

# Introduction

ISRO has developed the Solar Calculator for World as part of India's commitment to COP26. This was announced by the Honourable Prime Minister of India, Shri Narendra Modi, in Glasgow (UK) on November 2, 2021. The solar energy is one of the most sustainable form of renewable energy, and its promotion is likely to play a major role in realization of the Sustainable Development Goal (SDG) 7. The Solar Calculator application for India and Africa on VEDAS Platform of ISRO helped in ascertaining the solar energy potential at a given location, and it proved to be very useful to various stakeholders. The same framework and sub-routines have been extended to develop the Solar Calculator for World. The application has been developed using open source technology and in-house software. The website is set to play a vital role in the goal of 'One Sun, One World and One Grid'. It will be beneficial to the policy-makers, private companies, financial institutions, think tanks, citizens and all the stakeholders in the solar energy sector.

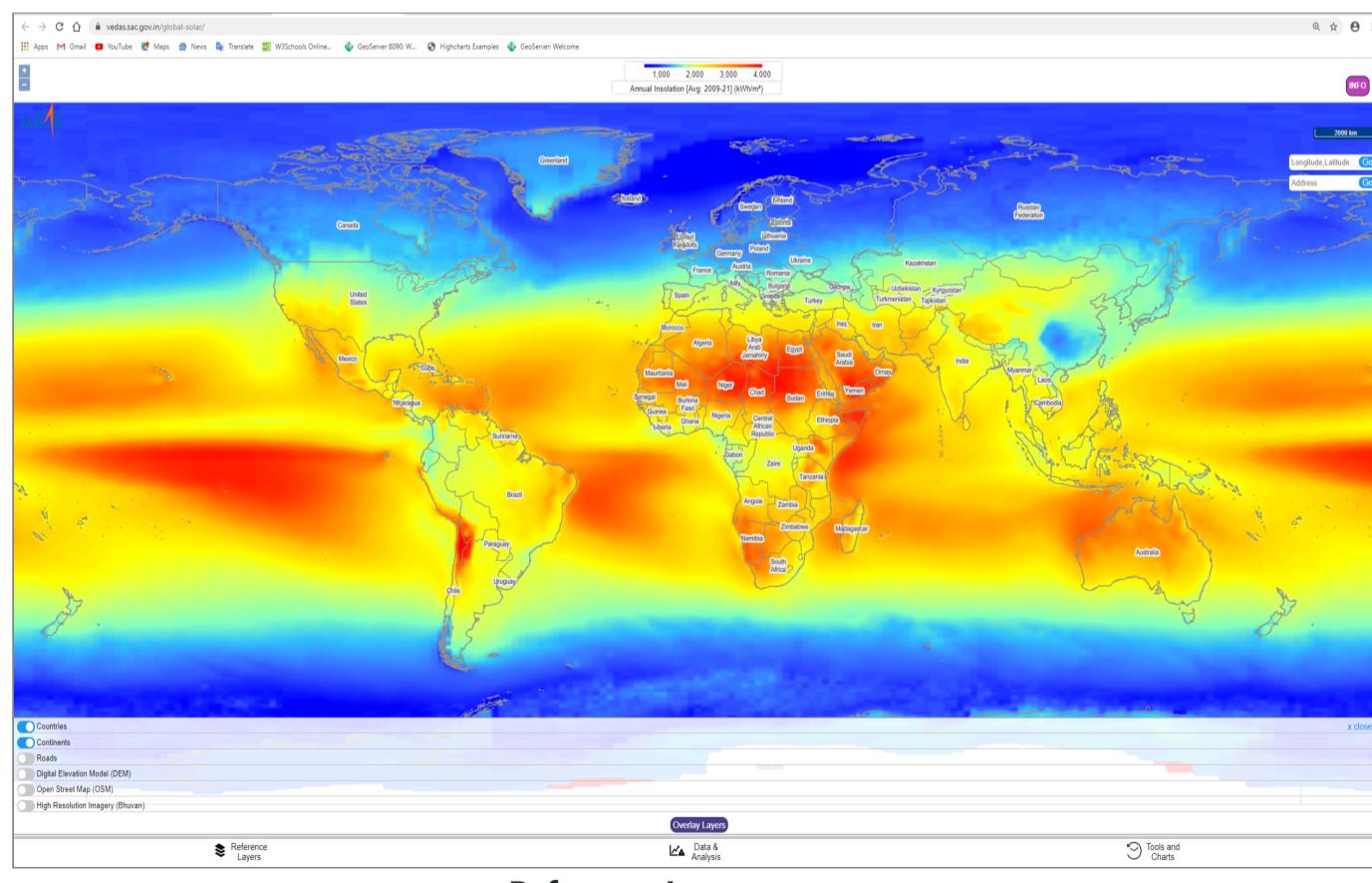
Global Solar Calculator Mobile app is developed to assess solar energy potential (2009 onwards) in tabular and graphical formats including monthly insolation and temperature profile, sunshine hours, day length, and sun path for location provided by the user. The user provides a location in the form of geographical co-ordinates by keying in or clicking on the map. It provides information in tabular and graphical format and interactive web maps. Solar site selection tool is also developed to facilitates user for identifying suitable sites for installing global solar power plants , based on 5 parameters.

Application is provided with three tabs shown in bottom and map area for geospatial data visualisation and analysis. Tabs include:

- I. Reference Layers**
- II. Data & Analysis**
- III. Tools and Charts**

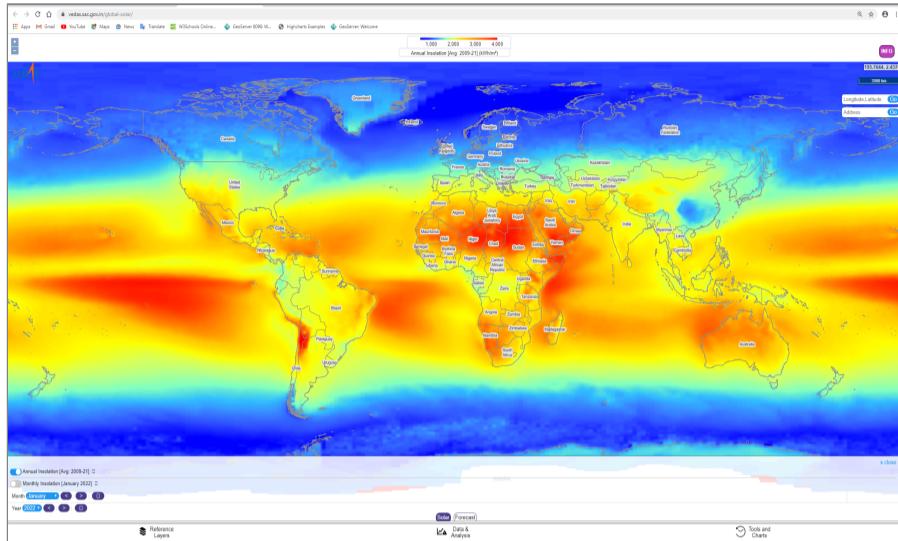
## 1. Reference Layers :

As seen in the below Figure, Reference layers contains overlay layers including Countries, Continents Roads, Digital Elevation Model (DEM), Open Street Map (OSM), High Resolution Satellite Imagery (Bhuvan).

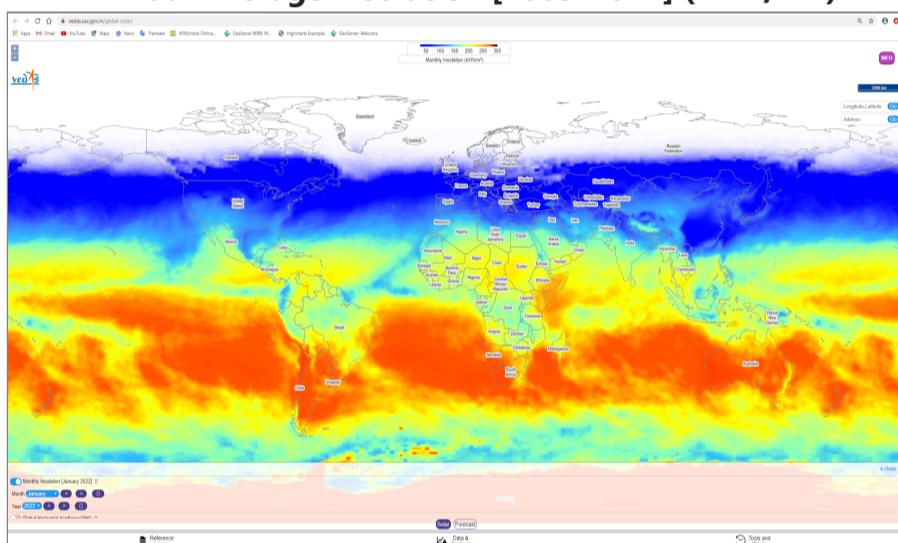


## 2. Data & Analysis :

Data & Analysis tab consists of two sub tabs **(i) solar** and **(ii) forecast**. Solar Tab contains monthly and annual solar insolation layer available 2009 onwards. Monthly solar insolation product is obtained from [NASA](#). It is estimated using Clouds and Earth's Radiant Energy System (CERES) instrument flying aboard NASA's Terra and Aqua Satellite and available at 25km resolution. It is also aggregated at annual interval. This product is published as Open Geospatial Consortium (OGC) compliant Web Map Service (WMS) and available for visualisation on completion of every month.

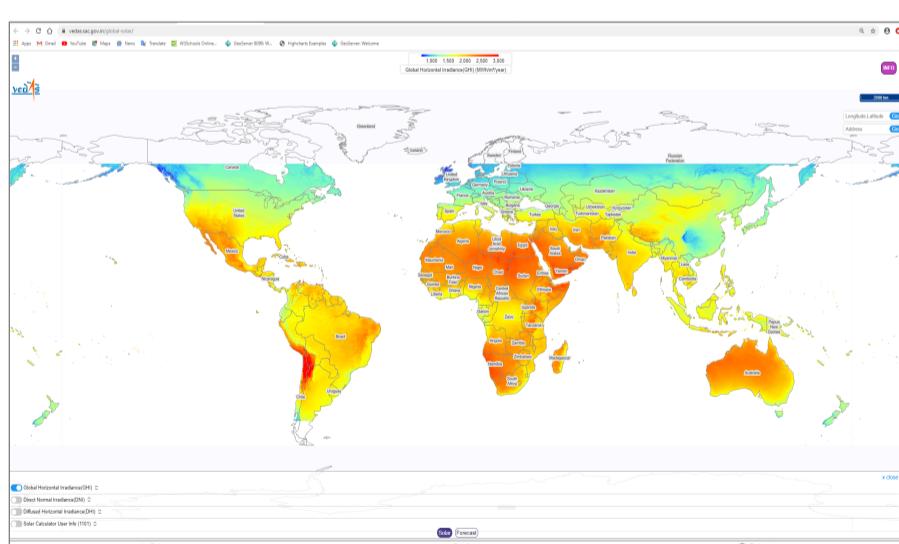


**Annual Average Insolation [2009-2021] (kWh/m<sup>2</sup>)**

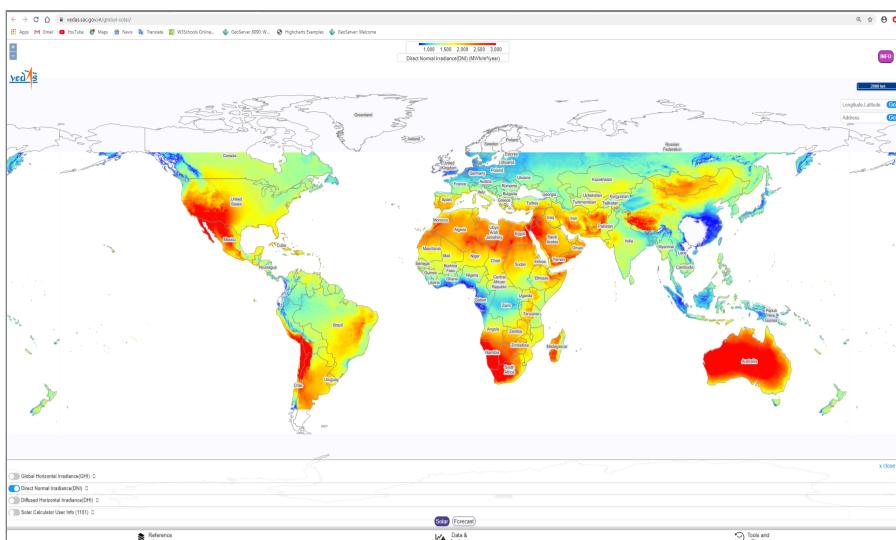
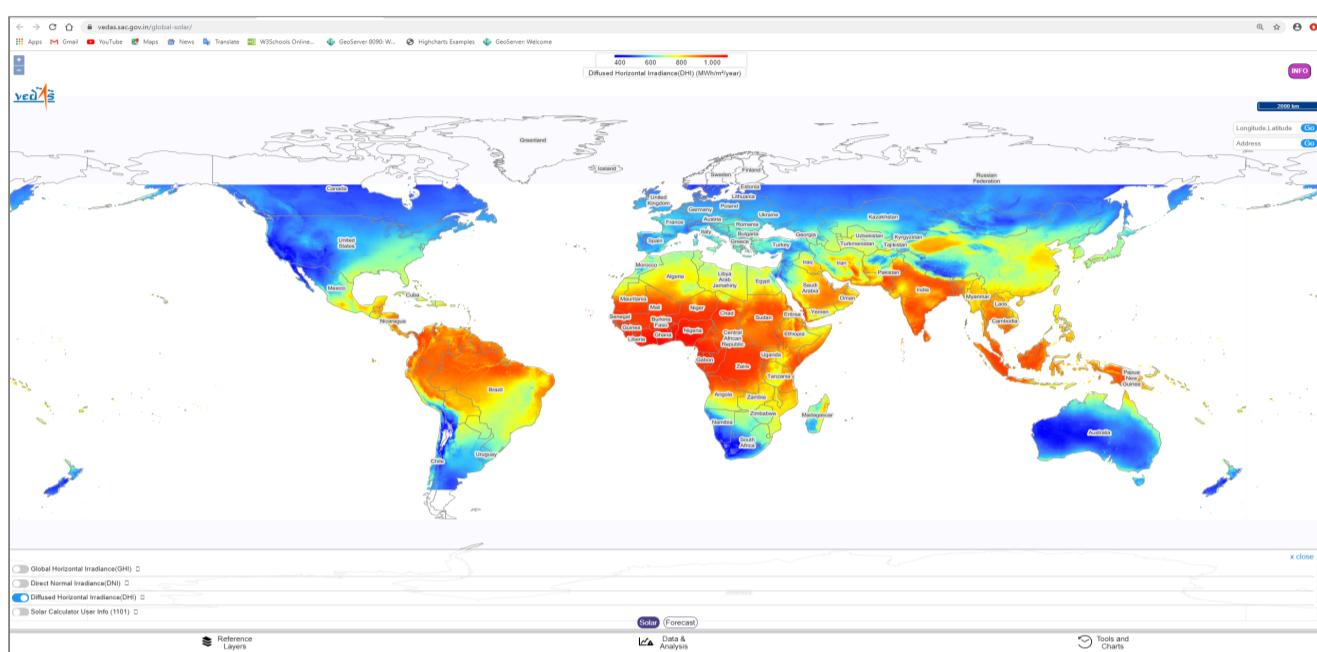


**Monthly Insolation Layer (kWh/m<sup>2</sup>)**

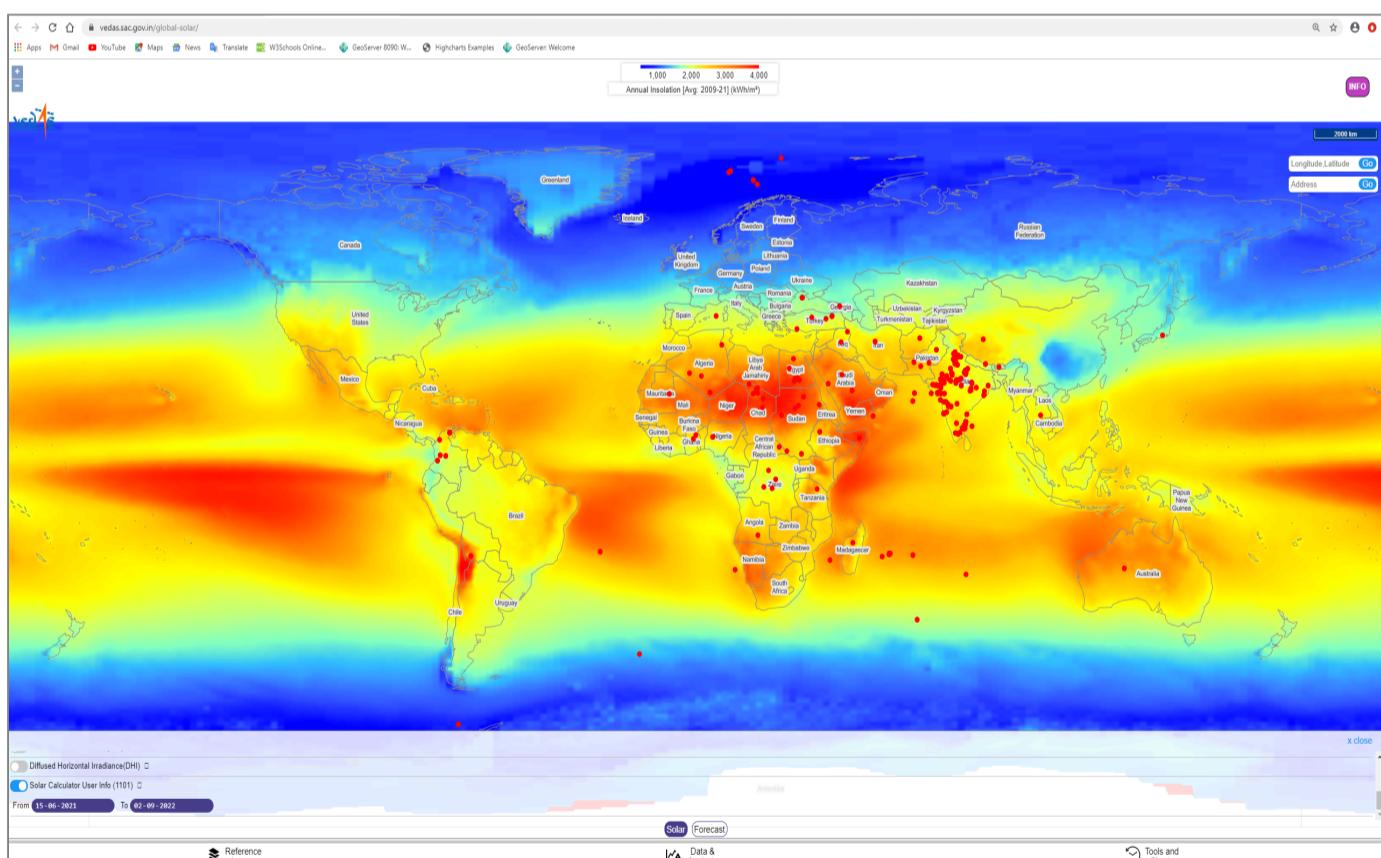
Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI) and Diffused Horizontal Irradiance (DHI) products are obtained from SOLARGIS project available at 250m resolution.



**Global Horizontal Irradiance**

**Direct Normal Irradiance****Diffused Horizontal Irradiance**

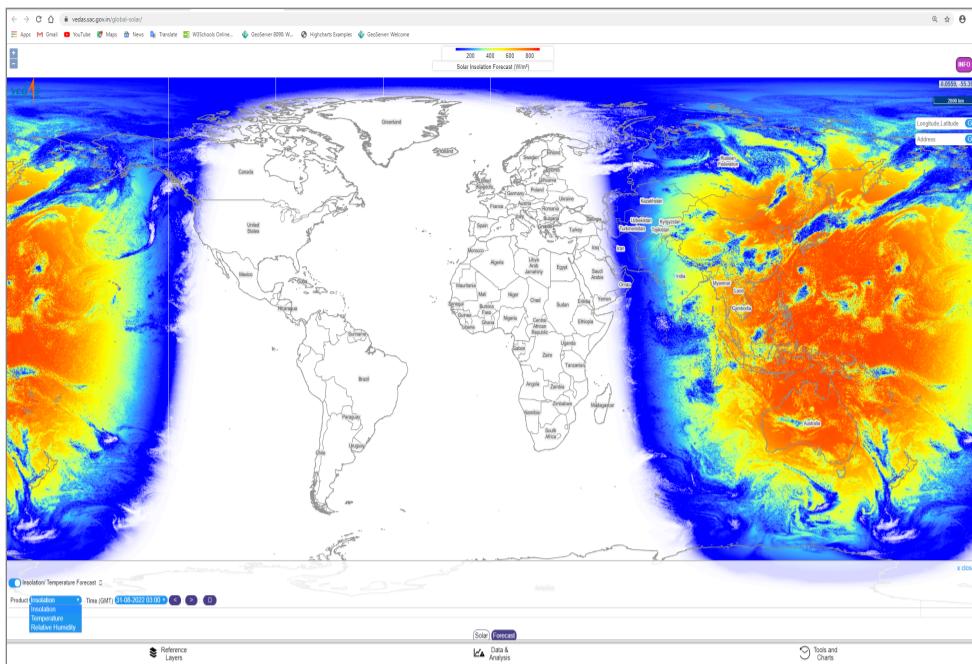
User Info layer shows the location for which solar calculator is used including number of users. Feature information is available by clicking on this layer .

**User Info Layer**

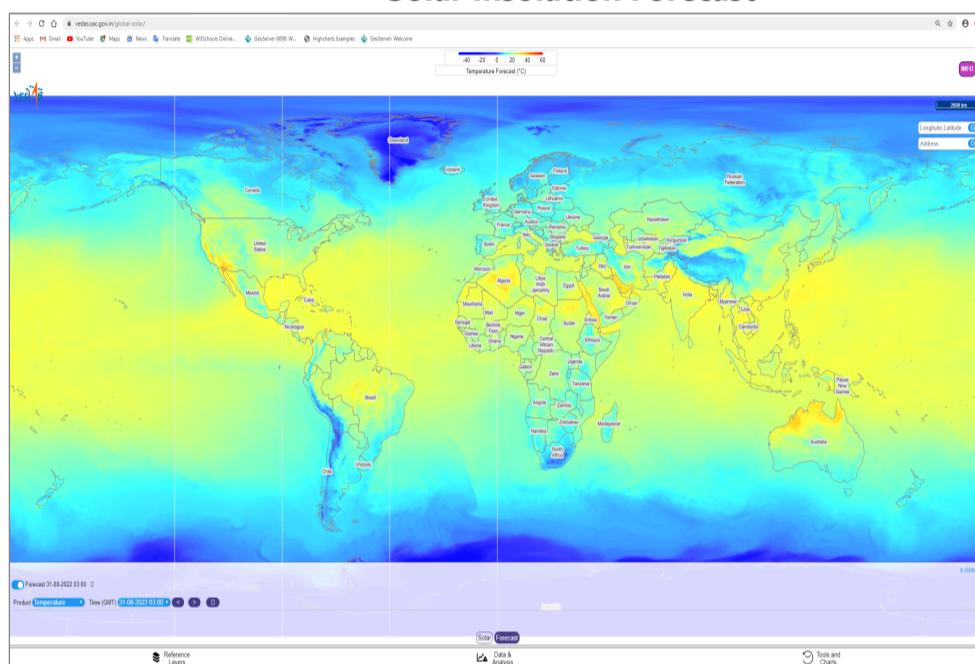
## ○ Forecast

Due to the growing demand of renewable energy, photovoltaic (PV) generation systems have increased considerably in recent years. Solar Insolation forecasting technology plays a very important role since depending on the accuracy of prediction, the amount of economic benefits from solar energy is significantly different. To cater the need of PV farm operators, Next 10 days solar insolation, temperature and relative

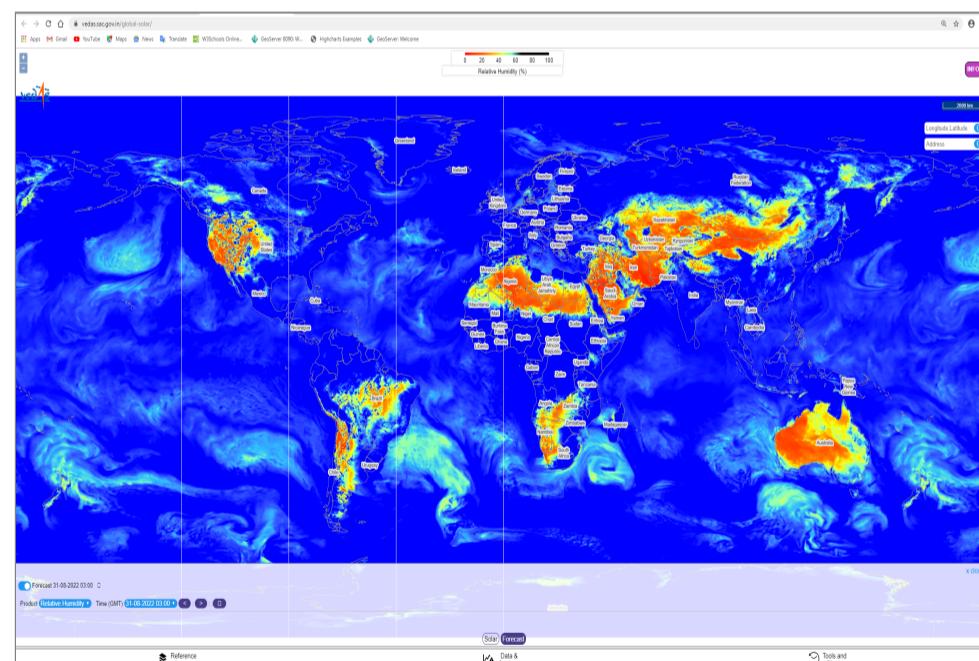
humidity forecast available at 3 hour interval are provided by National Centre for Medium Range Forecasting ([NCMRWF](#)). These forecast datasets are published as OGC (Open Geospatial Consortium) compliant Time enabled Web Map Services (WMS) and animation for same is also available on VEDAS.



**Solar Insolation Forecast**



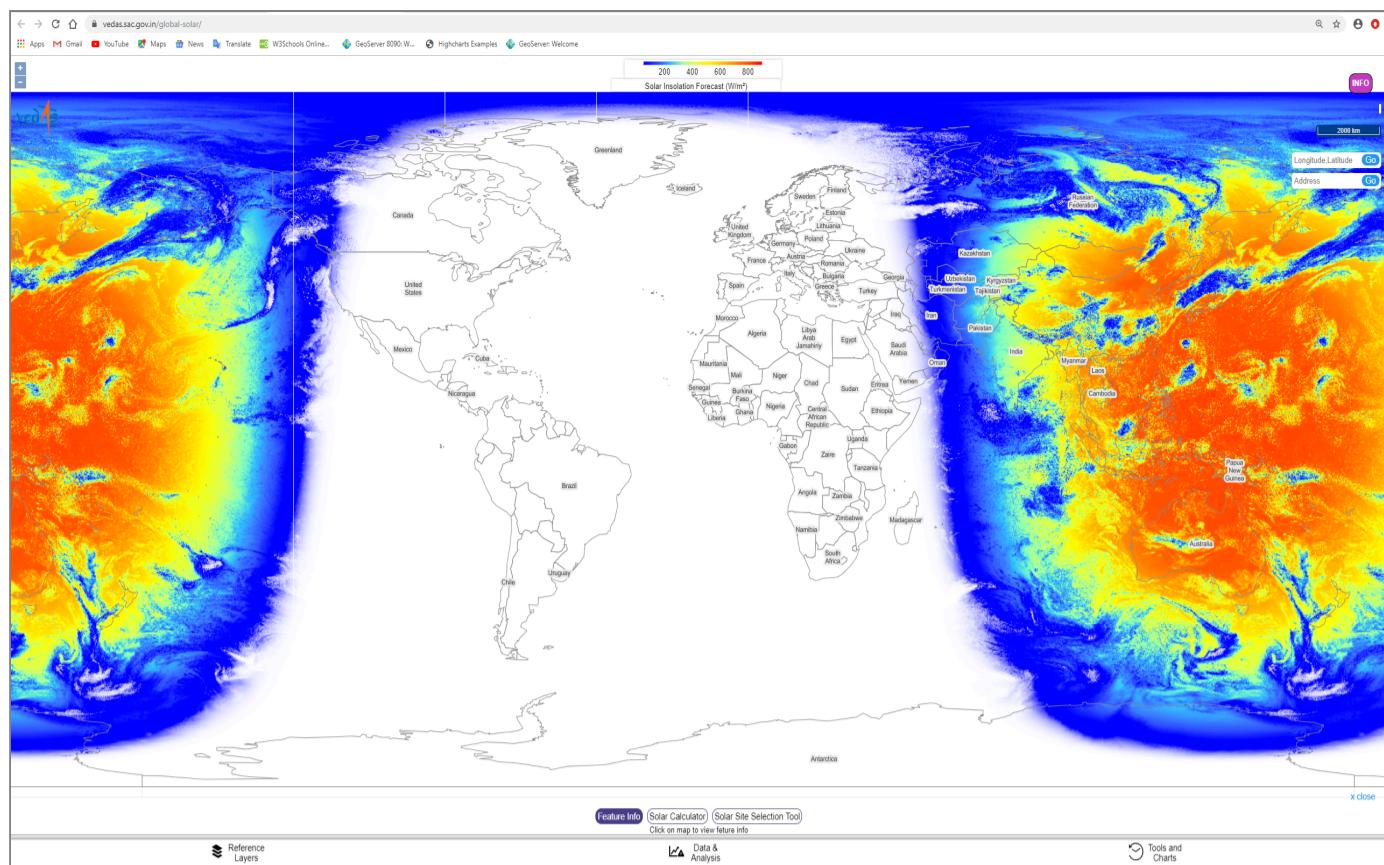
**Temperature Forecast**



**Relative Humidity Forecast**

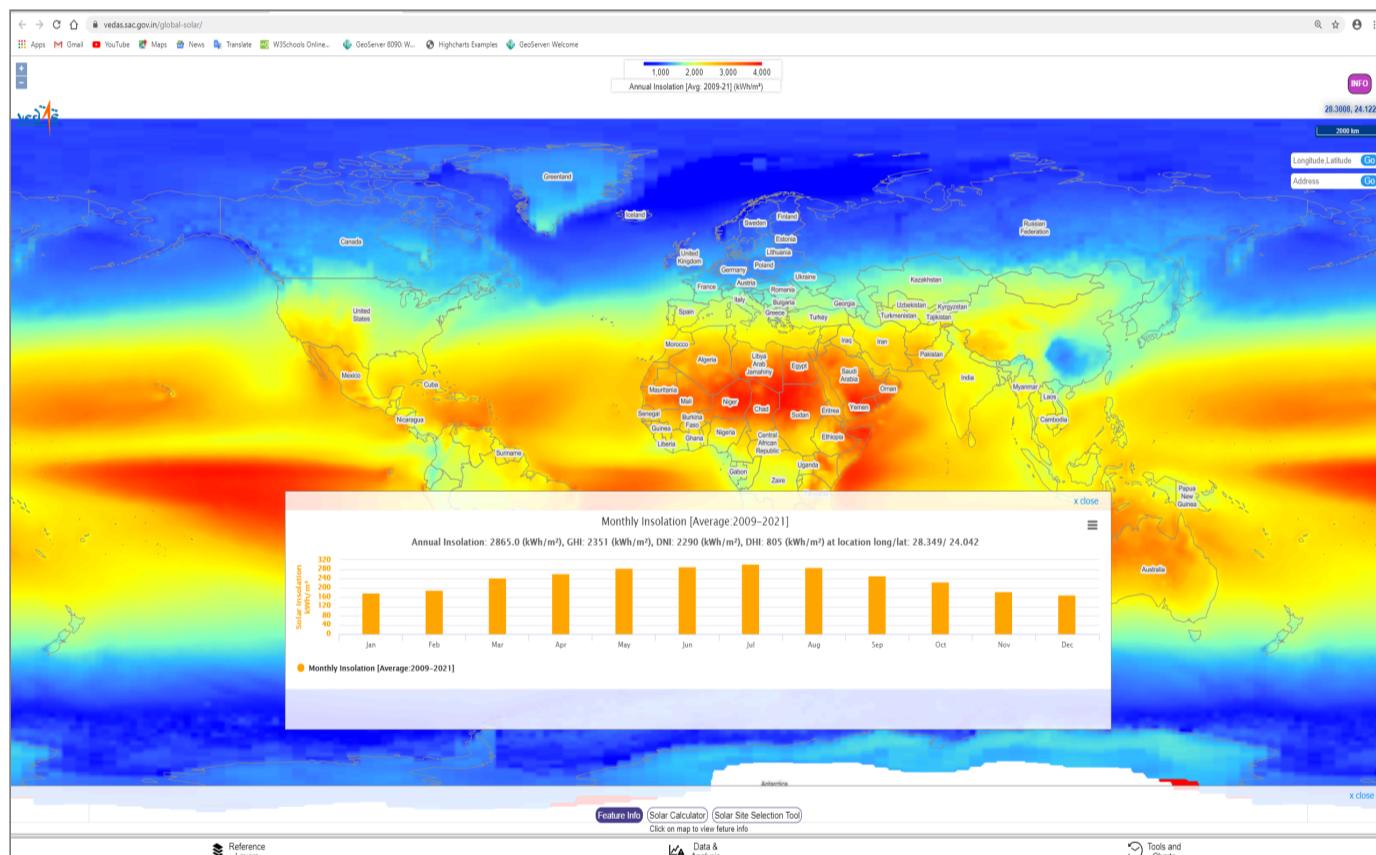
### 3. Tools and Charts

Under Tools and Charts section, Feature Info, Solar Calculator, and Solar Site Selection Tool options are provided. Feature Info facilitates user to provide information for the visible layer at clicked location on the map. Solar Calculator provides the information about solar insolation, temperature, tilt angle, GHI, DNI, DHI, day length and sun path in tabular and graphical format for clicked location on the map. User can also download this information in PDF format. A multi-criteria interactive web-based solar site selection tool has been developed that integrates five parameters viz. (1) GHI, (2) land use \ land cover, (3) slope, (4) proximity to roads, and (5) proximity to power transmission lines, to identify suitable sites for harnessing solar energy.

**Tools and Charts**

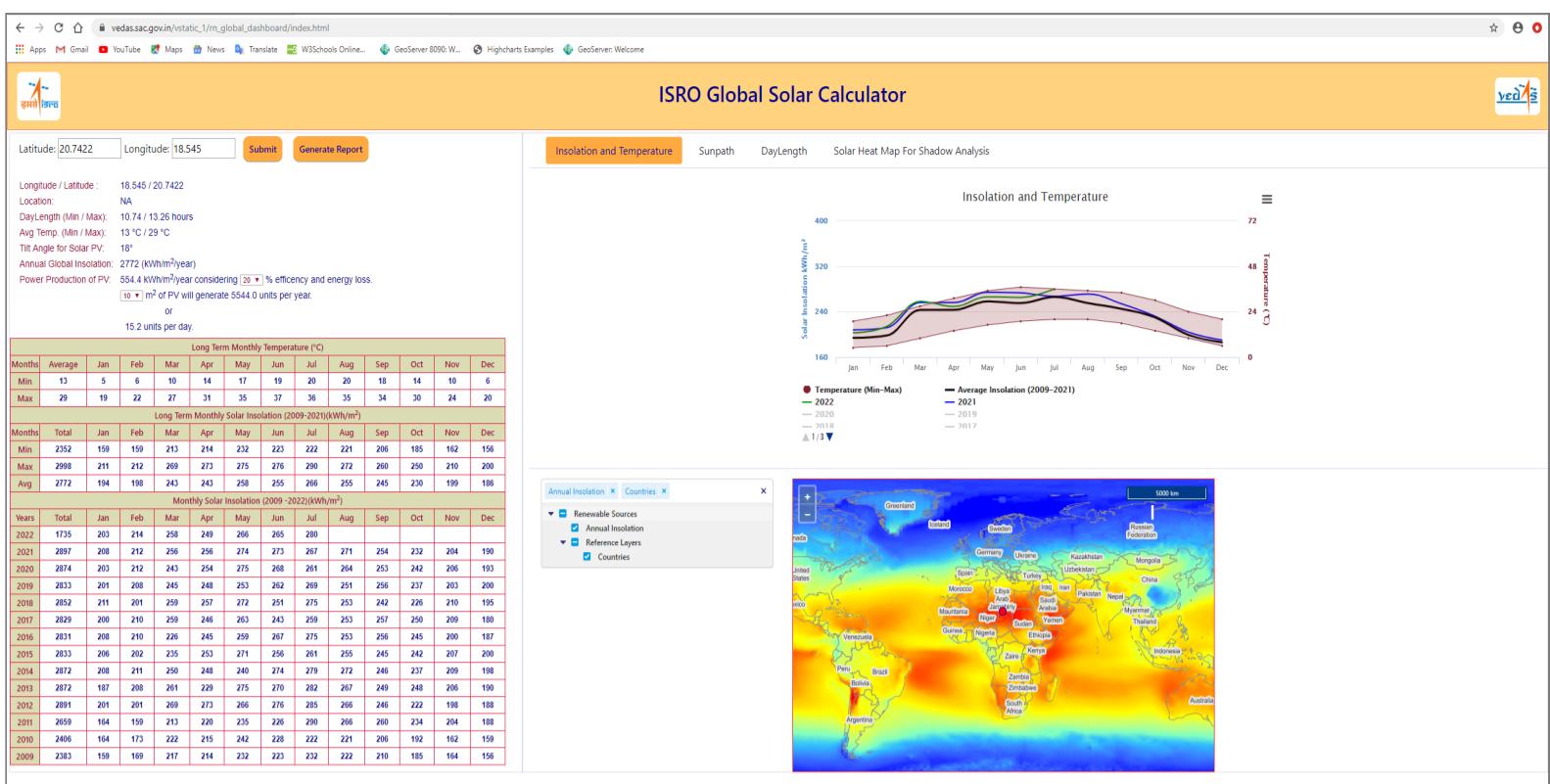
- **Feature Info:**

When user clicks on the map, the feature information is displayed for that layer at a clicked location.

**Long Term Monthly Insolation Average Profile**

- **Solar Calculator Dashboard:**

For any clicked location on map, Solar calculator provides information about long term monthly solar insolation and temperature (max/min/avg). It also include solar insolation and temperature long term profile for year over year comparison, sun path, optimum tilt angle for solar panels, day length and power production of PV. Map is also provided to show user selected location along with overlay layers for value addition.



### Solar Calculator Dashboard

Solar Calculator summary provides various Information like daylength min/max temperature, selected longitude/latitude, average temperature , tilt angle for Solar PV, Annual Global Insolation , Power Production of PV.

Latitude: 20.7422	Longitude: 18.545	Submit	Generate Report
<b>Longitude / Latitude :</b> 18.545 / 20.7422			
<b>Location:</b> Chad			
<b>DayLength (Min / Max):</b> 10.74 / 13.26 hours			
<b>Avg Temp. (Min / Max):</b> 13.0 °C / 29.0 °C			
<b>Tilt Angle for Solar PV:</b> 18°			
<b>Annual Global Insolation:</b> 2772 (kWh/m <sup>2</sup> /year)			
<b>Global Horizontal Irradiance (GHI):</b> 2406 (kWh/m <sup>2</sup> /year)			
<b>Direct Normal Irradiance (DNI):</b> 2391 (kWh/m <sup>2</sup> /year)			
<b>Diffused Horizontal Irradiance (DHI):</b> 711 (kWh/m <sup>2</sup> /year)			
<b>Power Production of PV:</b> 481.2 kWh/m <sup>2</sup> /year considering 20% efficiency and energy loss.			
10 m <sup>2</sup> of PV will generate 4811.7 units per year.			
or			
13.183 units per day.			

### Solar Calculator Summary

Solar Calculator table provides long term monthly average temperature , Long term as well as current monthly solar insolation (2009-2021).

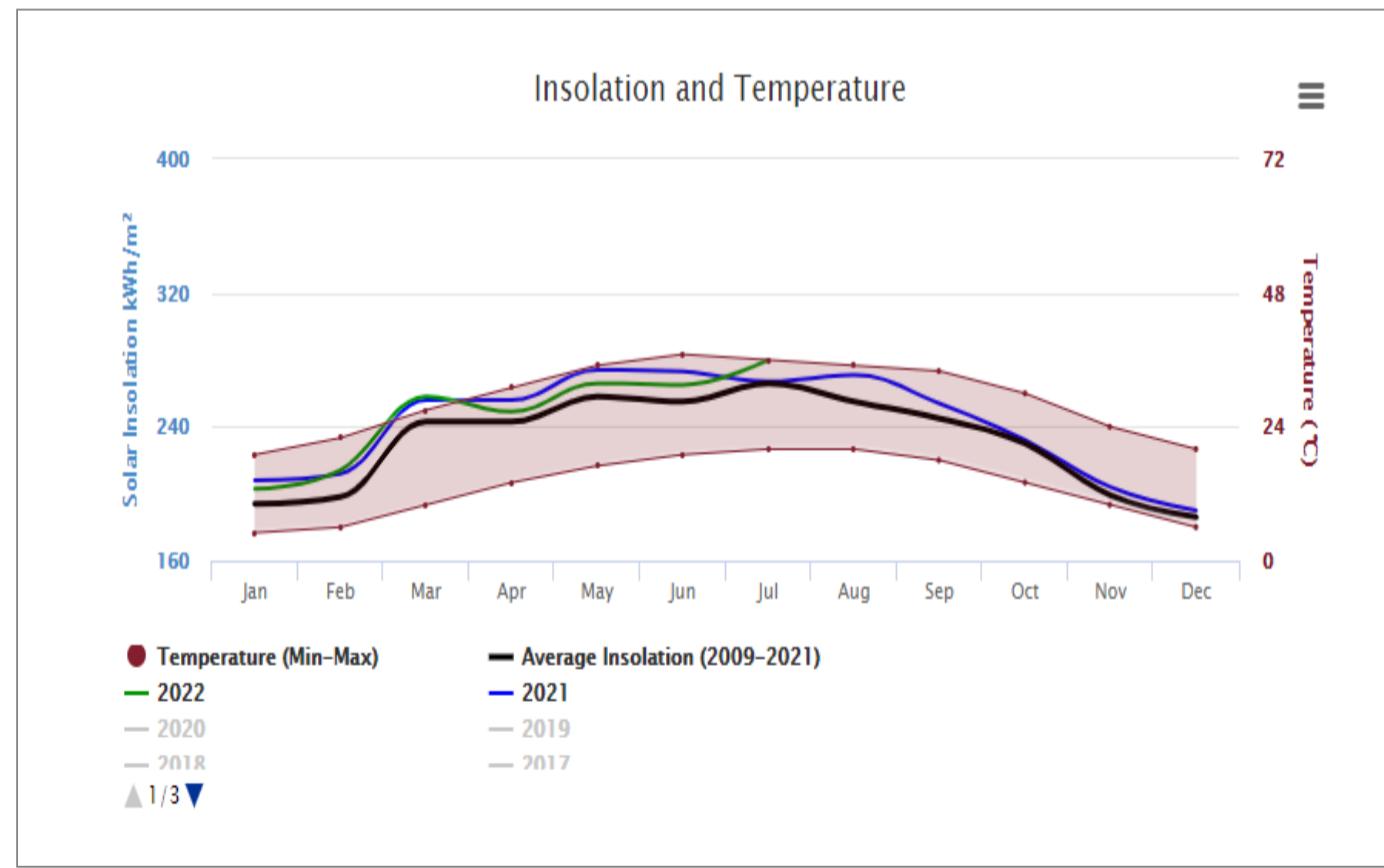
Long Term Monthly Temperature (°C)													
Months	Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	13	5	6	10	14	17	19	20	20	18	14	10	6
Max	29	19	22	27	31	35	37	36	35	34	30	24	20
Long Term Monthly Solar Insolation (2009-2021)(kWh/m <sup>2</sup> )													
Months	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	2352	159	159	213	214	232	223	222	221	206	185	162	156
Max	2998	211	212	269	273	275	276	290	272	260	250	210	200
Avg	2772	194	198	243	243	258	255	266	255	245	230	199	186
Monthly Solar Insolation (2009 -2022)(kWh/m <sup>2</sup> )													
Years	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	1735	203	214	258	249	266	265	280					
2021	2897	208	212	256	256	274	273	267	271	254	232	204	190
2020	2874	203	212	243	254	275	268	261	264	253	242	206	193
2019	2833	201	208	245	248	253	262	269	251	256	237	203	200
2018	2852	211	201	259	257	272	251	275	253	242	226	210	195
2017	2829	200	210	259	246	263	243	259	253	257	250	209	180
2016	2831	208	210	226	245	259	267	275	253	256	245	200	187
2015	2833	206	202	235	253	271	256	261	255	245	242	207	200
2014	2872	208	211	250	248	240	274	279	272	246	237	209	198
2013	2872	187	208	261	229	275	270	282	267	249	248	206	190
2012	2891	201	201	269	273	266	276	285	266	246	222	198	188
2011	2659	164	159	213	220	235	226	290	266	260	234	204	188
2010	2406	164	173	222	215	242	228	222	221	206	192	162	159
2009	2383	159	169	217	214	232	223	232	222	210	185	164	156

**Solar Calculator Table**

In the Chart Section, Solar Calculator provides Insolation and Temperature Profile, Sunpath, Daylength, Solar Heat Map for Shadow Analysis.

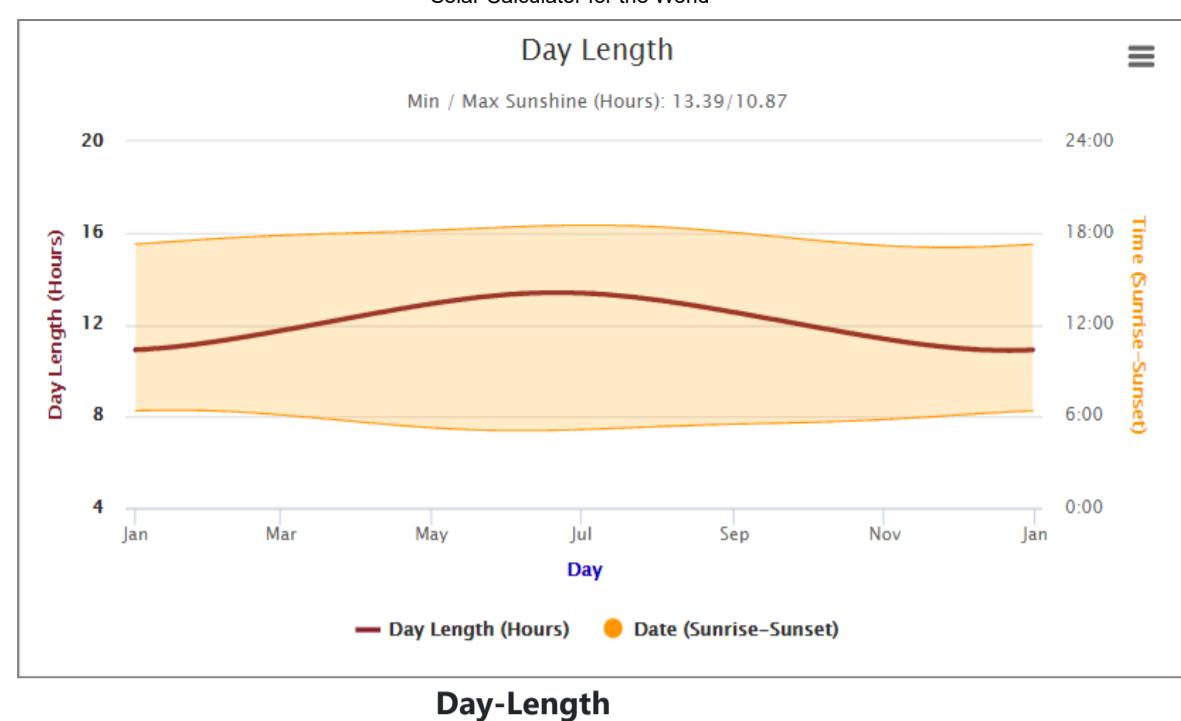
## Insolation and Temperature Profile

This chart provides 2009 onwards monthly solar insolation for year over year comparison and long term monthly average maximum/minimum temperature.

**Insolation and Temperature Chart**

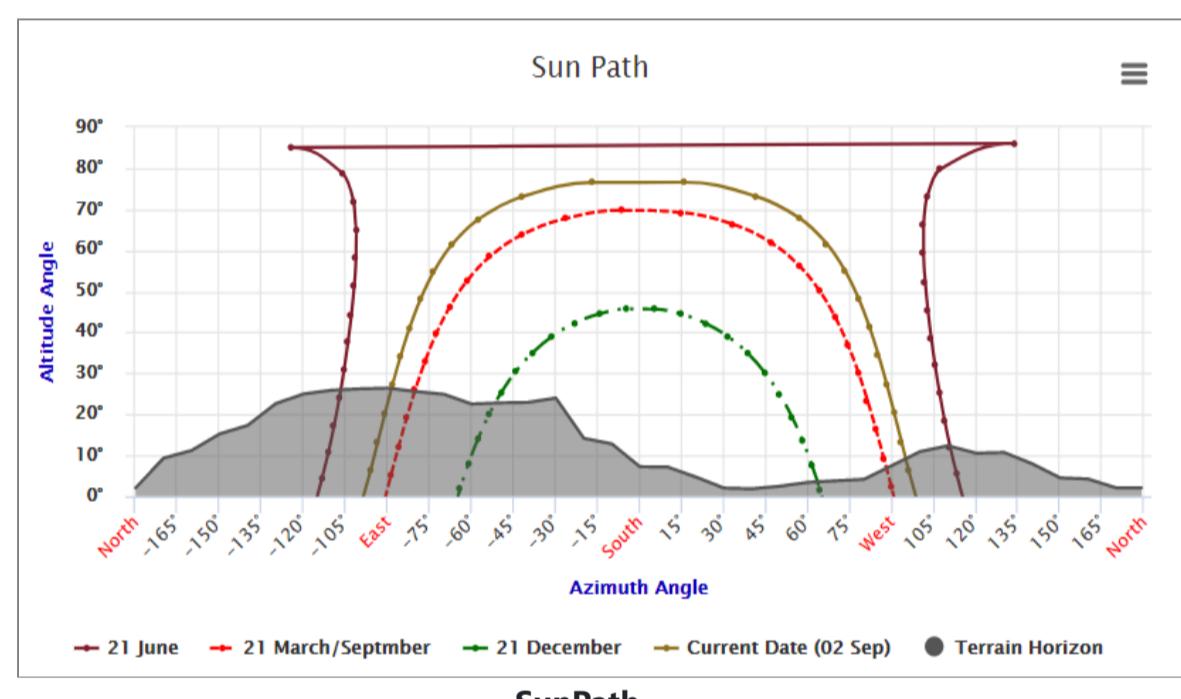
## Day-Length

It provides day length for a given latitude and day for the entire year.



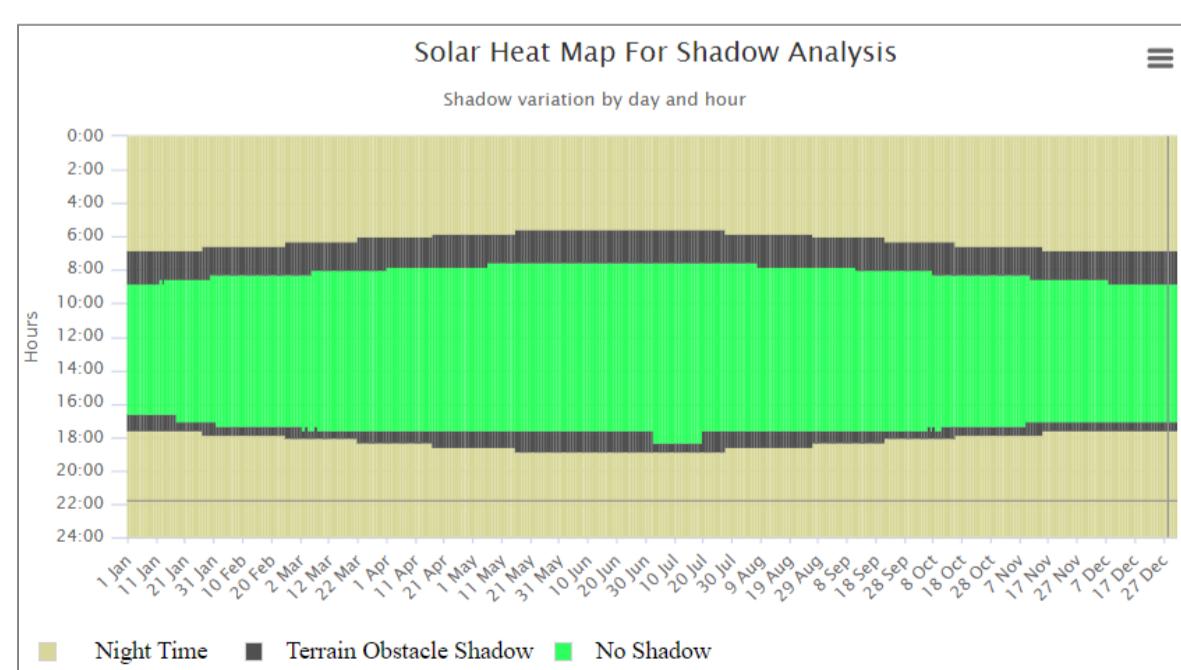
## SunPath

Sun's position in the sky for each location (latitude) on the earth at any time (GMT) of day, using Cartesian coordinates. Sunrise and sunset time is also calculated. 21 Jun Solstice - the longest day of the year 21 Dec Solstice - the smallest day of the year 21 Mar/Sep Equinox - day and night of equal length. Shadow of Sun due to terrain is also shown.



## Solar Heat Map for Shadow Analysis

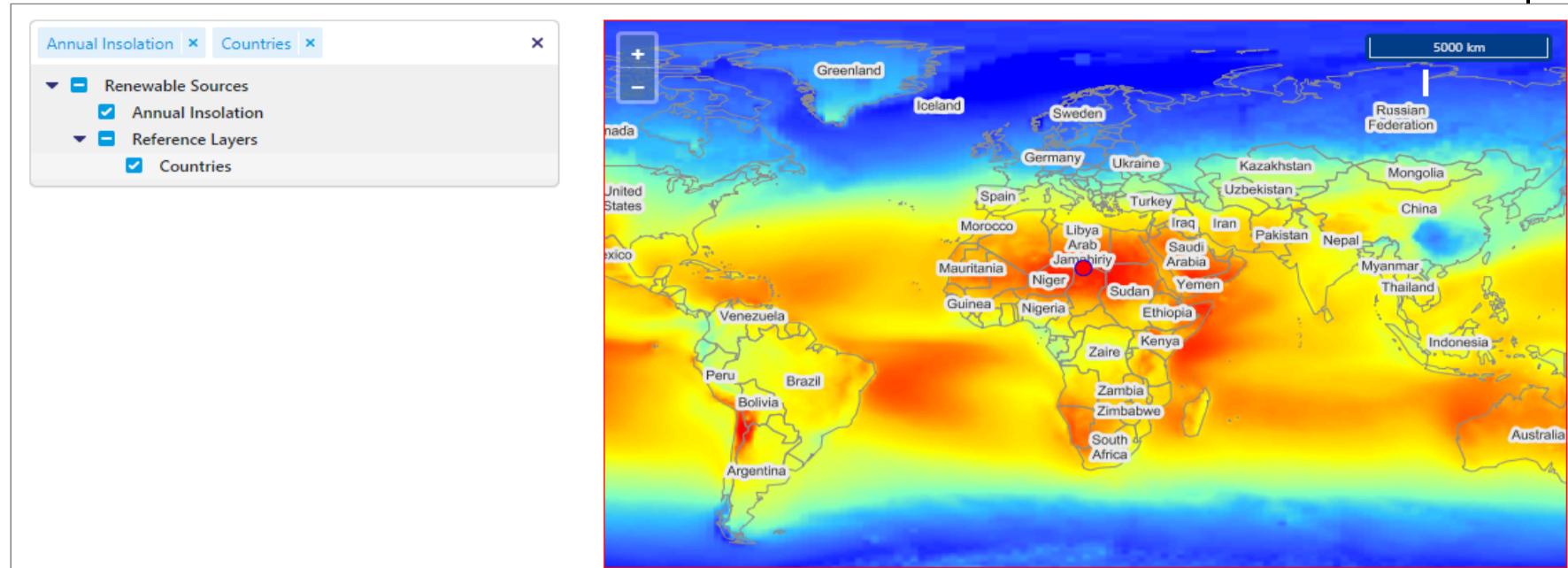
This Heat Map shows duration for which the solar energy will be available without any shadow due to terrain. Black Colour shows the shadowed time. Green colour shows the time during which solar energy is available. This is available during all days in the years. This is calculated using CARTOSAT Digital Elevation Model (DEM 30m) .



## Solar Heat Map for Shadow Analysis

## Location Map

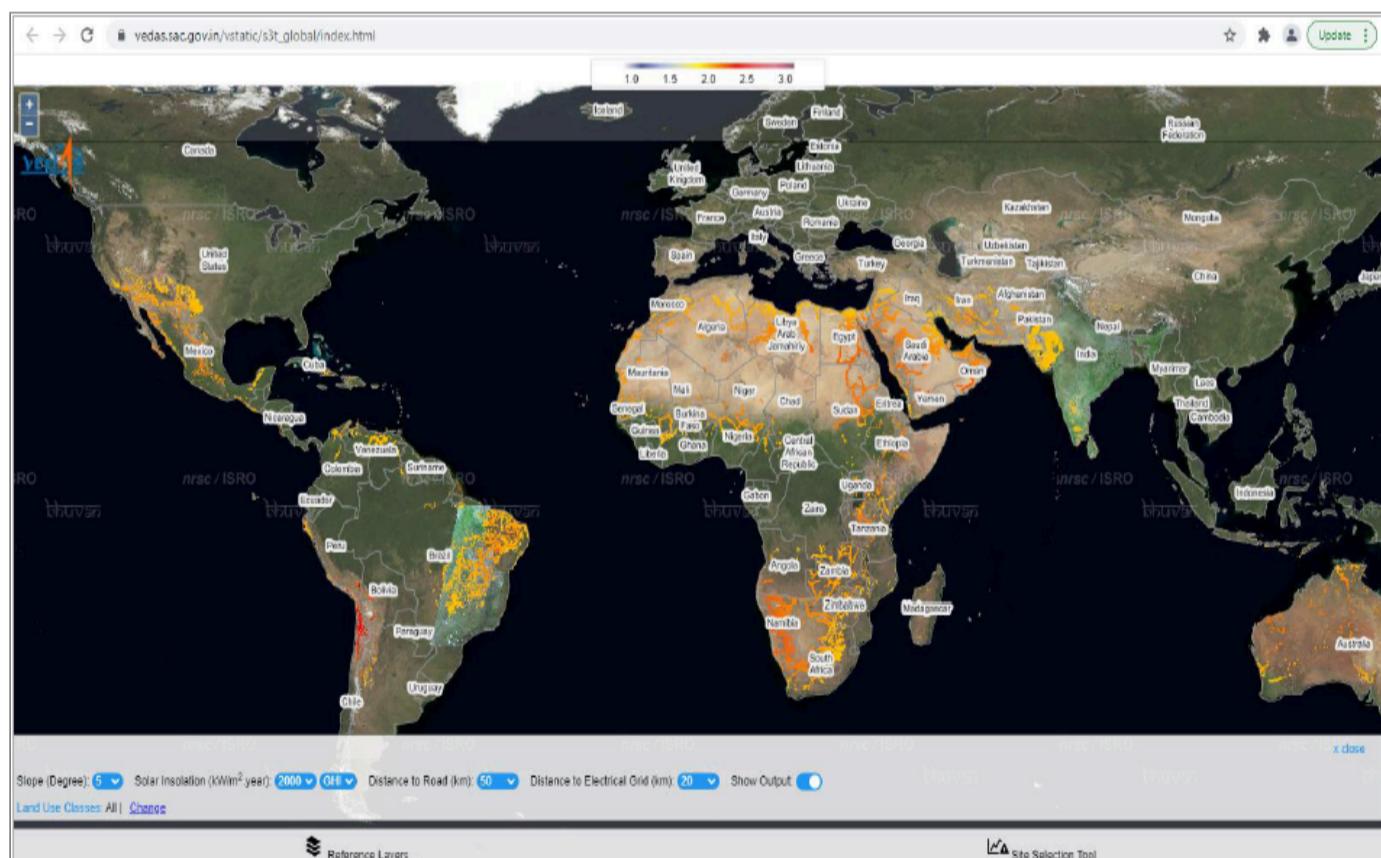
User selected location is shown on map along with administrative boundary and high resolution satellite imagery. Marker shows the location provided by user.



Location Map

## ○ Solar Site Selection Tool

A multi-criteria interactive web-based solar site selection tool has been developed that integrates five parameters to identify suitable sites for harnessing solar energy. These parameters include: (i) Solar Insolation (ii) Landuse (iii) Slope (iv) Distance from road (v) Distance from grid network. The system uses a custom built raster processing backend that utilizes in-memory techniques to give near real-time output based on input parameters.



Solar Site Selection Tool