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SOLAR ENERGY AVAILABILITY IN SUEZ CANAL'S ZONE – CASE STUDY: PORT SAID AND SUEZ CITIES, EGYPT

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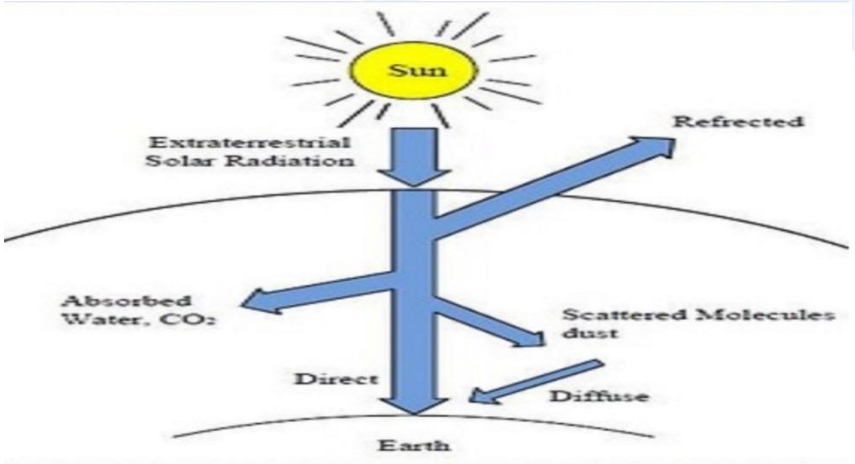
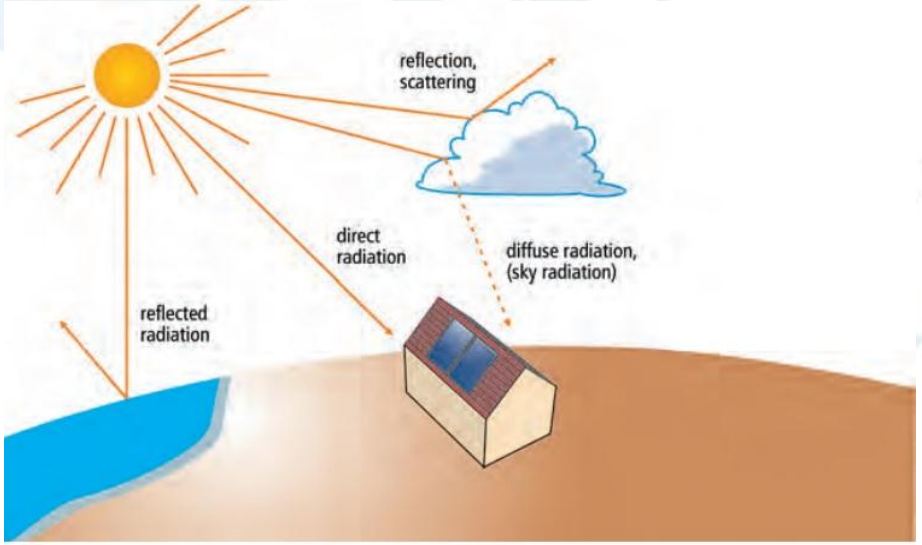
Problem Definition

- In solar systems, an accurate knowledge of solar radiation is considered:
  - The first step in solar energy availability assessment.
  - The primary input for different solar energy applications.
- Since the solar radiation measurement are not available due to:
  - The high cost and Equipment's calibration and maintenance.
- Different solar radiation models are developed to estimate solar radiation.
- **Therefore, the accurate solar radiation data as well the best solar radiation models should be recognized to know solar energy potential before setting up any solar energy system.**

Solar Radiation

- Solar radiation can be divide into two parts of solar radiation:
  - ❑ Extraterrestrial solar radiation; which is above the atmosphere.
  - ❑ Global solar radiation; GSRH = Direct radiation + Diffuse radiation.

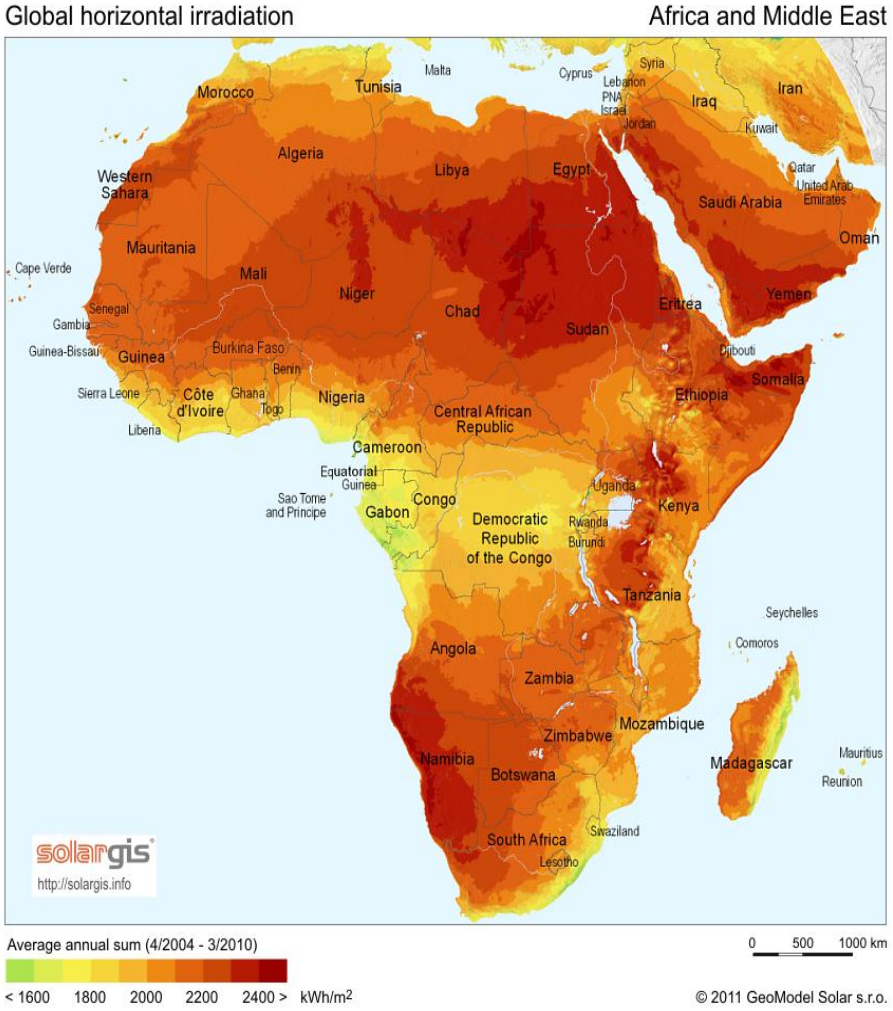




Global Solar Radiation over Egypt

- Egypt considers one of the countries which enjoys with abundant solar radiation.

- **Consequently, knowing the solar energy potential at any Egypt's location is important before setting up any solar energy system, which can be considered one of the available solutions for supplying energy demand.**



Studied locations and Data Collection

NASA Surface meteorology; over 30-Year.

Different parameters were used such as:

- Global Solar Radiation.
- Ambient Temperature.

Performance Evaluation

- Root mean square error (RMSE).

-10% ≤ **Acceptable Value** ≤ **+10%**

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{p}(G_{i,c} - G_{i,m})^2\right]^{1/2}$$

- Coefficient of determination (R^2).

$$\mathbf{0 \leq R^2 \leq 1}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{p}(G_{i,m} - G_{i,c})^2}{\sum_{i=1}^{p}(G_{i,m} - \overline{G_m})^2}$$

Global Solar Radiation Model, *G*

Hassan et al. Model: $$G/G_0 = a\,T^b\,G_0 + c$$

Where T and G_0 are the monthly averages of daily ambient temperature (˚C) and extra-terrestrial solar radiation on a horizontal surface (MJ/m^2 day^{-1}), respectively. *a*, *b*, and *c* are the empirical coefficients.

Why Hassan et al. Model

$$G/G_0 = a\,T^b\,G_0 + c$$

?

According to our previous studies:

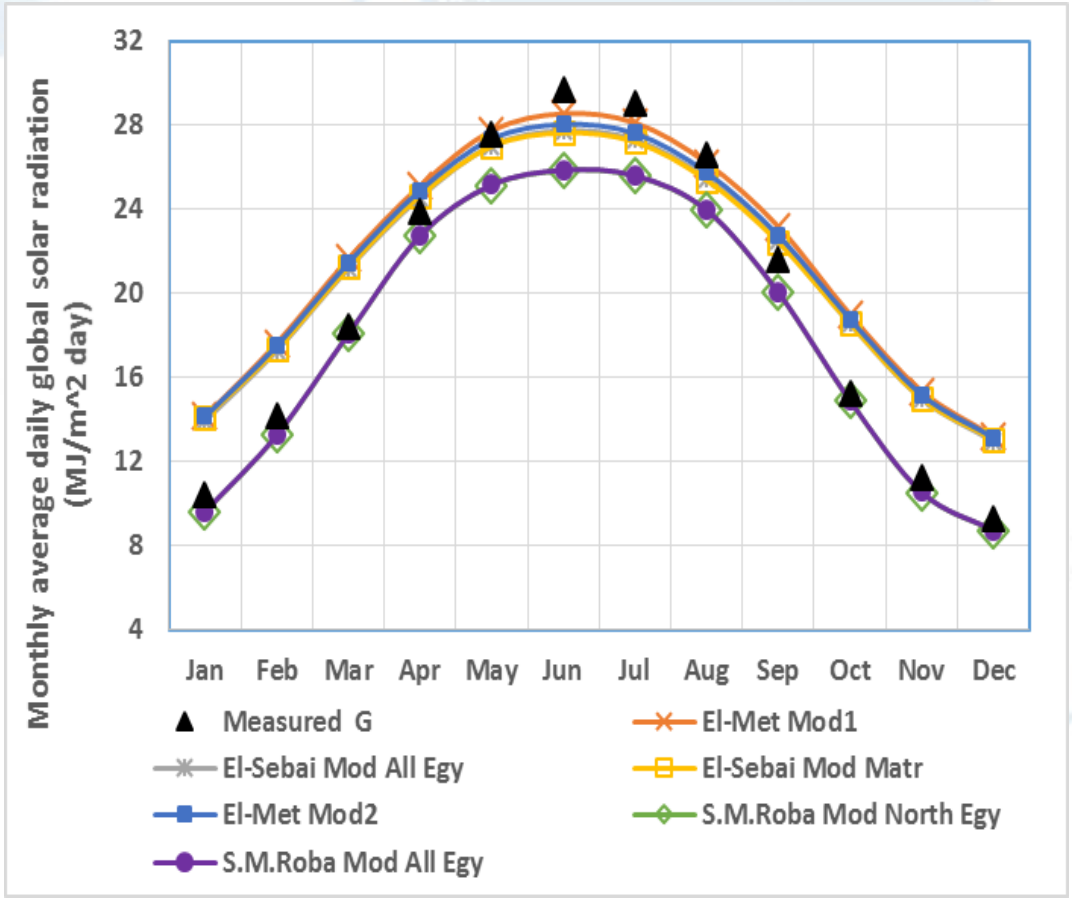
Assessment the performance of current Egypt's models (Case study: New Borg El-Arab)

$G/G_0 = a + b(s/s_0)$	Angostrom	Model 1, 2 and 3
$G/G_0 = a^{(1/S)}$	El-Metwally	Model 4
$G = a\,(s)^{1.24}(\alpha)^{-0.19} + 10550(\sin(\alpha))^{2.1} + 300(\sin(\alpha))^3$	Robaa	Model 5 and 6

Model No	GSR Models (Sunshine-based)	a	b
1	El-Metwally	0.228	0.527
2	El-Sebaii and Trabea (All Egypt)	0.3647	0.3505
3	El-Sebaii & Trabea	0.508	0.186
4	El-Metwally	0.713	
5	Robaa (North Egypt lat. ≥ 30˚)	13.7	
6	Robaa (All Egypt)	14.4	

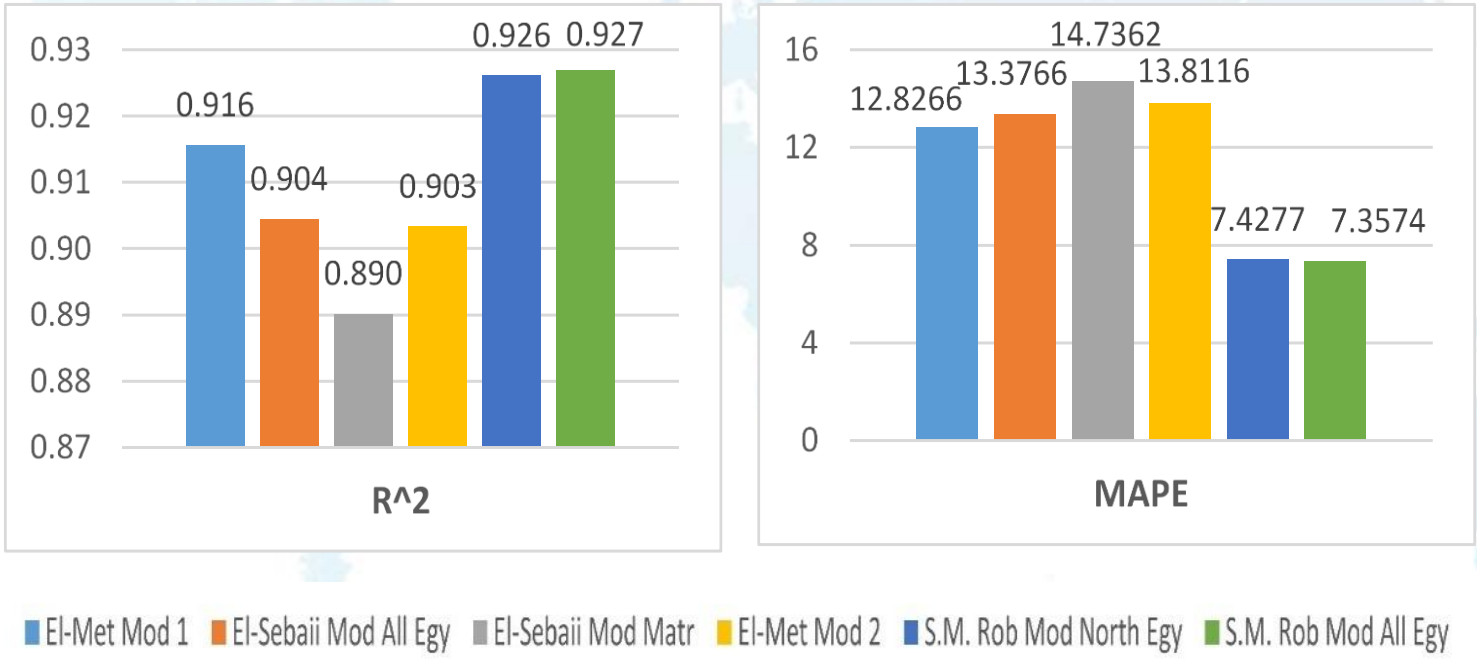
Assessment the performance of current Egypt's models (Case study: New Borg El-Arab)

- All these models are General models; which developed for the whole Egypt.



Assessment the performance of current Egypt's models (Case study: New Borg El-Arab)

$0 \leq R^2 \leq 1$ $-10\% \leq MAPE \leq +10\%$



- R^2 = 0.927%.

Suggesting a new simple global solar radiation models

- ✓ **Unavailability of Sunshine data.**
- ✓ **Lower performance at costal sites.**

- ❑ Seventeen new temperature-based models are established, validated to estimate the monthly average daily global solar radiation on a horizontal surface.
- ❑ As well, they are compared with other three models proposed in the literature (the Annandale, Allen and Goodin models).

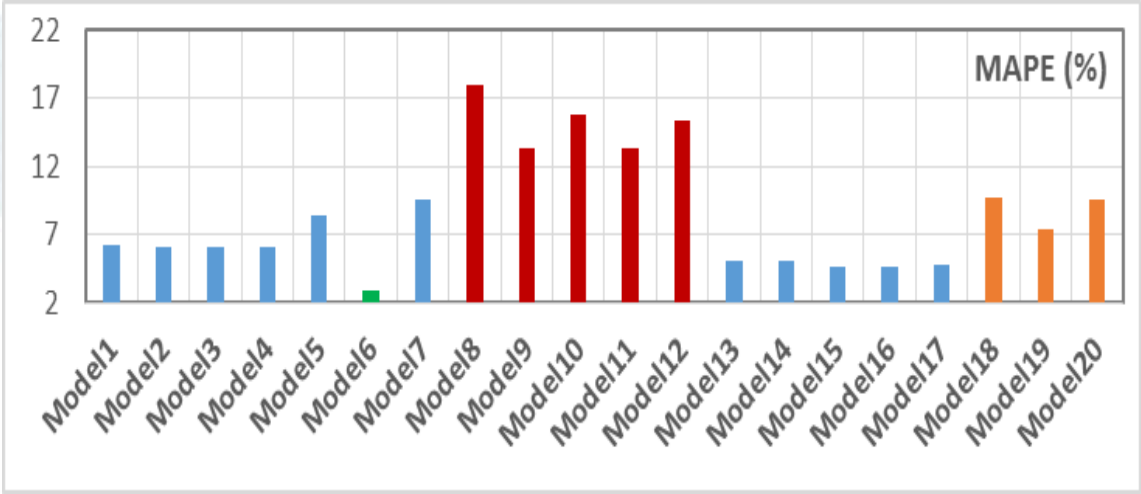
Suggesting a new simple global solar radiation models

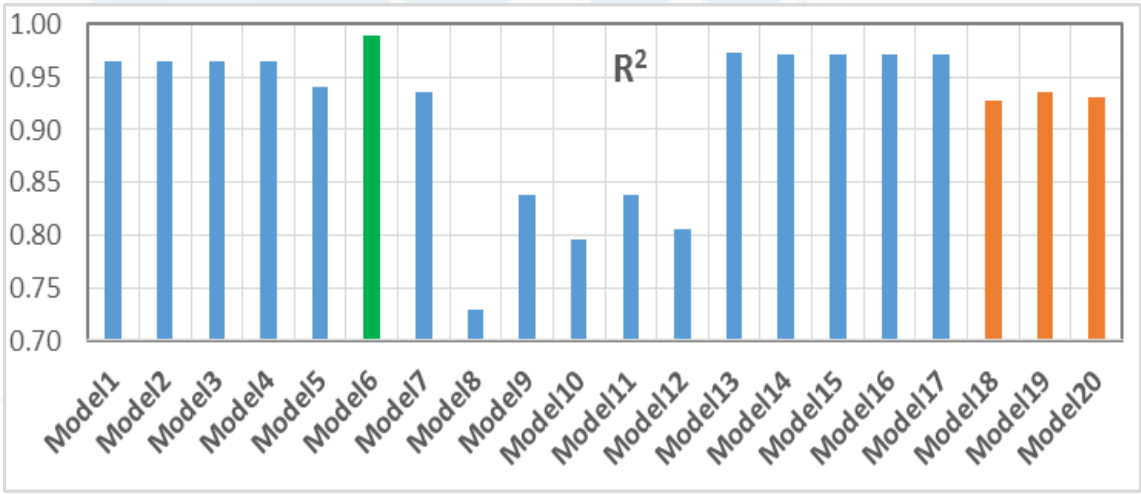
Model 6: ➢ $R^2 > 0.98\%$.

$$G/G_0 = a\,T^b\,G_0 + c$$

Model 19 (Allen Model) ➢ $R^2 > 0.93\%$.

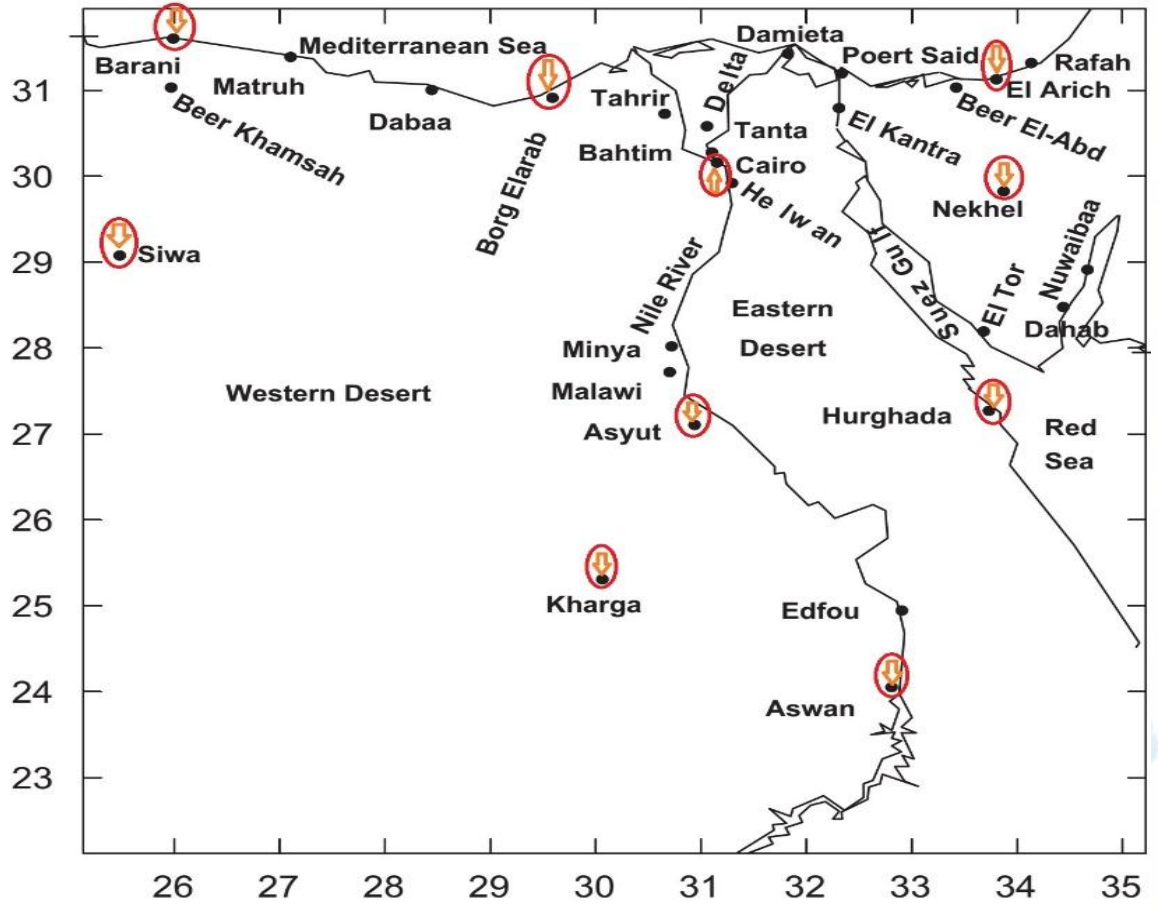
$$G/G_0 = a\,\Delta T^b$$





Suggesting a new simple global solar radiation models

The newly suggested models are validated and tested for ten different locations around Egypt.



Costal locations:

Sidi Barrani:

$R^2 > 0.881\%$ to $R^2 > 0.976\%$.

El-Arich: $R^2 > 0.956\%$ to $R^2 > 0.992\%$.

Suggesting a new simple global solar radiation models

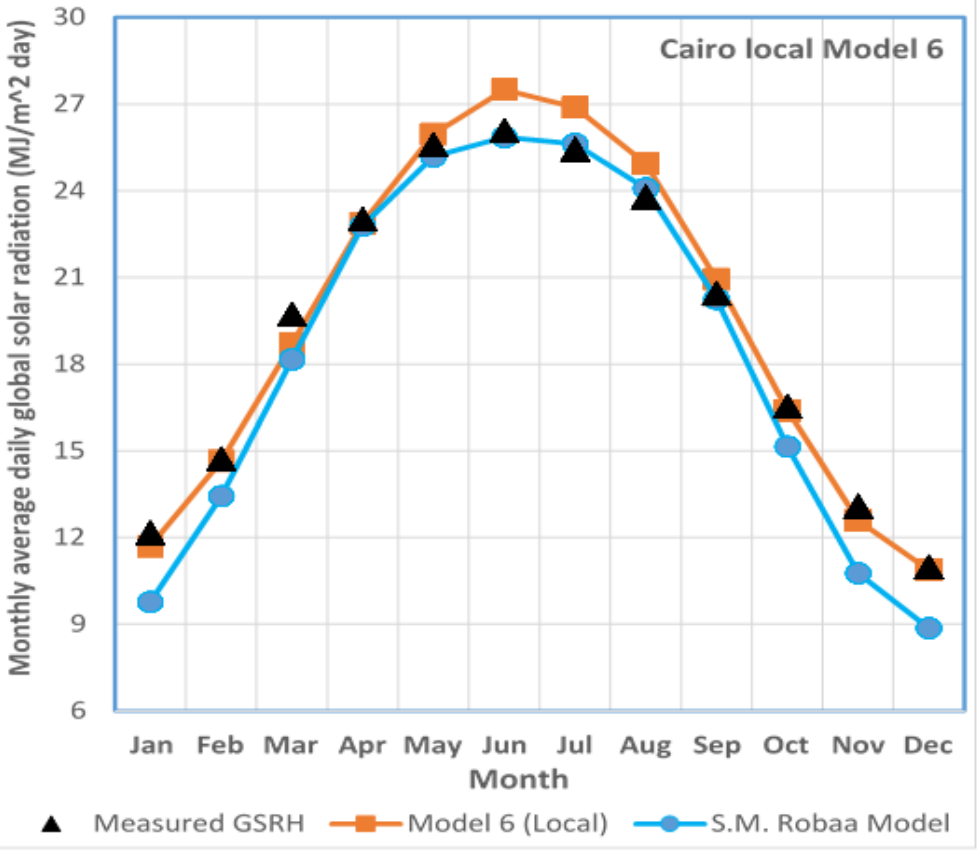
Comparing performance of the best model from newly suggested Model with the best sunshine-based model against the measured data in Cairo.

- $R^2 > 0.98\%$.
- $R^2 > 0.94\%$.

Relative Error:

- Jan > -3.8 %.
- Dec > -1.0 %.

- Jan > 19.6 %.
- Dec > 19.4 %.



Suggesting a new simple global solar radiation models

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New Temperature-based Models for Predicting Global Solar Radiation

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HIGHLIGHTS

- New temperature-based models for estimating solar radiation are investigated.
- The models are validated against 20-years measured data of global solar radiation.
- The new temperature-based model shows the best performance for coastal sites.
- The new temperature-based model is more accurate than the sunshine-based models.
- The new model is highly applicable with weather temperature forecast techniques.

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ABSTRACT

This study presents new ambient-temperature-based models for estimating global solar radiation as alternatives to the widely used sunshine-based models owing to the unavailability of sunshine data at all locations around the world. Seventeen new temperature-based models are established, validated and compared with other three models proposed in the literature (the Annandale, Allen and Goodin models) to estimate the monthly average daily global solar radiation on a horizontal surface. These models are developed using a 20-year measured dataset of global solar radiation for the case study location (Lat. 30°51′N and long. 29°34′E), and then, the general formulae of the newly suggested models are examined for ten different locations around Egypt. Moreover, the local formulae for the models are established and validated for two coastal locations where the general formulae give inaccurate predictions. Mostly common statistical errors are utilized to evaluate the performance of these models and identify the most accurate model. The obtained results show that the local formula for the most accurate new model provides good predictions for global solar radiation at different locations, especially at coastal sites. Moreover, the local and general formulas of the most accurate temperature-based model also perform better than the two most accurate sunshine-based models from the literature. The quick and accurate estimations of the global solar radiation using this approach can be employed in the design and evaluation of performance for different solar applications.

Advantages of Hassan et al. Model

$$G/G_0 = a\,T^b\,G_0 + c$$

It is a Temperature-Based Model

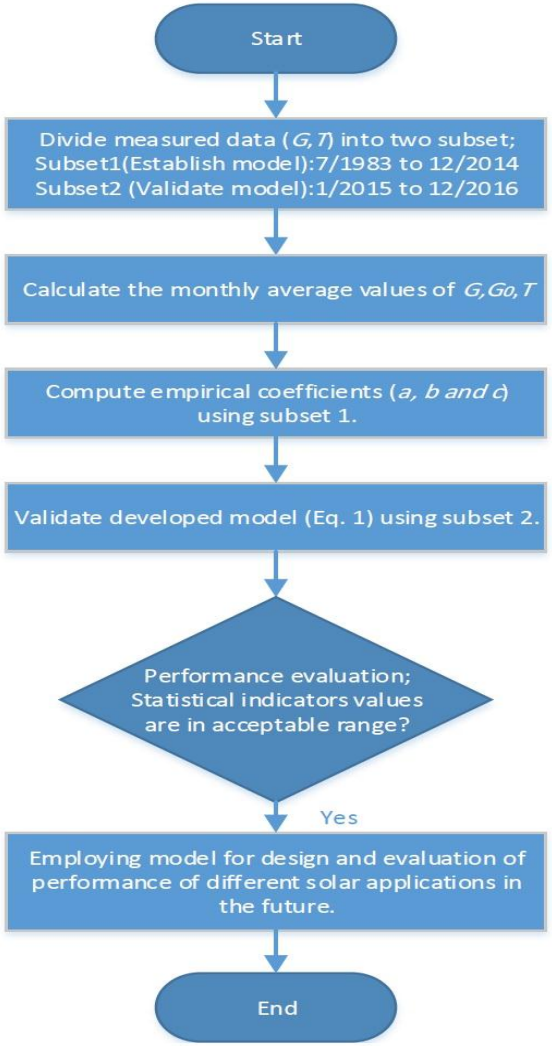
- Temperature information is already recorded and continuously for other aims, compared with other meteorological parameter; such sunshine data (Unavailable).
- The high applicability of the ambient temperature-based solar models can be achieved by coupling the developed models with different weather forecast techniques that are mainly employed to accurately forecast the weather temperature.

Results

Results and Discussion

- The measured data are divided into two subsets and averaged to get the monthly average daily values.
- The first subset is from 1 July 1983 to 31 December 2014, and it is utilized to establish models using regression analysis.
- Empirical coefficients values are computed and summarized **Table**.
- The second subset is from 1 January 2015 to 31 December 2016, and it is employed to evaluate and validate the established model using statistical indicators; RMSE and R^2.
- The predicted values of developed models are compared with the measured data of global solar radiation of selected locations based on RMSE and R^2 values.
- These statistical indicators are calculated and summarized in **Table**.

Diagram for the whole process of the establishing and validating models

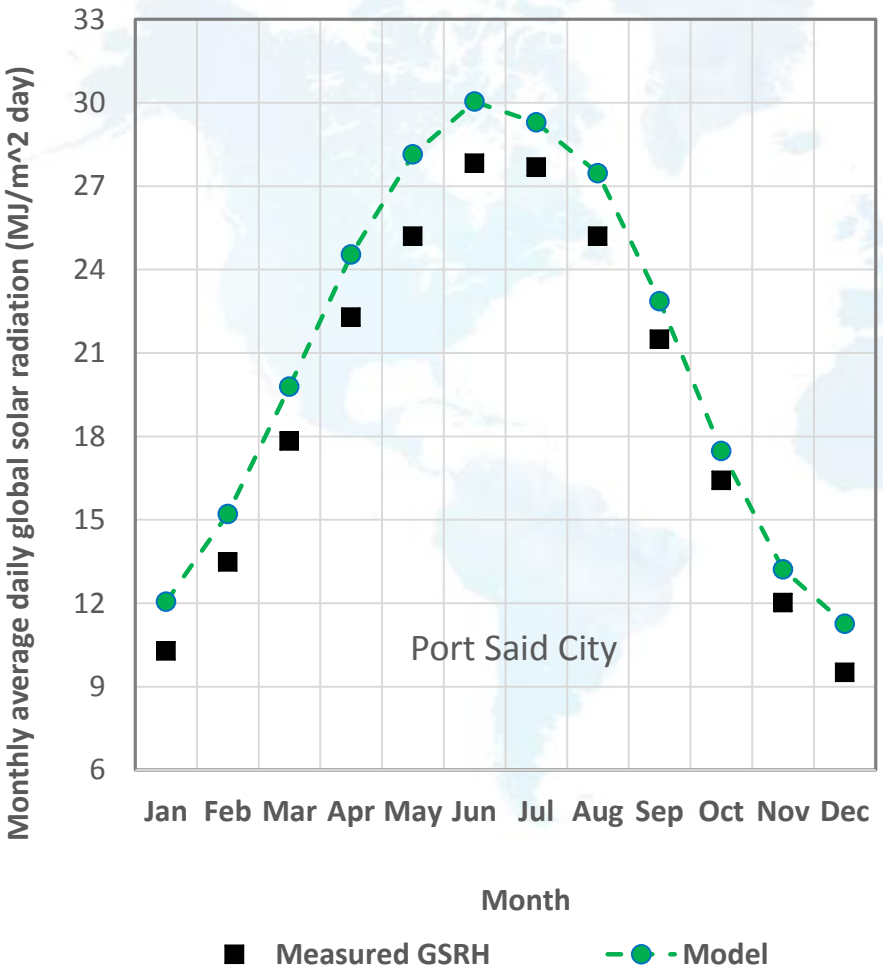


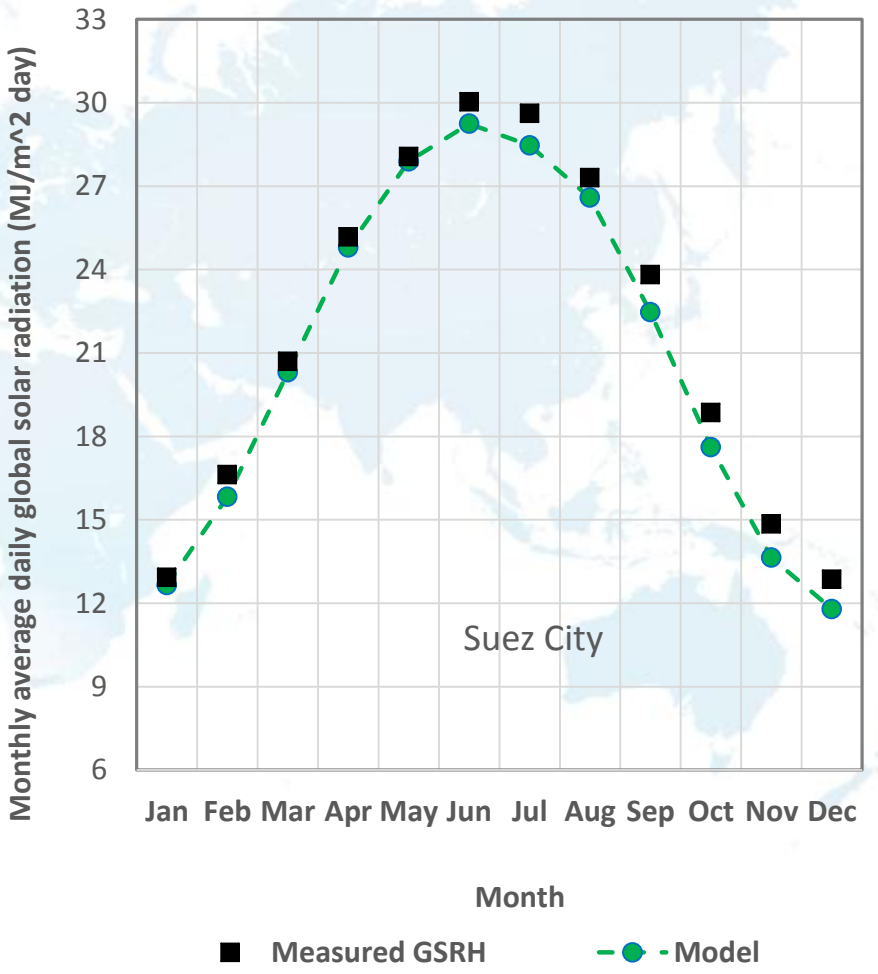
Empirical coefficients and statistical indicators

$$G/G_0 = a\,T^b\,G_0 + c$$

City	a	b	c	RMSE	R^2
Port Said	0.00034	0.83609	0.51841	1.91	0.91
Suez	0.00082	0.52864	0.51990	0.89	0.98

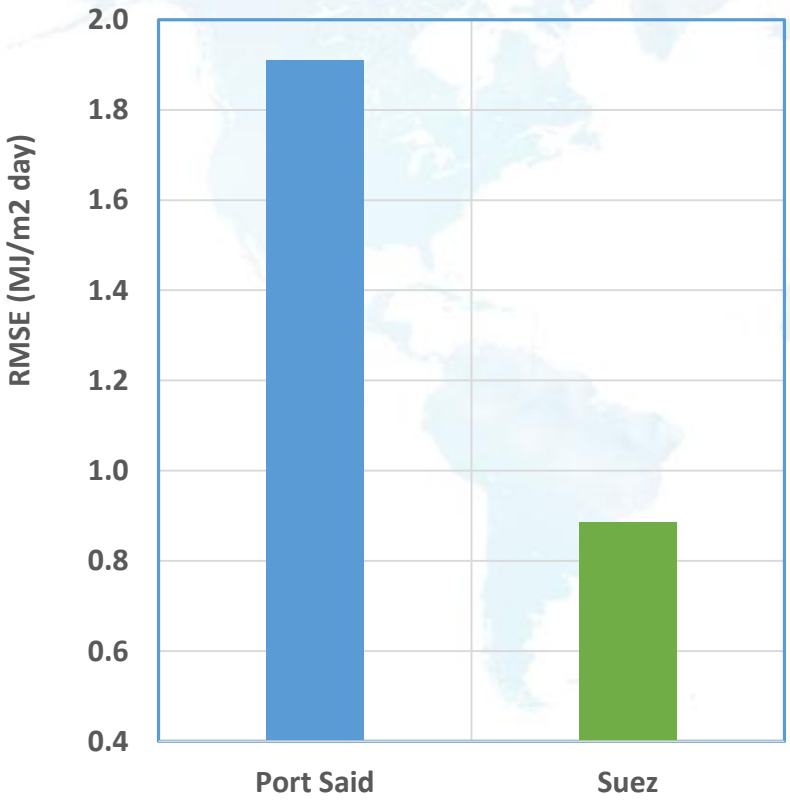
Overall Performance of the Proposed Models



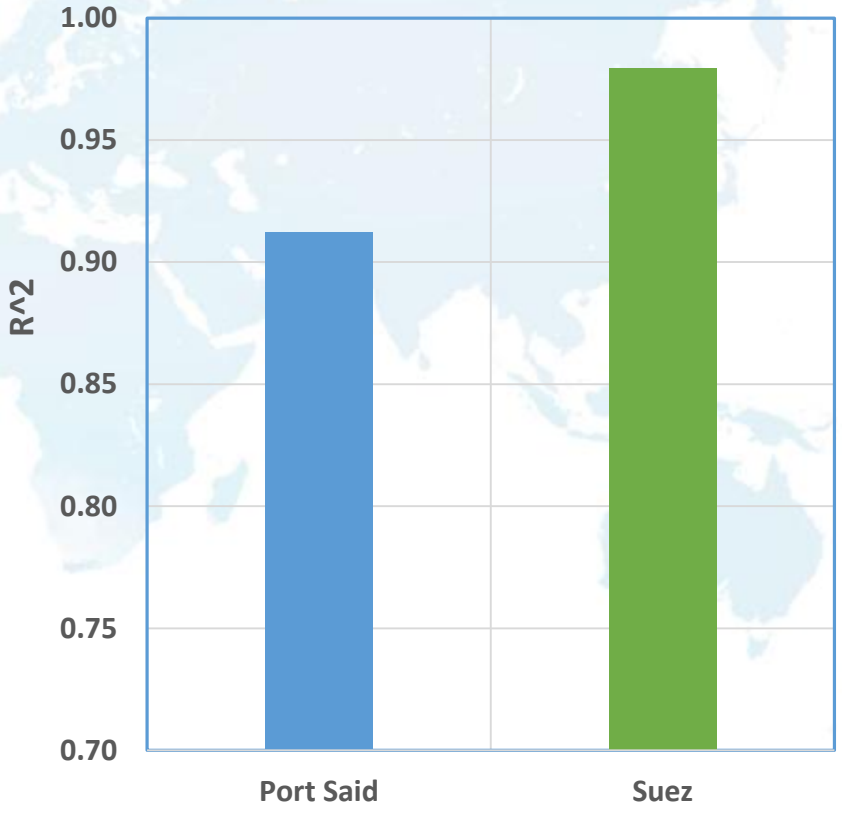


Statistical Indicators Graph of the Models

-10% ≤ RMSE values ≤ +10%



$0 \leq R^2 \leq 1$



Conclusion

From the above results, it can be concluded that:

- The proposed model in this work can be utilized for estimating global solar radiation with higher accuracy.
- The obtained results from this work are consistent with the results of previous studies, which conclude that the **Hassan et al. Model** has accurate estimation.
- The high applicability of the proposed model, which can be accomplished by coupling it with different temperature weather forecast methods.
- Hence, these accurate estimations for global solar radiation can be considered to be a valuable appliance for design and evaluation of performance of different solar applications in the future.

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Thanks