# AN ADVANCED WEB SITE OF SATELLITE-DERIVED, SOLAR RESOURCE DATA FOR THE GLOBE

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## ABSTRACT

A joint NASA/DOE web site of satellite-derived solar resource data has been developed for the renewable energy and agricultural industries. The web site provides easily accessible scientific data, for use in remote areas of the world, where no ground site data currently exist or are questionable. Release 1 was formally introduced at the Solar 98 Conference in Albuquerque, New Mexico. This paper discusses two future releases that include web page modifications, solar resource parameter additions, and spatial and temporal resolution improvements.

## 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

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 Fig. 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. Fig. 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.

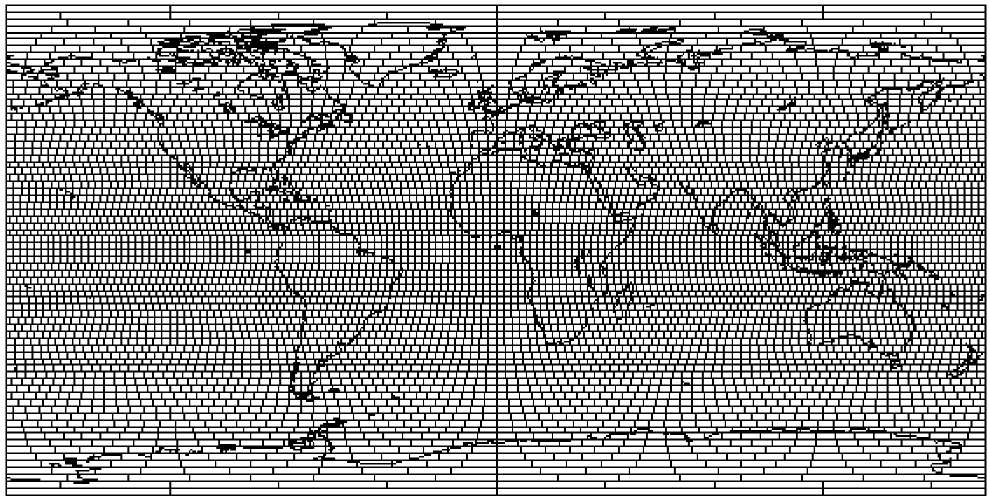

Fig. 1: 2.5 degree equal-area grid system.

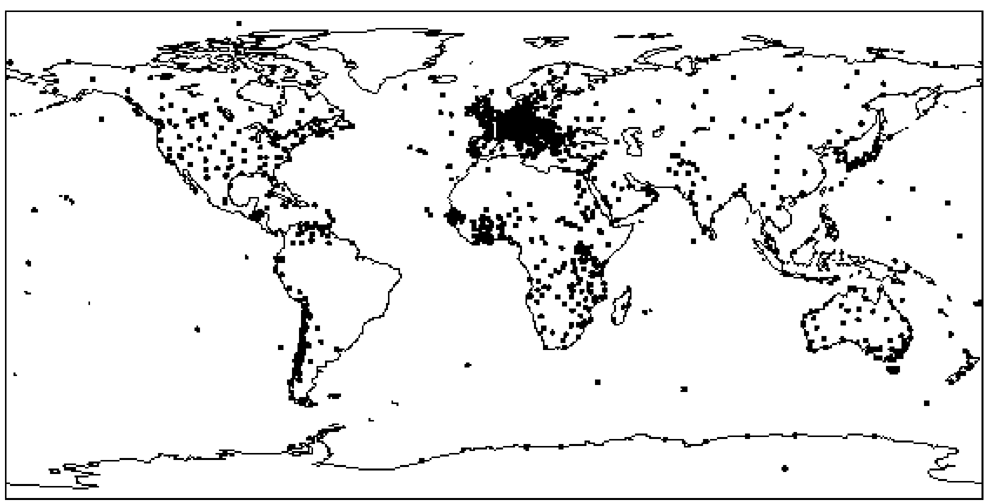

Fig. 2: Ground site data of the World Radiation Data Center.

## 2. ACCURACY OF THE SSE DATA SET

### 2.1 Regional Accuracy

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.

## 2.2 Surface Type Accuracy

In addition to the regional study, a comparison was performed on a global scale for different surface types. The data set used in this comparison consisted of 279 WRDC ground sites. These sites were quality checked using the flags provided by the WRDC. However, the sites were not screened for topographical effects, such as shading that occurs on instruments located in mountainous regions when the solar elevations are low. Bias and RMS percent values were calculated for January and July. The third column in each month represents the number of values (satellite – site) that were used in the statistical calculations. When multiple sites were located within a cell, the site measurements were averaged. The largest errors occur for the surface types designated as Rain Forest and Coastal.

TABLE 1: REGIONAL UNCERTAINTY ESTIMATES OF INSOLATION, PERCENT.

| REGION | JAN | APR | JUL | OCT |
|---|---|---|---|---|
| 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 (-) | NA | NA | NA |

TABLE 2: BIAS AND RMS BY SURFACE TYPE, PERCENT.

| SURFACE TYPE | JANUARY | | | JULY | | |
|---|---|---|---|---|---|---|
| | Bias | RMS | # | Bias | RMS | # |
| Coastal | 10 | 18 | 94 | 11 | 14 | 79 |
| Rain Forest | 20 | 23 | 10 | 16 | 17 | 05 |
| Deciduous Forest | 06 | 19 | 57 | 03 | 07 | 52 |
| Evergreen Forest | 02 | 19 | 28 | 06 | 11 | 27 |
| Grassland | 01 | 10 | 28 | 07 | 16 | 21 |
| Shrubland | 01 | 6 | 12 | 02 | 08 | 11 |

## 3. DESCRIPTION OF RELEASE 2 SSE

Release 2 of the web site will be 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 3 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.

TABLE 3: MINIMUM AVAILABLE INSOLATION AS PERCENT OF AVERAGE VALUES OVER THE SAME TIME PERIOD, PERCENT.

| **CELL 5042** | **JAN** | **APR** | **JUL** | **OCT** |
|---|---|---|---|---|
| Minimum/1 day | 5.14 | 25.6 | 34.0 | 17.7 |
| Minimum/3 days | 14.9 | 31.4 | 41.9 | 20.8 |
| Minimum/7 days | 29.8 | 41.9 | 56.7 | 33.7 |
| Minimum/14 days | 45.1 | 55.7 | 73.1 | 53.5 |
| Minimum/21 days | 65.8 | 72.8 | 82.6 | 66.1 |
| Monthly Minimum | 93.5 | 88.1 | 93.6 | 83.2 |

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. Fig. 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 the International Geosphere Biosphere Programme (IGBP).

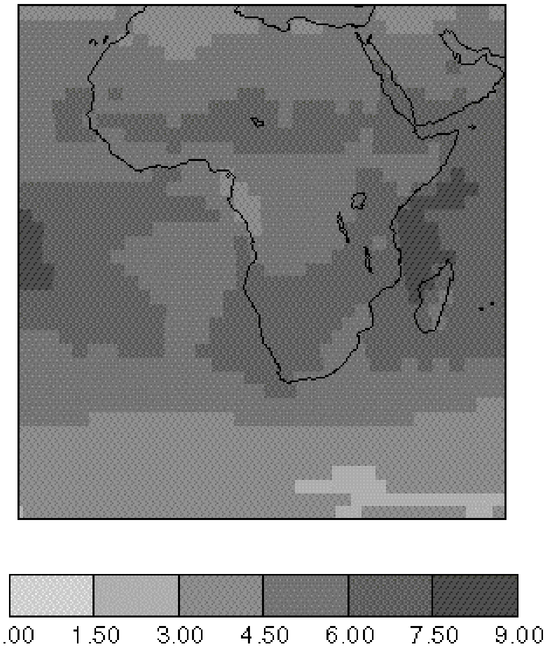


Fig 3: Total horizontal surface down irradiance for October 1985 – 1988, kwhm$^2$/day.

## 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, 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. Fig. 4 shows our preliminary results on interpolating to the higher resolution grid. The data is identical to Fig. 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.

The duration of the climatology will also be expanded from four years to eight years. Along with these modifications, additional surface meteorology and solar resource parameters will be included. In particular, information on winds, precipitation, air temperature, skin temperature, and surface reflectance will be included. We are now working with potential industry and government users of the data to define the parameters that are most needed.

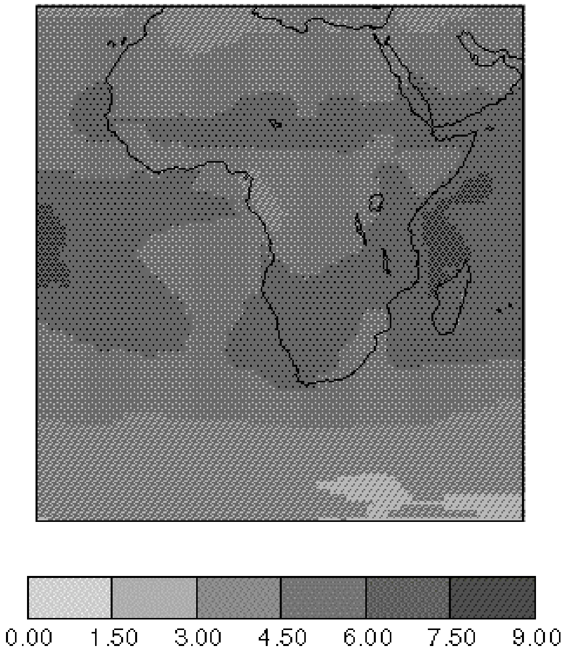


Fig 4: Interpolated total horizontal surface down irradiance for October 1985 – 1988, kwhm$^2$/day.

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.

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 Society, 71, 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