POWER model-simulated data could be frightful to obtain weather data sets where ground weather station data is not available. Nevertheless, additional studies suggested validating the use of NASA POWER in estimation of water requirement through calculation of evapotranspiration, and crop yield response to various weather parameters in the study area.

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