# PARAMETERS FOR DESIGNING BACK-UP EQUIPMENT FOR SOLAR ENERGY SYSTEMS

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## ABSTRACT

Solar energy systems that are not connected to an electrical grid system usually require back-up or storage equipment to provide energy during unusually cloudy days. Sizing of that equipment requires knowledge of historical daily solar energy variation in the local region. Determination of this information from ground-based observations is often difficult because a radiation measurement site may not be located in the region. The global coverage afforded by satellite-based observations offer data that is ideally suited to provide this type of information particularly in remote regions. This paper discusses and presents examples of new parameters available from the NASA/Earth Science Enterprise Release 5 Surface meteorology and Solar Energy (SSE) data set that facilitate the sizing of solar backup systems.

## 1. INTRODUCTION

Unusually cloudy conditions occurring over a number of consecutive days continually draw reserve power from batteries or other storage devices for solar systems not connected to an electrical grid. Storage devices must be designed to withstand continuous below-average conditions in various regions of the globe. This paper describes types of satellite-derived surface solar energy parameters available from the new NASA/Earth Science Enterprise Release 5 Surface meteorology and Solar Energy (SSE) data set (http://eosweb.larc.nasa.gov/sse/) that facilitate determining the reserve power required for a solar power system. These new parameters are based upon 3-hourly, 1-degree satellite cloud observations and concurrent estimates of surface solar radiation on 3-hour time steps with a global resolution of $1^o$ by $1^o$ degree. The new cloud data were input to a data analysis technique developed in conjunction with the World Meteorological Organization (WMO) World Climate Research Program over the past 21 years. The Release 5 SSE solar insolation values have been compared with data from hundreds of operational ground sites around the globe in the July, 1983 through June, 1993 period. The Release 5 SSE, 3-hourly and monthly and daily averaged values, exhibit a bias of less than -2, -2.5, and -3.5 percent, respectively relative to equivalent ground site values. RMS values relative to the ground site values are less than 16, 23, and 22 percent, respectively.

## 2. INDUSTRY BACKGROUND

A critical component of solar generators is often the back-up sub-system for use during extended cloudy periods. Organizations may use different solar insolation parameters when designing back-up systems, depending on local cloud characteristics and how critical the need for power. Review of backup procedures for a number of solar energy system design companies indicates that Days of Autonomy is a common design parameter used to size back-up systems for solar power generators. Days of Autonomy are defined as the number of consecutive days a stand-alone system will meet a defined load without any solar input [1], [2]. Some designers suggest Days of Autonomy between 1 and 5 [3], and others suggest 10 or more days for telecommunications sites [4]. These selections are usually based on a number of considerations such as the safety factors required, the availability of detailed cloud or surface solar insolation data, or an "educated" guess based on past experience.

True days without any sunshine (No-Sun days) actually occur in Polar Regions during the winter. More often, Equivalent No-Sun days occur at all latitudes when higher than average cloud cover occurs during consecutive days. Moderate consecutive-day deficits can accumulate until the total shortfall is equivalent to one or more No-Sun days. Equivalent No-Sun days are defined as:

Equivalent No-Sun Days =
Consecutive-Day deficit/(average daily expected value)

Values from actual cloud and insolation data over the local region can provide a more realistic data base from which the Days of Autonomy and required safety factors can be evaluated for many systems, leading to a more reliable backup system.

## 3. NASA RELEASE 5 SSE WEB SITE DATA

Both daily and monthly insolation values were computed for each day between July 1983 and June 1993 for all 64,800 1$^{o}$ by 1$^{o}$ cells over the globe. Monthly average values were then computed for the 10-yr period. For each month, daily values for each of the 10 years were then searched to find the minimum insolation value for several different consecutive-day periods. The minimum 1-day period might have occurred in 1984 and be 17% of the 10-yr monthly average expected for that day, for example. The minimum 7-day period might have occurred in 1987 and be 24% of the 10-yr average expected value integrated over those 7 days. In the Release 5 SSE web site, the worse consecutive-day values are determined and available for 1-, 3-, 7-, 14-, and 21-day periods for all 12 months for each cell.

Using Richmond, VA in the U.S. (37.583 deg N, 77.5 deg W) as an example, the following values are obtained from the Release 5 SSE web site for January between July 1983 and June 1993:

Average daily expected insolation = 2.15 kWh/m$^2$

| Worse Consecutive Days | Deficits below Expected Values | Equivalent No-Sun Days |
|---|---|---|
| 1 | 1.88 kWh/m$^2$ | 0.87 |
| 3 | 5.37 kWh/m$^2$ | 2.49 |
| 7 | 11.30 kWh/m$^2$ | 5.26 |
| 14 | 16.00 kWh/m$^2$ | 7.44 |
| 21 | 14.50 kWh/m$^2$ | 6.75 |
| Entire Month | 8.68 kWh/m$^2$ | 4.03 |

The worse case is slightly above 7.44 No-Sun days. This suggests that the backup system should be designed for at least 7.44 Days of Autonomy (equivalent No-Sun days) for January. In designing a back-up system, a similar analysis would be needed for the other 11 months. For Richmond, VA, maximum deficits and equivalent No-Sun days are:

| Month | Worse Consecutive-Day Deficits below Expected Values | Equivalent No-Sun Days |
|---|---|---|
| Jan | 16.0 kWh/m$^2$ | 7.44 |
| Feb | 25.2 kWh/m$^2$ | 8.90 |
| Mar | 19.0 kWh/m$^2$ | 4.80 |
| Apr | 24.0 kWh/m$^2$ | 4.91 |
| May | 23.5 kWh/m$^2$ | 4.24 |
| Jun | 21.7 kWh/m$^2$ | 3.50 |
| Jul | 31.0 kWh/m$^2$ | 5.34 |
| Aug | 27.3 kWh/m$^2$ | 5.42 |
| Sep | 16.8 kWh/m$^2$ | 3.90 |
| Oct | 16.8 kWh/m$^2$ | 4.86 |
| Nov | 15.3 kWh/m$^2$ | 6.45 |
| Dec | 13.1 kWh/m$^2$ | 6.79 |

Final selection of backup system size should be made on the basis of the most critical month as well as whatever safety factors and battery discharge limits are being used. The possibility of an unusually bad season should be considered. Adjacent worse case months in a particular year could prevent batteries from becoming fully charged from month to month.

Approximate values for equivalent No-Sun days over the globe are shown in figures 1 and 2. The charts show that the maximum number of No-Sun days varies with season for most regions of the globe. In some regions, the Spring or Fall may represent the most difficult situation. This type of maximum No-Sun day data may help in the selection of safety factors and the number of Days of Autonomy for future solar power systems.

## 4. CONCLUDING REMARKS

The Release 5 SSE web site offers solar system designers a new tool for evaluating Days of Autonomy requirements from global, 1$^{o}$ by 1$^{o}$, 3-hourly cloud and surface solar insolation data based upon satellite observations. The solar insolation data compare favorably with ground observations, and can provide realistic parameters for designing a reserve backup system. Figures presented here serve to illustrate the scope of the data available from the SSE web site. More precise digital values can be obtained from the Release 5 SSE web site (http://eosweb.larc.nasa.gov/sse/) for each 1$^{o}$ by 1$^{o}$ cell over the globe. The current values are based on weather events for the period between July 1983 and June 1993. Future data sets are planned which will extend the data to cover longer periods.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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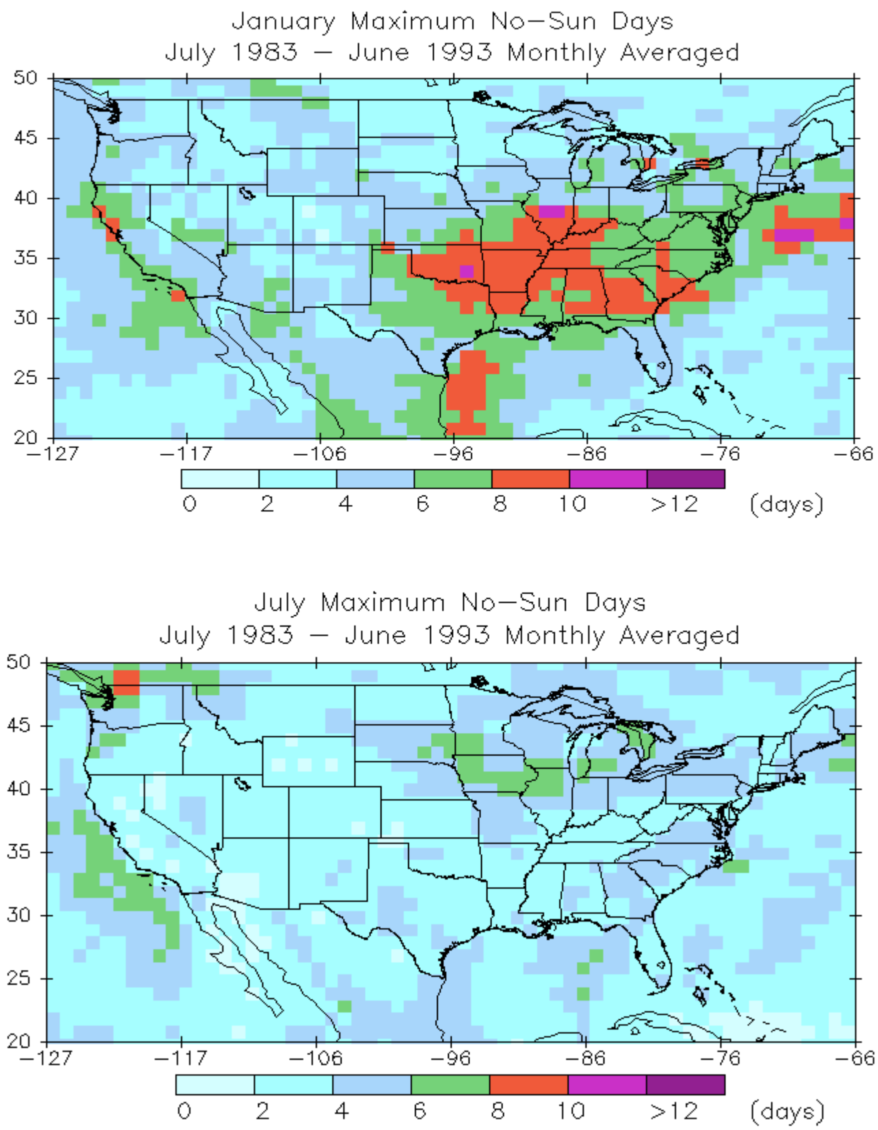


Fig. 1: U.S. Maximum No-Sun Days for January and July.

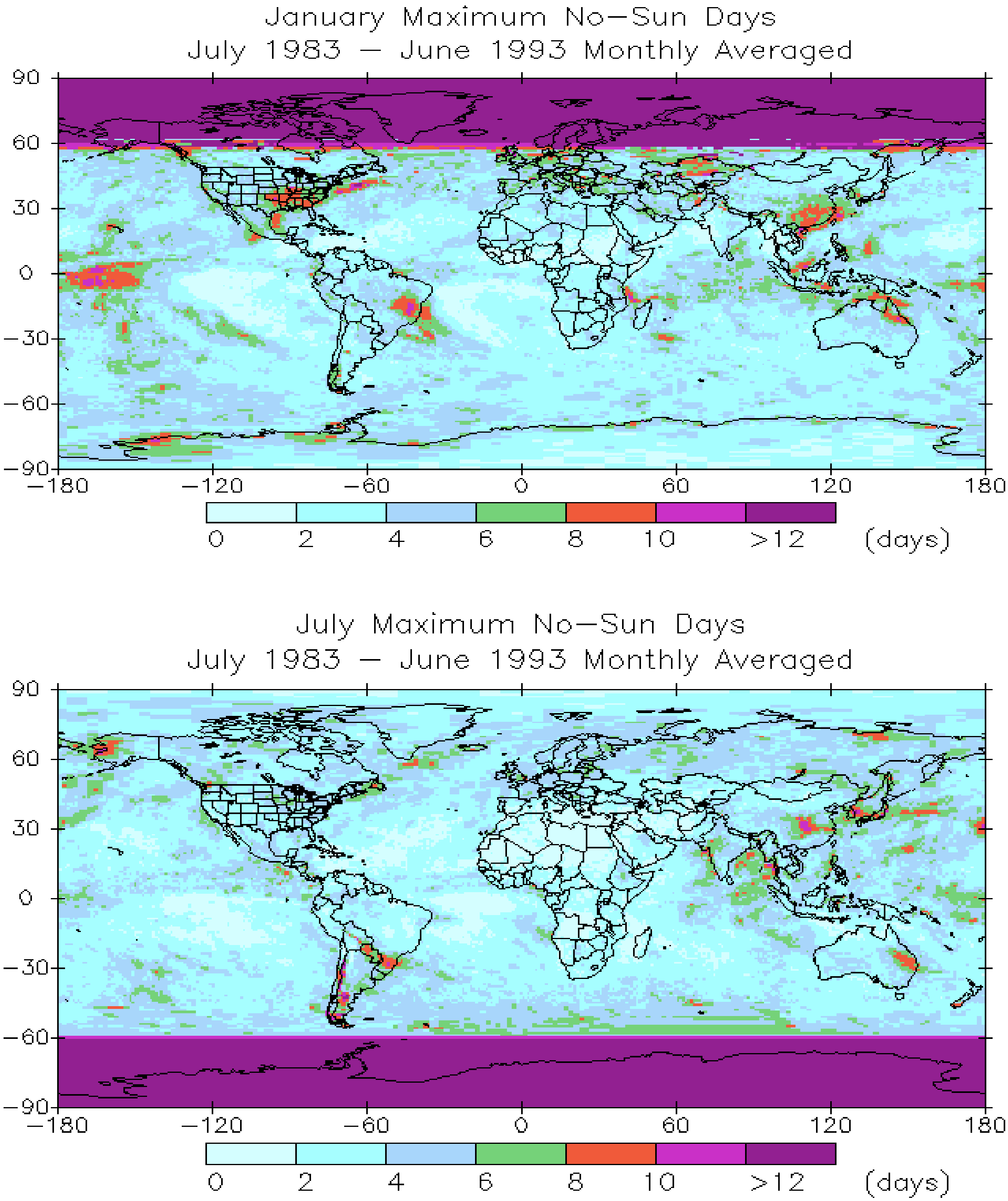


Fig. 2: Global Maximum No-Sun Days for January and July.