Estimation of Hourly Solar Radiation Using DM and GRNN Models

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Predicting hourly solar radiation

- The real-time measurement which records the solar radiation data on much smaller time intervals, such as one minute and several minutes is preferred for some precise researches and applications. However, the maintenance and calibration work is costly in addition to the greatly affected values by the time and location.
- As such, there is a requirement of using estimation models that use geographical and climatological parameters of locations.
- Among various models, hourly solar radiation estimation models are proposed assuming hourly solar radiation is much more accurate than daily average radiation, because it has recorded the detailed change of solar radiation in a day.

Data

- Measured irradiance and sun-earth parameters data in Mekelle, Ethiopia.

Indicator	Global Irradiance (Wm^{-2})	Solar Duration (hr)
Count	76616.00	76616.00
Mean	253.49	0.05
Std	347.55	0.07
Max	1408.07	0.17
Min	1.05	0.00

SN	Parameter	Value
1	Latitude (φ)	13.33 degrees
2	Longitude (λ)	39.30 degrees
3	Local time (T_{loc})	00:00 - 23:00 hours
4	Time zone	GMT + 3
5	Number of days (n_d)	1 and 365 (1st of January to 31st of December)

Materials and Methods

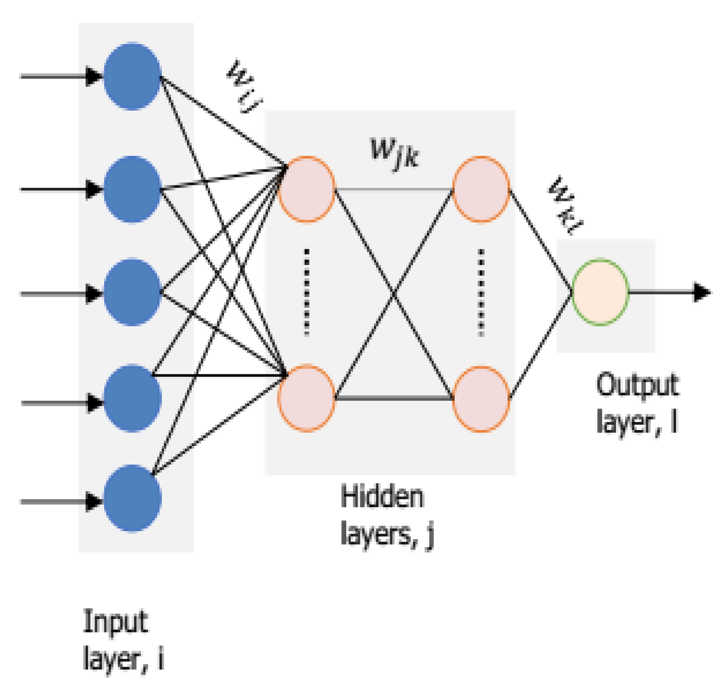
Data Mining (DM) Model: (Collares-Pereira and Rabel)

$$\frac{G_h}{G_D} = (a + bCos\ \omega)\frac{\left(\frac{\pi}{24}\right)(\cos\omega - \cos\omega_s)}{\sin\omega_s - \left(\frac{2\pi\omega_s}{360}\right)\cos\omega_s}$$

$$a = 0.409 + 0.5016\ \text{Sin}\ (\omega_s - 60)$$
$$b = 0.6609 - 0.4767\ \text{Sin}\ (\omega_s - 60)$$

Generalized Regression Neural Network (GRNN) Model:

SN	Method
1	Define training (T_{solar}, ω, ψ, h, I_o) and test data (I)
2	Normalization (scaling input data)
3	Define learning rate (weight update) - Standard deviation (Std)
4	Train (x_train, y_train)
5	Test (y_test = predict(x_test))



Features:

Parameter	Equation
Sunset hour angle	$\omega_s = \cos^{-1}(-\tan\varphi\tan\delta)$ $\delta = 23.45\sin(0.9863 * (248 + n_d))$
Hour angle	$\omega = 15\ (T_{Solar} - 12\ hour)$
True solar time	$T_{solar} = T_{loc} + EoT + (Dhg/degree)\ [(LSMT - \lambda)]$ $EoT = 9.87\sin(2B) - 7.53\cos(B) - 1.5\sin(B)$ $B = (360^0/365)\ (n_d - 81)$ $LSMT = 15^0 * \text{Time zone}$
Sun elevation	$h = \sin^{-1}(\sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\cos(\omega))$
Sun azimuth	$\Psi = \sin^{-1}(\cos(\delta)\sin(\omega)/\cos(h))$
Hourly Extraterrestrial Radiation	$I_o = \frac{12 * 3600 * G_{sc}}{\pi}\left[1 + 0.033 * \cos\left(\frac{360 n_d}{365}\right)\right] * \left[\cos\varphi\cos\delta\sin(\omega_2 - \omega_1) + \frac{\pi(\omega_2 - \omega_1)}{180}\sin\varphi\sin\delta\right]$

Performance Gauges:

$$MAE = \left(\frac{1}{n}\right)\sum|H_{est} - H_{mes}|$$

To weight all the individual differences equally.

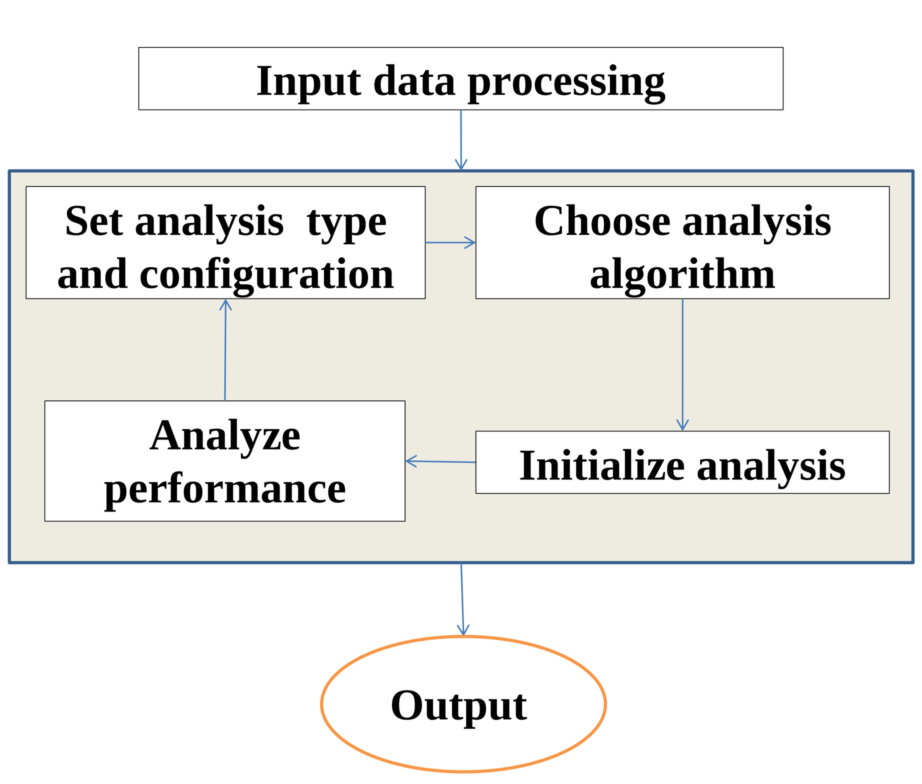
$$MSE = \sqrt{\frac{\sum(H_{est} - H_{mes})^2}{n}}$$

To make scale of the errors to be the same as the scale of targets.

$$R = \frac{\sum(H_{est} - \bar{H}_{est})(H_{mes} - \bar{H}_{mes})}{\sqrt{\sum(H_{est} - \bar{H}_{est})^2\sum(H_{mes} - \bar{H}_{mes})^2}}$$

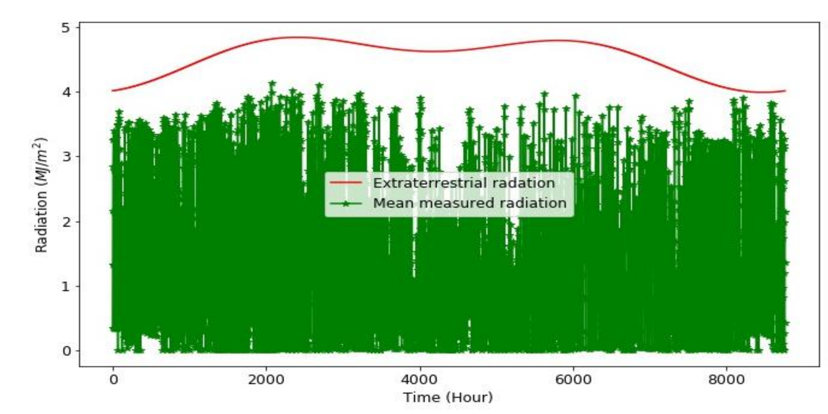
To measure if the model is good or not.

Forecast:

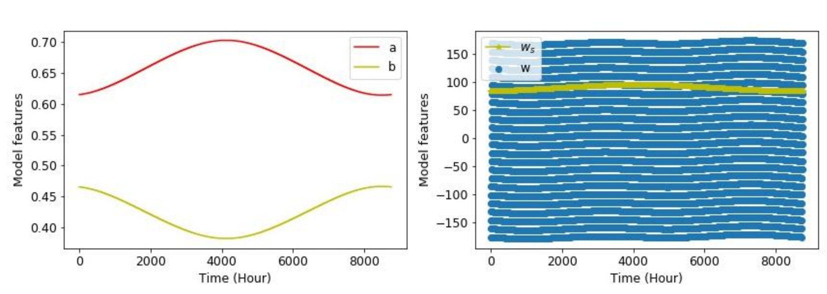


Results

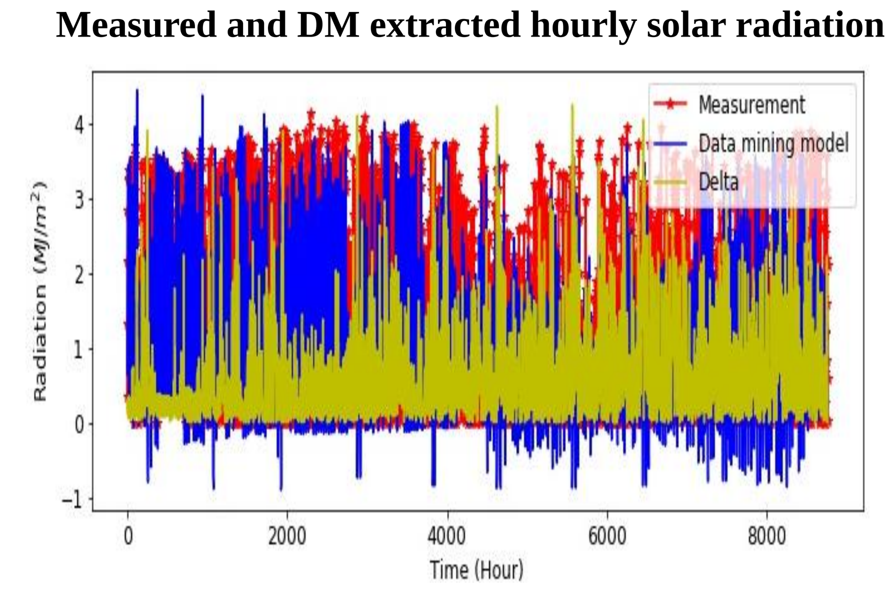
Hourly extraterrestrial and measured radiation



Feature values for the DM model



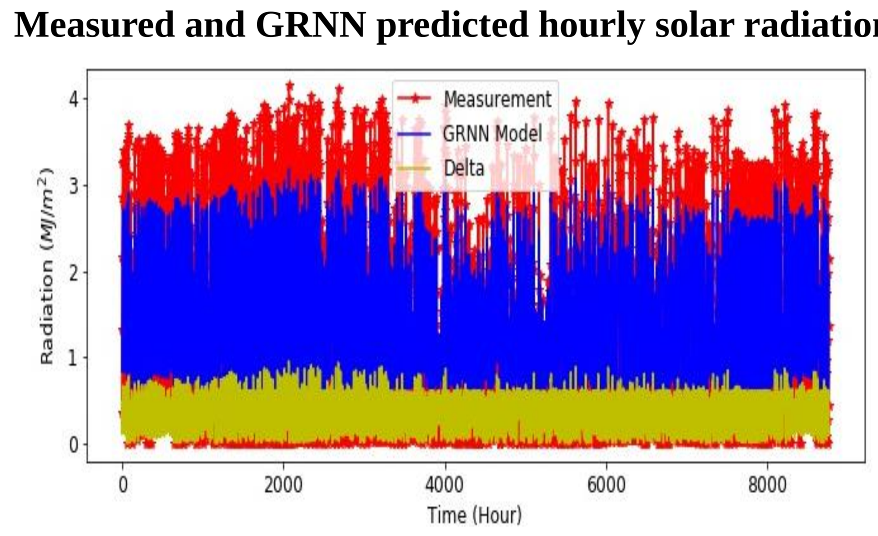
Measured and DM extracted hourly solar radiation



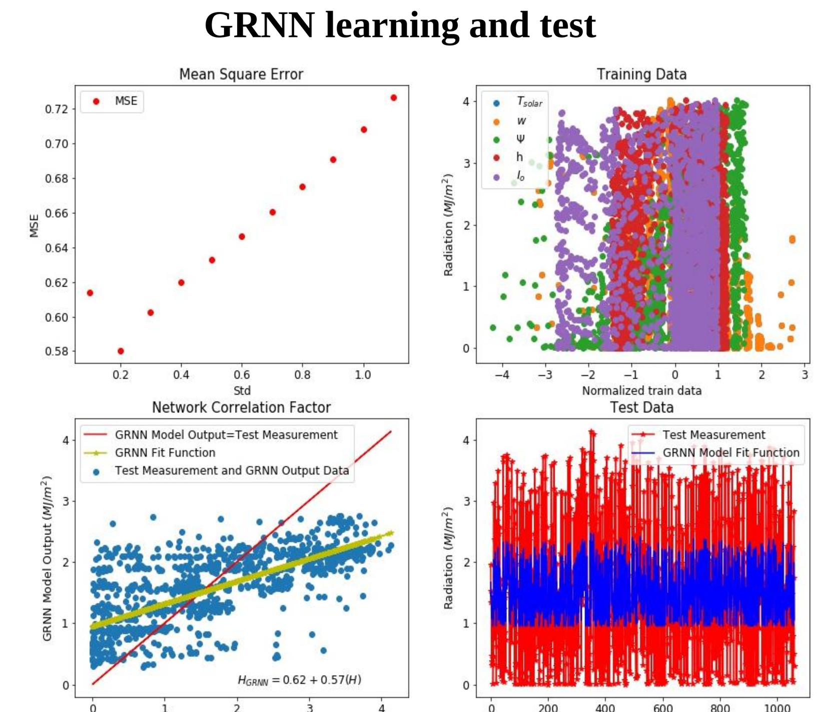
Parameters for the GRNN model

SN	Parameter	Description
1	Training data	70%
2	Test data	30%
3	Normalized training data	[-3, 3]
6	Std	[0.1, 0.11]

Measured and GRNN predicted hourly solar radiation



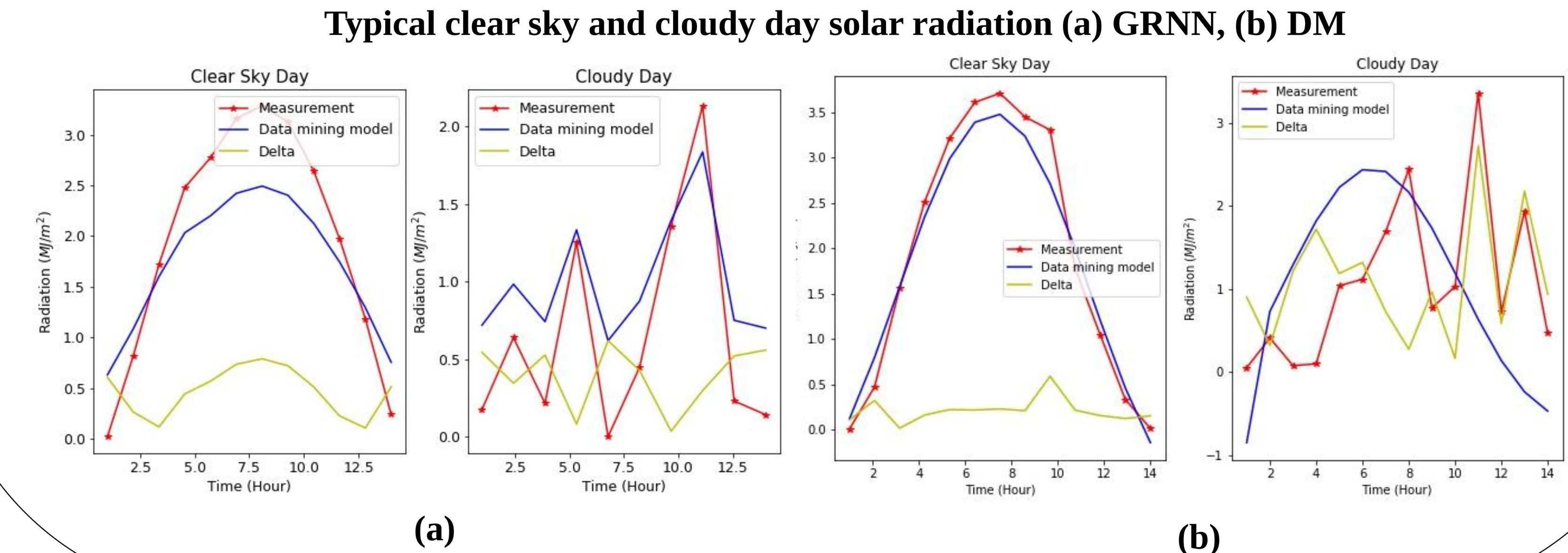
GRNN learning and test



The statistical test results of estimations

Indicator	DM	GRNN
MAE	0.74	0.42
RMSE	1.03	0.50
R	0.77	0.83

Typical clear sky and cloudy day solar radiation (a) GRNN, (b) DM



Conclusion and Future Work

- The models are able to predict the nature of the hourly solar radiation with reasonable accuracy.
- The GRNN model [I_{GRNN} = 0.62 + 0.57 (I)] showed better prediction compared to the DM.
- The DM model (with variable coefficients) showed acceptable prediction for clear sky days as compared to cloudy sky days.
- The limitations for accurate prediction of the models could be mainly due to the short-term measured average solar radiation values and the outlier input features of the training data space.
- Further study is recommended for thorough treatment and effective estimation of the models in the study area and elsewhere with comparable climatic conditions, especially for cloudy days.