

NASA SURFACE INSOLATION AND METEOROLOGY DATA FOR RENEWABLE ENERGY USE

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ABSTRACT

This paper reviews and demonstrates a NASA surface insolation and meteorology data set that is now available free of cost through a web site and optional FTP downloads. The data set is commercially oriented and was developed in cooperation with both the DOE National Renewable Energy Laboratory and several small renewable energy businesses. The existing data set contains parameters for sizing and pointing of solar panels, sizing battery and other backup systems, and the sizing of surplus product storage facilities for regions over the globe. Surface temperature, cloud, and solar geometry information are also available. Activities at the NASA Langley Research Center are underway to enhance the data set. Future releases will include web page modifications, parameter additions, and spatial and temporal resolution improvements. This paper will discuss these releases, and review accuracies and limitations of the satellite products on a region by region basis.

1. INTRODUCTION

In 1995, the NASA Langley Research Center collaborated with the National Renewable Energy Laboratory to define a satellite-derived surface solar energy data set useful to the renewable energy industry. From this collaboration, a 4-year climatology (March 1985 through December 1988) was derived from the insolation, cloud, and meteorology parameters of the World Climate Research Program (WCRP) Surface Radiation Budget (SRB) Project [1]. This Surface Solar Energy (SSE) data set is available on the web at: http://eosweb.larc.nasa.gov/DATDOCS/Surface_Solar_Energy.html.

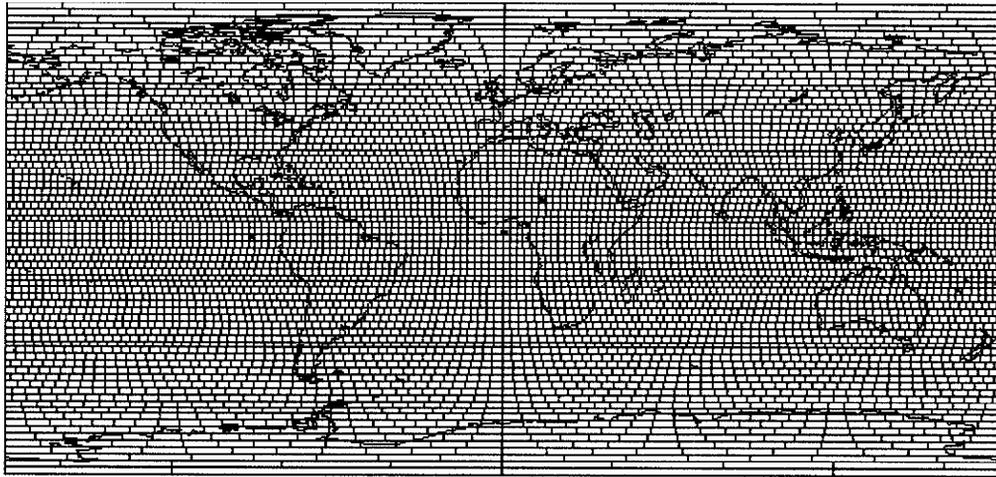


Fig. 1: 2.5 degree equal-area grid system.

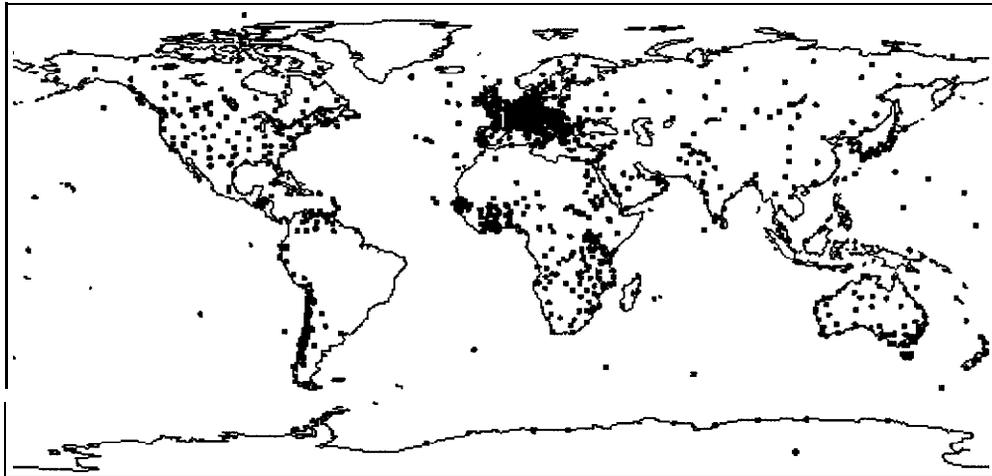


Fig. 2: Ground site data of the World Radiation Data Center.

The SSE data set (Release 1 & 2) provides worldwide coverage on a 2.5 degree equal-area grid system. This is a low resolution grid; a cell is approximately 280 by 280 km, as seen in Figure 1. Although the grid system is too large to resolve micro climates; the SSE data set can fill the gap where site data does not exist and interpolation is impossible. Figure 2 illustrates all of the ground sites that are currently available from the World Radiation Data Center (WRDC) for the years 1974 through 1993. Reasonable global coverage is provided (for Europe in particular); however, most sites are not in continual operation during the 20-year period. Also, large data gaps exist over several regions of the world including South America, China, and Saudi Arabia. Since it is not financially or technically feasible to deploy instruments worldwide to determine the availability of the solar resource, satellite-derived estimates become a viable alternative. As long as the limitations of satellite data are understood, the solar resource can be assessed with confidence.

2. ACCURACY OF THE SSE DATA SET

Comparisons with monthly data from approximately 140 quality ground sites suggest that satellite-derived values are generally within 10 percent of ground site measurements for most regions of the world. However, there are several notable exceptions:

1. Values may be as much as 40 percent high in regions of large biomass burning in months when total accumulated precipitation is below 24mm. There must be a burnable surface, of course. These areas are mostly in Africa and South America; however, other regions may also be affected if:
 - a. There is a very heavy wood, or coal, burning economy.
 - b. An extreme drought occurs as a result of El Nino or La Nina event and an unusual amount of fires occur.
 - c. There is a very large amount of industrial pollution.

The error is caused by the fact that the WCRP/SRB algorithms did not account for high levels of smoke or industrial pollution. The full extent of biomass burning, and its effect on surface solar energy, is not yet known by the scientific community. Studies at NASA Langley are being conducted to understand this phenomenon [2].

2. Satellite-derived values may be erratic for sites situated near coastlines. Satellite radiances observed in regions with sharp discontinuities in either surface albedo or temperature are difficult to interpret. Therefore, satellite-derived cloud fraction cannot be reliably computed and may be in error when there is an unusual change in clouds in the immediate vicinity of a coastline, within part of a cell. In a practical sense, the problem is most acute in cells that have a significant change in topography adjacent to the coast.
3. Values may be as much as 40 percent low over bare snow and ice surfaces because the satellite channels do not distinguish clouds from bare snow or ice. This is a result of the fact that the brightness of the radiances over snow or ice surfaces, and clouds, are similar. Comparisons with ground site data suggest that errors are usually within 10 percent for those snow regions with significant vegetation or topography to cause dark contrast or shadows.

Estimates of uncertainty for insolation values in cells that contain flat to low mountain topography are presented in Table 1. A positive value indicates that the satellite-derived values are usually higher in a region than ground site measurements. The reverse is true for negative values.

3. DESCRIPTION OF RELEASE 2 SSE

Release 2 of the web site was made available to the public by June 1999. In response to suggestions made by business owners in the renewable energy industry the new web site is configured to be more industry-oriented. Resource data is segregated by most probable application with simple definitions provided for each parameter. New parameters have been added to assist in the design of battery storage and agricultural systems. These parameters provide information concerning deficits and surpluses of solar insolation resource data.

Table 2 shows the minimum available insolation as a percent of the average of values over the same period, for an area encompassing part of the state of Georgia. These parameters are based on minimum consecutive-day insolation over various numbers of days within the month. The low values are most likely the result of consecutive days of unusually cloudy skies. Values are based on sequential day analysis of the satellite-derived results. Minimum worst case consecutive day values may come from different years for different number of days. As you can see from the table, 45 percent of the expected insolation is available for the worst case, 14 -day period during the month of January.

New resource maps have been created in the equal area grid system. Now, regional maps are available, in addition to the original global maps that were provided in Release 1. Figure 3 shows the total horizontal surface down irradiance in kwhm^2/day available for Africa during the month of October. Maximum values occur in the Sahel region and the southern part of Africa. **These** areas are designated as savannas based on the International Geosphere Biosphere Programme (IGBP).

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TABLE 1: REGIONAL UNCERTAINTY ESTIMATES OF INSOLATION, PERCENT.

REGION	JANUARY	APRIL	JULY	OCTOBER
Eastern & Western Europe	10 (+)	05 (+)	10 (+)	10 (+)
Central Asia	15 (-)	10 (-)	10 (-)	10 (-)
Central North America	05	10	10	10
Central Africa	30 (+)	15 (+)	40 (+)	10 (+)
Aswan Desert	08 (-)	08 (-)	08 (-)	08 (-)
Congo Rainforest	30 (+)	08 (-)	20 (+)	10
Amazon Rainforest	20 (+)	20 (+)	20 (+)	20 (+)
Guiana Highlands of South America	30	20 (+)	25 (+)	10 (+)
Koumac, New Caledonia	10	10 (-)	10 (-)	05 (-)
Fiji	15 (+)	15 (+)	15 (+)	15 (+)
Kwajalein	05 (-)	05 (-)	05 (-)	05 (-)
Bermuda	05 (-)	05 (-)	05 (-)	05 (-)
West Pacific Asia Coastal Cities	08	35 (+)	25 (+)	10 (+)
South Pole	20 (-)	N/A	N/A	N/A

TABLE 2: MINIMUM AVAILABLE INSOLATION AS PERCENT OF AVERAGE VALUES OVER THE SAME TIME PERIOD, PERCENT.

CELL 5042	JANUARY	APRIL	JULY	OCTOBER
Minimum over 1 day	5.14	25.6	34.0	17.7
Minimum over 3 days	14.9	31.4	41.9	20.8
Minimum over 7 days	29.8	41.9	56.7	33.7
Minimum over 14 days	45.1	55.7	73.1	53.5
Minimum over 21 days	65.8	72.8	82.6	66.1
Monthly Minimum	93.5	88.1	93.6	83.2

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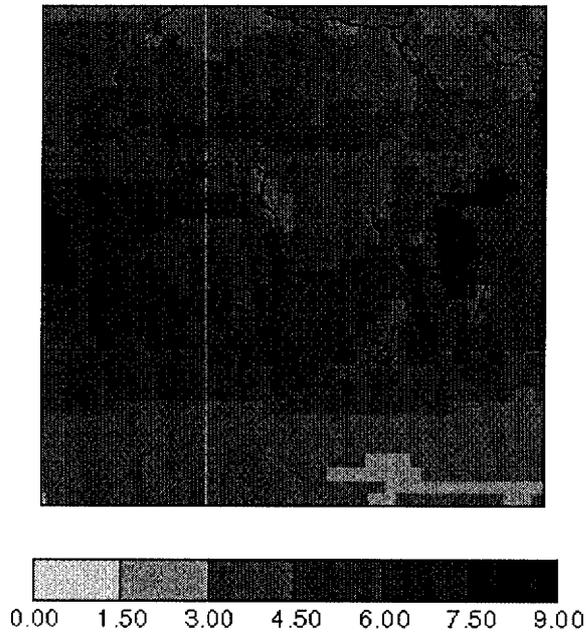


Fig. 3: Total horizontal surface down h-radiance for October 1985 - 1988, kwhm^2/day .

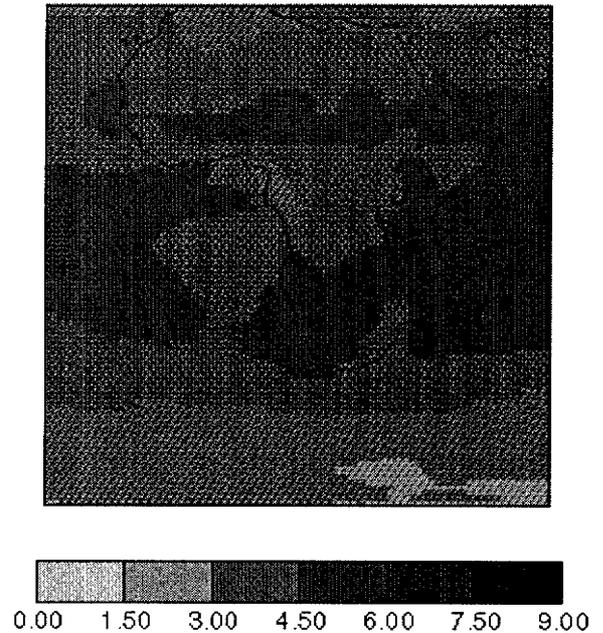


Fig 4: Interpolated total horizontal surface down h-radiance for October 1985 - 1988, kwhm^2/day .

4. DESCRIPTION OF RELEASE 3 SSE

Release 3 of the web site is planned for the winter of 1999-2000. This release will be created in response to requests from the renewable energy industry, the agribusiness community, the architectural community, and the hydrology community. The spatial resolution of the data set will be increased from a 2.5 degree equal area grid system to a 1 degree equal angle grid system through interpolation. Figure 4 shows our preliminary results on interpolating to a higher resolution grid. The data is identical to Figure 3. It is apparent that the edges of the grid boxes are smoothed however, maximums and minimums are lost in the interpolation. The maximum in the country of Mauritania has disappeared, as well as the minimum north of Lake Malawi in Southern Africa. Most interesting is the fact that RMS errors of ground sites are reduced because grid-cell edge discontinuities are smoothed.

It is planned that the duration of the climatology will also be expanded from four to eight years. Along with these modifications, additional surface meteorology (both satellite and ground site), and solar resource parameters will be included. In particular, information on winds, precipitation, air temperature, skin temperature, and surface reflectance will be included. Figures 5 and 6 show examples of wind velocity and frequency of occurrence over the globe for the month of October, 1986. We are now working with potential industry and government users of the data to define the parameters that are most needed.

5. SUMMARY

The SSE data set was created through the cooperation of the NASA Langley Research Center and the National Renewable Energy Laboratory to provide a global climatology of scientific information useful to the renewable energy and agricultural industries. This satellite-derived data set of solar resource and meteorological parameters is available on the world wide web. Research comparing the SSE data set results to ground site measurements is ongoing so that the limitations of the data set are understood and improvements can be implemented in future releases.

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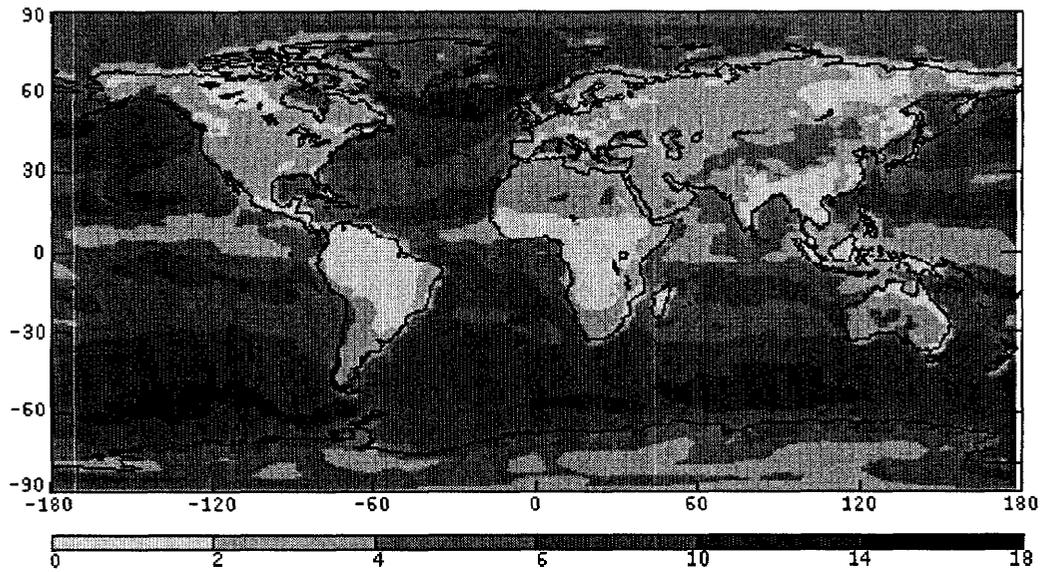


Fig. 5: 10 meter average wind speed for October 1986, m/sec.

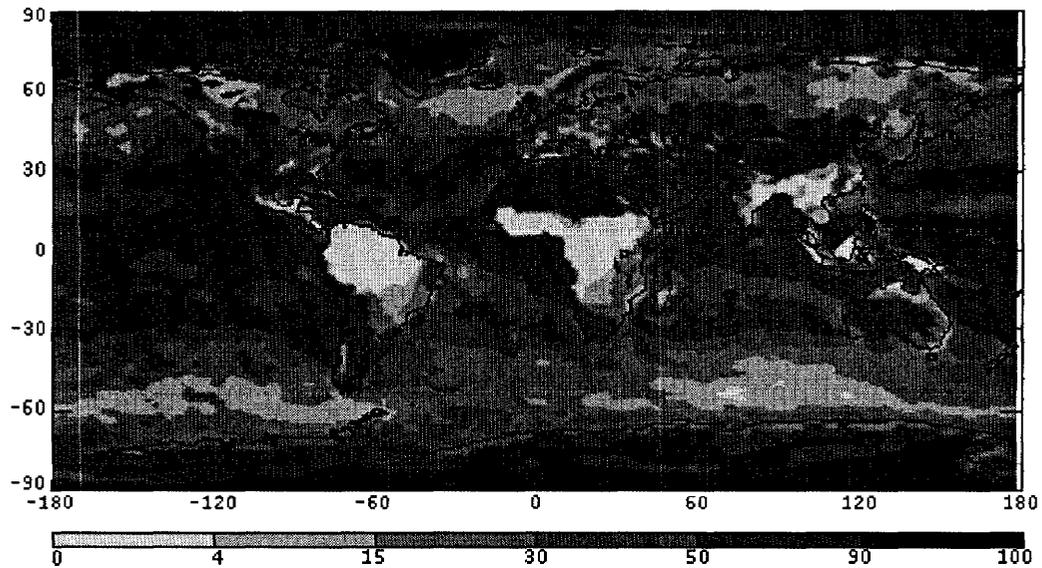


Fig. 6: Frequency of 10 meter wind speeds between 3 and 6 m/sec, percent of time.
Note: Frequencies of other speed ranges are also calculated.

6. REFERENCES

- (1) Whitlock, C.H., T.P. Charlock, W.F. Staylor, R.T. Pinker, I. Laszlo, A. Ohmura, H. Gilgen, T. Konzelmann, R.C. DiPasquale, C.D. Moats, S.R. LeCroy and N.A. Ritchey, First Global WCRP Surface Radiation Budget Data Set: *Bulletin American Meteorology Societv*, 7 1,905 - 922, 1995.
- (2) Whitlock, C.H., D.R. Cahoon, T. Konzelmann, Biomass Burning Effects on Satellite Estimates of Shortwave Surface Radiation in Africa, *Biomass Burning and Global Change*, 1995.