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TO STUDY THE METEONORM MODEL VALIDATION AND BIRD CLEAR SKY MODEL VALIDATION FOR GLOBAL SOLAR RADIATION ANALYSIS

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ABSTRACT

The amount of solar energy that reaches the earth's surface depends on its location, orientation, time of day, season, and atmospheric makeup. As a result, there are large temporal and spatial variations in solar radiation. The earth's rotation around its own axis, which alters the angle at which solar radiation strikes the surface, is what causes the diurnal cycle. Seasonal variations in day duration and sun elevation angle are brought on by the earth's orbit around the sun and its axial tilt with respect to the orbital plane. The latitude of a site also affects the length of the day and the sun's elevation angle there. The solar radiation that reaches the top of the atmosphere can be calculated for any location and time by taking into account these regular (diurnal and seasonal) variations in the earth-sun geometry and the solar constant. Extraterrestrial radiation is another name for the radiation that is present at the top of the atmosphere.

KEY WORDS: **Meteonorm, Model Validation, Bird Clear, Sky Model, Global Solar Radiation.**

INTRODUCTION

On Earth, the solar radiation fluctuates with the position of the sun above the horizon. In the summer, longer periods of sunlight are experienced at higher latitudes, whereas wintertime near the relevant pole experiences little to no sunlight. When clouds are not present to obscure the direct radiation, it is perceived as sunshine. The absorption of electromagnetic radiation in the form of heat results in the warming of the ground (and other things).

The square of the distance between a star and a planet has an inverse relationship with the amount of radiation that body intercepts. Over millions of years, the Earth's orbit and obliquity shift, sometimes forming a nearly perfect circle and other times elongating to an orbital eccentricity of 5%. The average distance from the sun (the semi-major axis) does not considerably change when the orbital eccentricity changes, therefore Kepler's second law ensures that the total insolation during a year stays almost constant.

$$\frac{2A}{r^2}dt = d\theta$$

where A denotes the invariant of "areal velocity." In other words, the orbital period integration—which is also invariant—is constant.

$$\int_0^T \frac{2A}{r^2}dt = \int_0^{2\pi} d\theta$$

If we take the solar radiation power P and solar irradiation provided by the inverse-square rule as constants across time, we also get the average insolation as a constant.

However, there are seasonal and latitudinal variations in the distribution and intensity of solar radiation that reaches Earth's surface. Solar energy varies in the summer and winter due to the sun's influence on climate. This can change by more than 25% at latitudes of 65 degrees as a result of the Earth's orbital fluctuation. The difference in the annual average insolation at any particular site is nearly zero since variations in winter and summer tend to balance each other out, but the strength of seasonal cycles is highly influenced by the energy distribution between summer and winter.

SOLAR RADIATION TYPES

The sum of direct, diffuse, and reflected solar radiation is what is commonly referred to as global radiation. The three elements stated above combine to form the solar radiation that is present on the surface of the earth. As the various elements, such as weather, location, etc., change, so does the actual percentage of each of these components.

DIRECT EXPOSURE

The earth receives direct radiation from solar rays that are directed in a straight line from the sun to it. Beam radiation or direct beam radiation are other names for direct radiation. As direct radiation consists of sun beams moving in a straight line, things that block the path of the sun rays cast shadows on them. Direct radiation is present when there are shadows.

Summertime and in sunny areas, direct radiation makes up roughly 70–80 percent of the total radiation. Solar tracking is used in solar power plants to absorb the majority of direct sunlight. Without a sun tracking device, beneficial direct rays would not be gathered.

OMNIPRESENT RADIATION

The direction of direct radiation is fixed. There is no definite direction for diffuse radiation. The diffuse radiation is caused by sun rays that have been scattered by atmospheric particles. If there is only diffuse radiation present and no direct radiation, no shadows of the objects will develop.

Diffuse radiation increases along with pollution levels. The amount of diffuse radiation increases in mountainous areas and in the winter. The solar panels are best able to capture diffuse energy when they are kept horizontal. The amount of diffuse radiation that solar panels that use automatic tracking systems are able to capture declines. Less diffuse radiation would be captured by the solar panels the wider the angle they create with the ground.

RADIANT REFLECTION

The portion of radiation that is reflected from surfaces other than air particles is known as reflected radiation. Reflected radiation comes from surfaces like hills, trees, buildings, and water. Reflected radiation typically makes up a minor portion of the total radiation, but in areas with snow, it can reach 15%.

DATA ABOUT SOLAR RADIATION

For solar energy applications including photovoltaic technology, solar thermal systems, and passive solar designs, solar radiation data is a vital input. For the design, development, and performance assessment of solar technologies for any specific geographic area, solar radiation data should be current, trustworthy, and easily accessible. Applications for solar energy demand thorough understanding and a thorough assessment of the possibilities of the site. As a result, a key component of solar energy conversion systems is the detection of solar radiation at ground level. This data can be acquired from a variety of data sources, such as satellite data or measurements made on the ground using pyranometers or reference cells. Installing pyranometers at numerous points around the target area, and taking care of their ongoing maintenance and recording, is the best technique to determine the amount of solar radiation components. In order to create a reliable database, thorough quality control is required when measurements are recorded.

Data on global solar radiation is also a crucial and significant variable for models of agriculture, the environment, hydrology, and ecology. Despite its importance, there is a lack of access to worldwide sun radiation data since monitoring equipment is expensive and difficult to maintain. In several nations around the world, there have been reports of insufficient radiation data.

RESEARCH METHODOLOGY

STUDY AREA

For the measurements of the worldwide sun radiation, six cities in Tamilnadu were taken into account. For a whole year, data on solar radiation were continuously gathered in these six cities.

CHENNAI (LOCATION 1)

The capital of Tamil Nadu is Chennai, previously Madras. It is one of the largest cultural, commercial, and educational hubs in South India and is situated on the Coromandel Coast, off the Bay of Bengal.

MADURAI (LOCATION 2)

Tamil Nadu's capital city is Madurai. It serves as the district's administrative center. The 25th most populous city in India is Madurai, which is also the second most populous city in Tamil Nadu.

ERODE (LOCATION 3)

Erode, the administrative center of the Erode District, is the seventh-largest urban agglomeration in Tamil Nadu. The coordinates of Erode are 11.21°N 77.44°E.

TIRUCHIRAPPALLI (LOCATION 4)

The administrative center of the Tiruchirappalli District is located in Tiruchirappalli. It is also the state's fourth-largest urban agglomeration and fourth-largest municipal corporation.

RAMANATHAPURAM (LOCATION 5)

In Tamil Nadu's Ramanathapuram district, there are two municipalities: Ramanathapuram and Ramnad. It is the second-largest town in Ramanathapuram district (by population) and the administrative center of the district.

TIRUNELVELI (LOCATION 6)

Tirunelveli, sometimes referred to as Nellai, is where the Tirunelveli District's administrative center is located. It ranks as the state's sixth-largest municipal corporation.

GEOGRAPHICAL FEATURES OF THE LOCATIONS IN TAMIL NADU

Tamil Nadu, one of India's two most southern states, is located between latitudes 8 N and 13 N and longitudes 76 E and 81 E. Table -1 provides the latitude and longitude of the various study locations. As can be observed, the several places' latitudes range from 8.72 N to 13.09 N and their longitudes from 77.73 E to 80.28 E. From 3 meters in Ramanathapuram to 184 meters in Erode, the altitude varies.

RESULTS AND DISCUSSION

A variable's difference or deviation is a measurement of the variation between the observed value and another value, frequently the variable's mean. The deviation's sign (positive or negative) indicates the difference's direction (the deviation is positive when the observed value exceeds the reference value). The size of the difference is indicated by the value's magnitude. A residual is the gap between the observed value and an estimate of the true value, which might be the sample mean. An error is the difference between the observed value and the true value of a quantity of interest. These ideas can be applied to data at the ratio and interval levels of measurement.

DEGREE INDICES

The index of agreement frequently contrasts model predictions or estimates (P) with reliable pair-wise matched observations (O). P and O should have the same units. The (Pi Oi) values often make up the set of model-prediction errors, and the central tendency of the set is used as the basis for most dimensioned measurements of model performance.

The results of the validation of the Meteonorm and Bird clear sky models are analyzed statistically, and the results are summarized in Tables.

Table-1: Statistical analysis for Meteonorm model validation

Sl. No.	Statistical Measure	Calculated values of statistical measures (kWh/m^2/day)					
		Location 1	**Location 2**	**Location 3**	**Location 4**	**Location 5**	**Location 6**
1	Averae measures Measured mean (O) Predicted mean (P)	5.32 5.09	5.56 5.42	4.54 4.41	4.88 5.03	4.50 4.44	4.73 4.72
2	Correlation measures Slope (B) Intercept (A) Correlation coefficient	1.15 -1.07 0.96	1.16 -1.05 γ 0.92	0.92 0.22 0.98	0.97 0.28 0.96	0.99 -0.02 0.97	0.96 0.16 0.98
3	Difference measures Measured deviation Predicted deviation Bias Fractional Bias Normalized mean square error (NMSE) Mean square error – systematic (MSEs) Mean square error – unsystematic (MSEu) Total mean square error (RMSE)	0.81 0.97 0.47 0.04 0.002 0.27 0.28 0.38	0.54 0.69 0.28 0.03 0.0007 0.17 0.27 0.32	1.47 1.37 0.27 0.03 0.0009 0.18 0.23 0.29	1.35 1.36 -0.32 -0.03 0.001 0.16 0.38 0.40	1.19 1.21 0.12 0.01 0.0002 0.06 0.26 0.27	1.26 1.24 0.02 0.002 0.000003 0.04 0.21 0.22
4	Degree measures Index of agreement (D)	0.95	0.93	0.99	0.98	0.99	0.99

Table-2 Statistical analysis for Bird Clear Sky model validation

Sl. No.	Statistical Measure	Calculated values of statistical measures (kWh/m²/day)					
		Location 1	**Location 2**	**Location 3**	**Location 4**	**Location 5**	**Location 6**
1	Average measures Measured mean (O)	5.04	5.20	4.38	4.83	4.39	4.69
	Predicted mean (P)	5.10	5.42	4.41	4.89	4.44	4.73
2	Correlation measures Slope (B)	0.91	0.77	1.04	0.97	0.98	0.93
	Intercept (A)	0.53	1.39	-0.15	0.19	0.12	0.38
	Correlation coefficient	0.93	0.93	0.97	0.97	0.98	0.98
3	Difference measures Measured deviation	1.00	0.83	1.28	1.25	1.20	1.31
	Predicted deviation	0.97	0.69	1.37	1.25	1.21	1.24
	Bias	-0.12	-0.43	-0.07	-0.13	-0.99	-0.07
	Fractional Bias	-0.01	-0.04	-0.008	-0.01	-0.01	-0.007
	Normalized mean square error (NMSE)	0.001	0.002	0.00006	0.0002	0.0002	0.00005
	Mean square error – systematic (MSEs)	0.11	0.23	0.06	0.07	0.05	0.10
	Mean square error – unsystematic (MSEu)	0.35	0.25	0.31	0.29	0.26	0.22
	Total mean square error (RMSE)	0.37	0.38	0.31	0.30	0.27	0.24
4	Degree measures Index of agreement (D)	0.96	0.94	0.98	0.98	0.99	0.99

At the chosen locations in Tamil Nadu, the values of the global solar radiation were predicted using the Meteonorm model and the Bird clear sky model. The effectiveness of these models is examined in the part that follows by I comparing the concentrations predicted and observed, and (ii) computing the statistical measures between the expected and observed values. These models' validation findings have been presented, along with a comparison analysis and a conclusion.

METEONORM MODEL VERIFICATION

For the six chosen areas in Tamil Nadu, solar radiation was simulated using the Meteonorm model. It should be noted that for the Meteonorm model, the difference between predicted and measured values of global solar radiation varies from 4.1 to 6.4 kWh/m2/day and 4.3 to 6.3 kWh/m2/day respectively during the winter season, 4.2 to 6.6 kWh/m2/day and 4.5 to 6.9 kWh/m2/day respectively during the pre monsoon season, 3.0 to 5.6 kWh/m2/day and 3.3 to 6.0 kWh/m2/day It is clear that all of the study's locations' expected and measured quantities of global sun radiation are comparable.

The statistical analysis shows that there are, respectively, differences of 0.54 and 1.47 kWh/m2/day and 0.69 to 1.37 kWh/m2/day between the expected and measured global solar radiation. The estimated correlation measures demonstrate that the predicted and measured values are well correlated. In the case of difference measurements, it should be observed that the systematic error value is nearly zero and the unsystematic error value is getting close to the root mean square error value. An indicator of agreement (D) value of 1.0 would indicate perfect agreement between the predicted and measured values. It should be noted that the Meteonorm model's index of agreement ranges from 0.93 to 0.99, indicating a good level of agreement between projected and measured values. It is noted that the predicted concentrations match well with the measured concentrations with lower discrepancies and errors when evaluating the overall performance of this model based on general observation and statistical analysis.

PROVING THE BIRD CLEAR SKY MODEL'S ACCURACY

The Bird clear sky model was verified for six places in Tamil Nadu in the current study. The difference between the global solar radiation predicted by the Bird clear sky model and the measured value varies from 4.1 to 6.4 kWh/m2/day and 3.8 to 6.2 kWh/m2/day respectively during the winter season, 4.2 to 6.6 kWh/m2/day and 4.6 to 6.8 kWh/m2/day respectively during the pre monsoon season, 3.0 to 5.6 kWh/m2/day and 3.3 to 5.6 kWh/m2/day respectively during the south west mons It is clear that all of the study's locations' expected and measured quantities of global sun radiation are comparable.

The statistical study shows that there are, respectively, differences of 0.69 and 1.37 kWh/m2/day and 0.83 and 1.31 kWh/m2/day between the expected and measured global solar radiation. The estimated correlation measures demonstrate that the predicted and measured values are well correlated. In the case of difference measurements, it should be observed that the systematic error value is nearly zero and the unsystematic error value is getting close to the root mean square error value. An indicator of agreement (D) value of 1.0 would indicate perfect agreement between the predicted and measured values. It should be noted that the Bird Clear Sky model's index of agreement varies from 0.94 to 0.99, indicating a good level of agreement between predicted and measured values. It is noted that the predicted concentrations match well with the measured concentrations with lower discrepancies and errors when evaluating the overall performance of this model based on general observation and statistical analysis.

Two models have been compared in the current study in order to forecast the global solar radiation at six locations in Tamil Nadu. Given that these models' prediction patterns are generally reliable, it is inferred that they can be used to estimate global solar radiation for different areas with comparable meteorological trends. Alternative sources of data for regions lacking global sun radiation data include empirical models that use meteorological characteristics as inputs.

CONCLUSION

The Bird clear sky model and the Meteonorm program, which is based on a combination of models, are validated for the study's chosen areas in Tamil Nadu. The predicted and measured values are analyzed statistically in order to interpret them. The effectiveness of these models is assessed using four different statistical measure types: average measurements, correlation measures, difference measures, and degree measures.

The estimated correlation measures demonstrate that the predicted and measured values are well correlated. In the case of difference measurements, it should be observed that the systematic error value is nearly zero and the unsystematic error value is getting close to the root mean square error value. An indicator of agreement (D) value of 1.0 would indicate perfect agreement between the predicted and measured values. It should be emphasized that both models' indexes of agreement, which quantify how well predicted and observed values agree, range from 0.93 to 0.99. It is noted that the predicted concentrations match well with the measured concentrations with lower discrepancies and errors when evaluating the overall performance of these models based on general observation and statistical analysis. Given that these models' prediction patterns are generally reliable, it has been determined that they can be used to forecast global solar radiation for regions with comparable meteorological trends.

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