A SATELLITE-DERIVED GLOBAL CLIMATOLOGICAL DATA SET FOR THE RENEWABLE ENERGY INDUSTRY

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Abstract

The Surface meteorology and Solar Energy (SSE) commercial outreach project of NASA's Earth Science Enterprise (ESE) Program Office distributes free of charge, via the internet, a global climatological data set of radiation and meteorology parameters useful to the renewable energy industry. The SSE web site http://eosweb.larc.nasa.gov/sse/ contains over 100 parameters accessible in tabular or graphical format. These are provided for the 10-year period from mid-1983 to mid 1993 on a 1° latitude by 1° longitude grid. A user accessing the site can select from these parameters and produce a table showing monthly average values, or they can generate an image displaying their selected parameter over a region of interest. This gives the user the ability to control how they would like to explore the data set. The SSE data set is derived from NASA satellite insolation and meteorological data, and is considered to be accurate for preliminary feasibility studies of renewable energy projects.

Since the SSE public release in 1996, people from financial institutions, universities, commercial businesses, and non-profit organizations have used the data set to help make decisions in the viability of renewable energy projects for a desired location. Organizations include The World Bank, International Financial Corporation, BP Amoco, Shell, and the United States Forest Service. The SSE data set is also linked to RETScreen®, a standardized and integrated renewable energy project analysis software tool developed by Natural Resources Canada's CANMET Energy Diversification Laboratory (CEDRL) which evaluates the viability of renewable energy technologies for any location of the globe.

The intent of this paper is to serve as an introduction to the SSE data set and web site, to show how a person may locate desired radiation and meteorology parameters, and to make users aware of what can be expected in the future from the SSE project.

1. INTRODUCTION

Renewable energy technologies such as the simple solar cooker to the more advanced photovoltaic and wind energy systems are helping to bring the power of renewable energy to people all over the world. These technologies help power buildings and homes in urban and rural environments, and provide practical solutions to those living in the remotest of areas. Critical to the application of these technologies is the need for information. Is an area prone to having a large number of cloudy days? What is the typical wind speed for an area in a given month? Industry professionals designing renewable energy systems can answer questions like these by using global solar radiation and meteorology data sets.

The Surface meteorology and Solar Energy (SSE) commercial outreach project of NASA's Earth Science Enterprise (ESE) provides the renewable energy industry with a resource to aide in the design of renewable energy technologies. This resource is a satellite-derived 10-year climatology of global insolation, cloud cover, temperature, relative humidity, and wind parameters, among many others. The data are provided on a 1-degree grid system and are available via the Internet at no cost to the user. The web site is an easy and intuitive tool for accessing data in graphical and tabular formats. It offers software applications, like Natural Resources Canada's (NRCan) CANMET Energy Diversification Laboratory's (CEDRL) RETScreen® a quick method for incorporating the SSE data into their software. RETScreen® is a renewable energy project analysis software

tool used to evaluate the annual energy production, costs, and financial viability of renewable energy technology projects.

1.1. Background

The SSE commercial outreach project released its first data set providing global coverage on a low-resolution 2.5-degree equal-area grid system in 1996. It was calculated from International Satellite Cloud Climatology Project (ISCCP) C-1 data and NASA Goddard Earth Observing System Version 1 (GEOS-1) meteorology. This release provided the renewable energy industry with 52 solar and meteorology parameters. At that time it was a 4-year climatology spanning March 1985 through December 1988. The web site was scientific in nature, less user-defined, and offered only a few methods for exploring the data. Access to the data was provided using a map showing nine pre-selected regions, an interface for entering the latitude and longitude of the location of interest, and only pre-made global maps of SSE parameters allowed the user the ability to view the data graphically.

Over the past 5 years, through continuing collaborations and discussions with industry and government users, the SSE data set is now at its third release and has become a tool applicable to many areas of the renewable energy industry. The data has been interpolated from the 2.5-degree grid system to a 1-degree equal angle grid system, thus providing improved accuracy. The algorithm used to generate the data set from satellite data now accounts for natural aerosol conditions over regions of the globe and uses the ISCCP D-1 data set, which has improved cloud information over snow/ice. The SSE web site provides access to well over 100 parameters spanning a 10-year climatology from July 1983 through June 1993. It also gives the user control in defining their own area of interest on a globe and the ability to view the data on a map or in tabular form.

1.2 SSE User Access And Success

The SSE web site was made public in 1996 and since than has seen a measurable increase in usage, as can be seen in Figure 1. The initial release of the web site and data products was scientific in nature. Collaborations with renewable energy industry professionals helped the SSE project reorganize the web site into a more user-friendly and understandable product. Release 2 marked these improvements, and usage of the web site increased. During the months following this release, NRCan announced the availability of the SSE data for use with their renewable energy pre-feasibility software RETScreen®. RETScreen® was designed to evaluate the viability of renewable energy technologies, and is now becoming the international standard for designers, government agencies, and lending institutions, with well over 17,000 registered users in 170 countries.

The third release of the SSE data product was made available in October 2000. It touted improved accuracy, higher resolution, an advanced user-designed graphics capability, and the addition of parameters for ground-source heat pump and biomass heating renewable energy technologies. Because of the improvements and additions it was expected to have wider appeal within the industry as well as to educational institutions. Since its release the SSE web site has registered more than 2225 users who have downloaded over 600,000 documents. These users include, The World Bank, BP Amoco, and Siemans Solar Industries, among many other individuals from industry, government, and educational institutions.

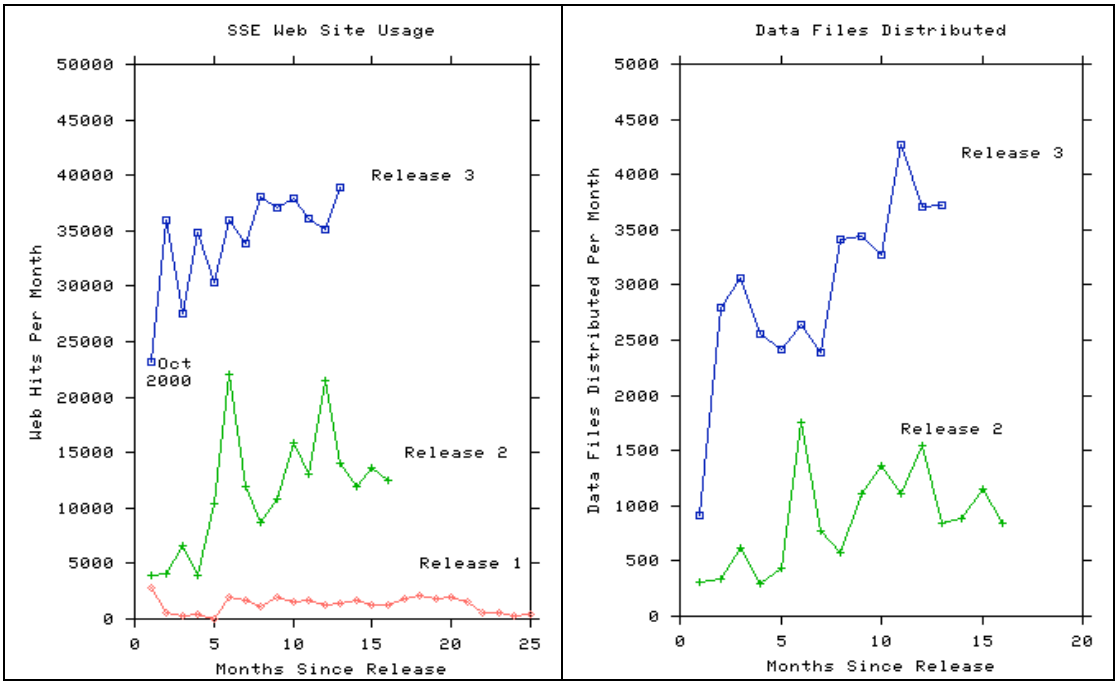

Figure 1 SSE web site statistics since 1996.

1.3 Accuracy of SSE Data Set

Accuracy of the SSE data set was determined using comparisons to ground measurement data sets. Historical ground measurements were obtained from NRCan's CANMET Energy Diversification Research Laboratory (CEDRL) and the National Renewable Energy Laboratory (NREL). The 30-year average RETScreen Ground Monitoring Stations Weather Database ("RETScreen") from CEDRL contains temperature, wind, humidity, and insolation data from over 1000 sites. The RETScreen database is available from the RETScreen Website (http://retscreen.gc.ca). NREL distributes the World Radiation Data Center (WRDC) ground measurements of insolation from 1195 sites for the period from 1964 through 1993 from their web site (http://wrdc-mgo.nrel.gov/). All ground stations were not operating for every year in either data set. When more than one ground measurement station was located in a grid cell, the ground measurements were averaged for comparison to the SSE data.

It is generally considered measured data are more accurate than satellite-derived values. Unfortunately, measurement uncertainties are not precisely known for either ground measurement data set. For this reason, SSE differences from ground measurements are considered as estimates of uncertainty. It should be noted that smoke and pollution in the atmosphere scatters and absorbs insolation and will decrease the amount reaching the Earth's surface. The calculation of the SSE data accounts for typical regional pollution and smoke; however, atypical events are not accounted for and may cause distortions in accuracy. Thus during these events the SSE data may be higher than ground measurement data.

Following usual industry standards, estimated uncertainty is assumed as the Root-Mean-Square (RMS) difference when large sample sizes exist and statistical correlation has been performed. Estimated uncertainty is the average of the absolute values of each error when sample sizes are smaller. Both methods give similar magnitudes of error according to Statistics by Freedman, Pisani, Purves, and Adhikari (New York: W.W. Norton & Company, 1991). It is emphasized that larger values of uncertainty can occur in actual practice, however, they are not frequent.

Both NASA and CEDRL teams performed comparisons. Parameters were compared on a global basis and at 100 to 200 sites in 7 continental regions that are considered typical locations for future renewable energy systems. A summary of estimated uncertainty is shown in table 1.

Table 1. SSE Estimated Uncertainties

Parameter	Global sites WRDC	Global sites RETScreen	Renewable sites RETScreen
Solar Insolation (kWh/m^2/day)	14.2%	13.0%	
Near–Surface Air Temperature (K) (10 meter altitude)		< 243 K = 3.2% > 263 K = 1.1% linear variation between 243 K and 263 K	1.2%
Heating Design Temperature (K)			1.3%
Cooling Design Temperature (K)			1.4%
Summer mean daily design range (K)			0.9%
Heating degree–days below 18° C (degree–days)			14.6%
Relative Humidity (%)		15.3%	9.7%
Surface Air Pressure (kPa)		3.6%	2.4%
Wind Speed (m/s) (10 meter altitude)		1.9 m/s	1.4 m/s

1.4 Description of SSE Web site

The SSE project makes available over 100 global radiation and meteorology parameters. These include parameters useful to solar cooker developers like, solar insolation and clear sky days. Developers of solar thermal systems may find the data set useful with additional parameters like insolation and clear sky clearness indices. Included are parameters for wind energy systems like, wind speed and direction. The SSE project also provides data at 3 hourly intervals, minimums and maximums, and provides insolation during El Nino and La Nino events over the 10-year data period.

The SSE web site has a user-friendly interface for locating data, graphics, and supporting information. All choices are plainly laid out on the SSE homepage, and the user can go immediately to data retrieval, or if desired, view supporting information about the web site and data set.

To retrieve SSE data a user would select the Meteorology and Solar Energy link. Options are then made available for retrieving data in either tabular or graphical form. To view data in tabular form the user can either click on a desired location by using an interactive globe, or they can simply enter in the latitude and longitude of the location of interest. Once the location is entered choices can be made as to what parameter to view. An example SSE data table is shown in table 2.

Table 2. SSE Data Table Example

Insolation on horizontal surface (kWh/m^2/day)

Lat -34 Lon 138	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 Year Average	7.21	6.62	5.35	4.03	2.77	2.38	2.61	3.32	4.58	5.78	6.64	6.83

The SSE web site also offers an interactive method for retrieving color graphics of user-defined areas displaying SSE data. By selecting the Global/Regional Plots link the user is shown a map of the globe. Using the mouse the user defines two corners of a rectangular region to produce an area of the globe they would like to view. Scrolling down the window a selection of month and data parameters can be made. The smallest region that can be defined is 6 by 6 degrees. Clicking the submit button produces a plot of the desired region and parameter. An example is shown in Figure 2. By using their browser the user can then generate an image of their plot.

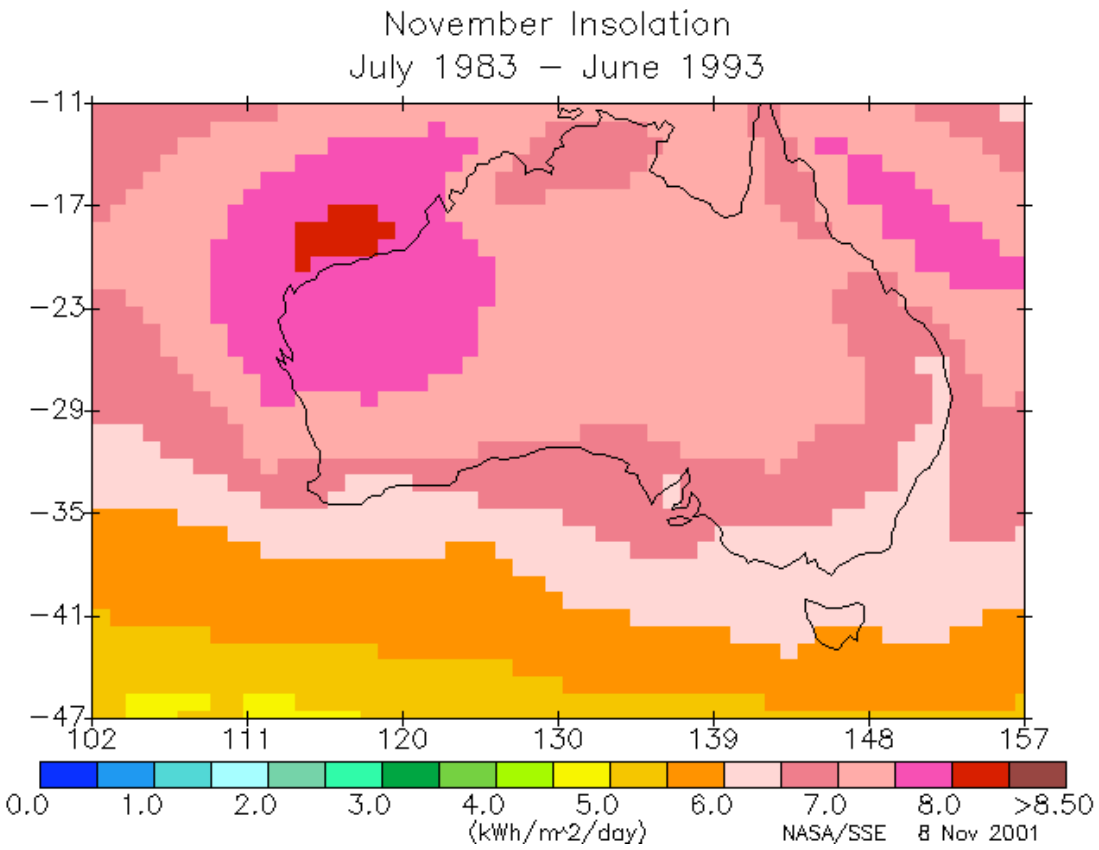

Figure 2 Ten-Year Monthly Average Insolation For November.

1.5 The Future Of The SSE

The SSE data has been limited to a 10-year data period. Requests have been made for more recent data at higher spatial resolution and additional parameters. Data from such projects as the Global Energy and Water Cycle Experiment, Clouds and Earth's Radiant Energy System, and Goddard Earth Observing System Version 3 will be included in the web site after the respective teams make their data available for reprocessing for commercial applications.

The needs of industries such as architecture can be met with an improved data set. In the U.S., buildings account for 62% of electricity use, 36% of total energy consumption, 37% of ozone depletion, and 30% of greenhouse gas emissions. The architectural industry has shown it is possible to design new buildings that require 50% less energy for the same construction costs. To help architects meet lower energy design parameters, the SSE is working to provide this industry with the necessary global solar and meteorology data.

There are other fields/industries that may benefit from NASA ESE surface solar and meteorology data, such as Environment and Human Health, Hydrology, Precision Agriculture, and Urban Climatology. Preliminary contacts indicate each area has good possibilities for future ESE applications.

Software applications, such as Natural Resource Canada CANMET Energy Diversification Research Laboratory's RETScreen®, use SSE data for direct insertion into their software tools. The SSE recently collaborated with the Renewable Energy Policy Project-Center for Renewable Energy and Sustainable Technologies (REPP-CREST) organization. REPP-CREST is an organization delivering analysis, information and strategies to facilitate the use of renewable technologies all over the world. Their software application, called SolarSizer, is a professional tool used for designing photovoltaic systems, and makes direct use of SSE insolation data, when necessary, by inserting it directly from the SSE web site. Based on initial contacts with Orion Energy Corporation of Frederick, MD, USA they are interested in using the SSE data for use in their software application called NSol. Orion Energy Corp. is a business that designs and manufacture integrated power systems like PV standalone, PV-generator hybrids, and their own line of microprocessor controllers. NSol is a tool used by sales and systems engineers to size renewable energy applications. The SSE hopes to

provide data for additional renewable energy assessment and design software that is either in use or in development.

To stay up-to-date with the needs of the industry and its professionals, the SSE project encourages feedback on data parameters that may be useful, and seeks to partner with designers of renewable energy design tools.

1.6 Conclusions

The SSE commercial outreach project of the NASA ESE program continues its mission to provide quality satellite-derived climatological global solar and meteorology data to the renewable energy industry. To do this it provides free access to its data via the Internet by maintaining a user-friendly web interface. The project is driven by the needs of the renewable energy industry and its professionals. Through collaborations and discussions with its users the SSE project has provided an increasing number of parameters relevant to the industry and provides assistance to those who wish to use the SSE data in renewable energy design tools.

2.0 ACKNOWLEDGEMENTS

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