Effect of Air Quality on Solar Radiation Prediction

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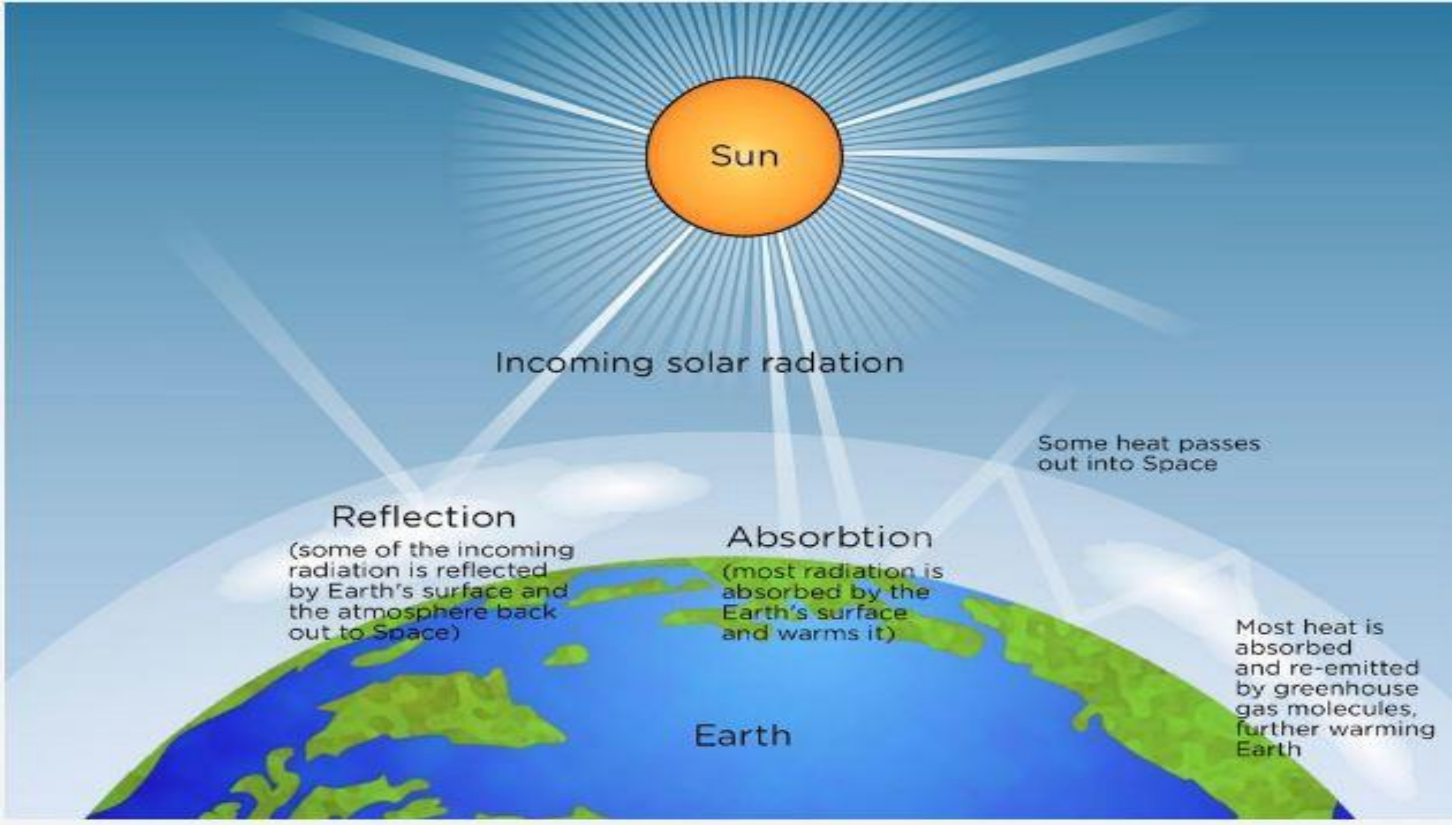
Installed Power Capacity (31 May, 2022)		
Fossil fuel	236 GW	58.6%
Nuclear	6.8 GW	1.7%
Hydro	46.7 GW	11.6%
Solar	Solar 57 GW	14.1%
Wind	40.7 GW	10.1%
Biomass+ Cogen +Waste-to-Energy	10. 7 GW	2.6%
Small hydro	4.9 GW	1.2%
Total Renewables		
Total Installed capacity	403 GW (Renewables: 114 GW other than Hydro. Along with hydro our RE capacity is ~40% of the total installed capacity) RE Electricity 24.2%	

RE Target for 2022: 175 GW

RE Target for 2030: 500 GW


Sun
Incoming solar radiation
Some heat passes out into Space
Reflection
(some of the incoming radiation is reflected by Earth's surface and the atmosphere back out to Space)
Absorbtion
(most radiation is absorbed by the Earth's surface and warms it)
Most heat is absorbed and re-emitted by greenhouse gas molecules, further warming Earth
Earth

Motivation

- Solar Radiation forecasting models considering Global Horizontal Irradiance(GHI) is quite common in practice.But there is lack of research in forming a forecasting model that includes Air Quality data.

- From the year around 2000 to present, Satellites from different nations, with high volume and high speed, are capturing Air Quality Informations which are helping tremendously to generate and store data.In this study performance of GHI forecasting model including Air Quality Data has been studied.

Study Objectives

- Aerosol Optical Width is a Satellite Captured Air property that correlates to Particulate Matter everywhere.To find how the diameter of Aerosol optical width effects on the performance of the model.

- To try different combinations of Air Quality Parameters and see which combination among them has the best performance in Solar Radiation Forecasting.

Satellite Captured Air Quality Data Sources

Data Product	Time Period	Satelite	Space agency	Specification
Aerosol Optical Depth	2014-present	Insat 3d	ISRO	TR: 30 min SR:
Aerosol Optical Depth	2002-present	Modis aqua	NASA	SR: 10x10 1-km pixel array TR: 5 min.
Aerosol Optical Depth	2000-present	Modis terra	NASA	SR: 10x10 1-km pixel array TR: 5 min.
NO2	2004-	OMI NO2	NASA	TR: Daily One Data SR:0.25 degree

TR-Temporal Resolution

SR-Spatial Resolution

Satellite Captured Air Quality Data Sources

Data Product	Time Period	Satelite	Space agency	Specification
SO2	2004-	OMI SO2	NASA	TR: Daily One Data SR:0.25 degree
CO Column	2000-	Moppit	NASA	T.R. - One data per day
O3 Column	2019-	SentineL 5P	NASA	T.R. - One data per day

Data used in this study

- The forecasting model in this study has been trained with data of one hour Temporal Resolution from Modis Terra and Aqua Satellite NASA

Data used in this study

Parameter	Data Used	Temporal resolution	Data Sources
Solar Radiation	Global Horizontal Irradiance	One hour	NIWE
Air Quality	Aerosol Optical Width	One hour	Modis Terra & Aqua Satellite from NASA CERES
Air Quality	Cloud Temperature	One hour	Modis Terra & Aqua Satellite from NASA CERES
Air Quality	Cloud Surface Albedo	One hour	Modis Terra & Aqua Satellite from NASA CERES
Air Quality	Ozone Level	One hour	Modis Terra & Aqua Satellite from NASA CERES

Description of Air Quality Parameters

Air Quality Parameters	Description	Correlation Value found With GHI
Aerosol Optical Width	Aerosol Distributed in a column of Air from measuring instrument to top of the atmosphere	~ -0.45
Cloud Temperature	Temperature in a column of Air from measuring instrument to top of the atmosphere	~ 0.08
Cloud Surface Albedo	Measure of Reflectivity of the Cloud	~ 0.28
Ozone Level	Ozone Distributed in a column of Air from measuring instrument to top of the atmosphere	~ 0.32

Forecasting Model

- In this study, a Deep learning based Recurrent Neural Network, named Long Short Term Memory(LSTM) has been utilized.

- LSTM models have the facility of having a memory of all previous timestamps, which makes it an efficient forecasting model in a time series that has long term time dependencies like weather and stock market etc.

Stations in which the Model were tested

	Stations Location(Latitude and Longitude)	Station Name
1	12.956,80.217	NIWE CHENNAI
2	13.09,79.974	THIRUVALLUR ; PRATHYUSHA COLLEGE OF ENGINEERING
3	12.974,79.397	VELLORE ; VIT UNIVERSITY CO2 LABORATORY
4	13.627,79.397	TIRUPATI
5	11.96,79.811	PUDUCHERRY WOMEN’S POLYTECHNIQUE COLLEGE

Experiment 1:

- Performance Metrics MAE and NRMSE has been compared before and after including Aerosol Optical Width of 0.84 micron.

- Two version of the model has been compared with Window Size = 30 (i.e. Considering previous 30 hours to predict future 5 hr) and window size = 10.

Exp.1.1:GHI Prediction After Including Aerosol width 0.84 micron

Stations	Window	**MAE(GHI)**	**MAE(GHI +AOD)**
CHENNAI	10	**37.30**	**19.36**
THIRUVALLUR	10	**36.98**	**23.36**
VELLORE	10	**28.33**	**21.36**
TIRUPATI	10	**20.76**	**14.65**
PUDUCHERRY	10	**34.77**	**17.34**

Exp.1.2: GHI Prediction After Including Aerosol width 0.84 micron

Stations	Window	**MAE(GHI)**	**MAE(GHI +AOD)**
CHENNAI	30	**10.07**	**4.57**
THIRUVALLUR	30	**17.65**	**3.42**
VELLORE	30	**18.89**	**4.23**
TIRUPATI	30	**20.76**	**2.83**
PUDUCHERRY	30	**9.865**	**4.99**

Remarks:

- Mean Absolute Error and Normalized Root Mean Square Error of both the models showed significant improvements after including Aerosol Optical Width of 0.84 micron.

- Window Size of 30 (i.e. Considering previous 30 hours to predict future 5 hr) gives better result rather than Window size of 10.

Experiment 2:

- Performance Metrics MAE and NRMSE has been compared before and after including Aerosol Optical Width of 0.84 micron and 0.55 micron.

- Two version of the model has been compared with Window Size = 30 (i.e. Considering previous 30 hours to predict future 5 hr) and window size = 10.

Exp 2.1: Effect after changing Aerosol Optical width Diameter

Stations	Aerosol Diameter (Micron)	Window	NRMSE	MAE
CHENNAI	**0.55**	10	**0.512**	**19.07**
CHENNAI	**0.84**	10	**0.530**	**19.36**
PUDUCHERRY	**0,55**	10	**0.450**	**17.31**
PUDUCHERRY	**0.84**	10	**0.452**	**17.34**

Exp 2.2: Effect after changing Aerosol Optical width Diameter

Stations	Aerosol Diameter (Micron)	Window	NRMSE	MAE
CHENNAI	**0.55**	30	**0.288**	**4.44**
CHENNAI	**0.84**	30	**0.298**	**4.57**
PUDUCHERRY	**0,55**	30	**0.294**	**4.732**
PUDUCHERRY	**0.84**	30	**0.306**	**4.99**

Remarks:

- Diameter with 0.55 Micron has slightly better accuracy than 0.84 micron.

- The reason behind this is the amount of reflected Electromagnetic ray on a smaller surface area is smaller than a larger surface area.

- We need to include Aerosol Optical Width of both the sizes in our final forecasting model.

Experiment 3:

- Performance Metrics MAE and NRMSE has been compared after including different parameters Cloud Surface Albedo,Cloud Temperature and Ozone level.

Exp. 3.1 Effects after including Cloud Surface Albedo,Temperature and Ozone Level

Stations	Input	Window	NRMSE	MAE
CHENNAI	**AOD (0.55)**	30	0.288	4.44
CHENNAI	**AOD (0.55) + S.A.**	30	0.356	3.08
CHENNAI	**AOD (0.55) + S.A. + + T.**	30	0.157	2.305
CHENNAI	**AOD (0.55) + S.A. + T +O.L.**	30	0.129	1.84
CHENNAI	**AOD(0.55) + AOD(0.84) + S.A.+ T + O.L,**	**30**	**0.117**	**1.52**

Exp.3.2. Effects after including Cloud Surface Albedo,Temperature and Ozone Level

Station	Input	Window	NRMSE	MAE
PUDUCHERRY	**AOD (0.55)**	30	0.294	4.732
PUDUCHERRY	**AOD (0.55) + S.A.**	30	0.353	3.134
PUDUCHERRY	**AOD (0.55) + S.A. + T.**		0.164	2.359
PUDUCHERRY	**AOD (0.55) + S.A. +O.L.**	30	0.136	2.050
PUDUCHERRY	**AOD(0.55) + AOD(0.84) + S.A.+ T + O.L,**	**30**	**0.125**	**1.67**

Conclusion

- Considering all the variables, Aerosol Optical Width of both Sizes, Cloud Surface Albedo (S.A.), Cloud Temperature(T), Ozone layer (O.L) for window size = 30; we achieved MAE less than 2 and NRMSE of less than 0.15

- On the other hand, before considering these Air Quality Informations we had MAE less than 20 and N.R.M.S.E. higher than 0

Reference:

- Cleaner air would enhance India’s annual solar energy production by 6-28 TWh
  Sushovan Ghosh, Sagnik Dey,Dilip Ganguly,Somnath Baidya Roy, Kunal Bali
  https://iopscience.iop.org/article/10.1088/1748-9326/ac5d9a

Thank You