VARIABILITY OF DIFFUSE SOLAR RADIATION OVER THE GLOBE

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ABSTRACT

The NASA Earth Science Enterprise (ESE) program is in the process of developing and validating several approaches for estimating surface radiation over the globe. Short wave insolation as well as its components, diffuse-horizontal and direct horizontal, is desired for a number of commercial applications in different industries. ESE Surface meteorology and Solar Energy (SSE) satellite data has measurement frequency characteristics that do not allow the use of industry methods that require hourly data. This paper describes a method to provide useful data for preliminary design use in regions where precise measurements do not exist. The method is tested against several data sets. Global maps are presented showing average values for the four mid-season months, each averaged over the 10-yr period from July 1983 through June 1993. Sample maps are also shown giving monthly deviations from the averages for the highest- and lowest-months within the 10-yr period. That 10-yr period contained 4.5 near-average years, 3.5 El Nino years, and 2 La Nina years.

1. APPROACH

Based on results from Brunger and Thevenard (1), the method of Page (2) was selected to estimate monthly diffuse irradiance from SSE monthly insolation. The original Page method employed only 10 reference ground sites in its analysis of variance procedure. ESE upgraded the number of reference sites to include new data for a wider range of atmospheric climate types. Additional sites are located in 12 of the 13 global climates defined in Wilber, Smith, and Stackhouse (3), and Smith, et al. (4). Seventy-three sites at North and South America, the Caribbean Sea, the mid-Pacific Ocean, the South Pole, Australia, Indonesia, Japan, Asia and the Middle East locations are now used in a seasonally consistent analysis of variance. Method applicability is for latitudes from 68^{o}N to 68^{o}S.

2. ESTIMATED UNCERTAINTY

Precise uncertainty estimates of SSE diffuse irradiance cannot be obtained because ground-site data is often noisy. Misalignment of devices blocking the Sun's beam from the instrument's detector sometimes produces diffuse values that are too high. It has been noted that historic site measurements may also be too low for one popular brand of instrument under both clear and partly cloudy conditions (Haeffelin et al. (5)). Mid-latitude tests under 25% cloud-cover suggest diffuse measurement values may be 10 to 15% below actual values because of instrument thermodynamic imbalances as a result of shadowing the detector. Values for overcast skies are more accurate.

The SSE-upgraded Page method has been tested against historical diffuse-horizontal data from two global and two U.S. data sets. One comparison is 30-yr average World Radiation Data Center (WRDC) values (courtesy NREL) versus 10-yr average SSE values. Another is a month-by-month comparison for 1988 and 1989 values for a subset of WRDC sites that are believed to be of unusually high quality by the Swiss Federal Institute of Technology. That data set is known as the Global Energy Budget Archive (GEBA). The third comparison is month-by-month for data from Dodge City, KS, Golden, CO, Las Vegas, NV, and Omaha, NE for the period 1985 through 1988 (courtesy NREL). A fourth comparison was made with the well-respected DOE TMY2 data set. Most TMY2 data is described as being modeled based on other measurements. Results of the comparisons are shown in the table.

Estimated RMS uncertainty of SSE diffuse irradiance appears to be in the 15 to 22% ranges.

3. DIFFUSE IRRADIANCE ESTIMATES OVER THE GLOBE

Figures 1 through 4 show monthly averages as well as deviations from the averages for the highest- and lowest-months within the 10-yr period. Only general magnitudes can be shown with a legible gray scale. In general, the largest average values are in regions with a longer number of daylight hours in a particular season in combination with few clear-sky days (see <http://eosweb.larc.nasa.gov/sse/> for various supporting data).

Most observers expect a wide variation of clouds (and diffuse skylight) on a daily basis. A surprise is the very large (> 60%) year-to-year diffuse irradiance deviations on a monthly average time scale. The high percentage deviations in an unusual year are the result of abnormal, longer-term cloud variations.

These diffuse irradiance results have different impacts on various industries ranging from safety, energy, and daylighting issues to crop growth, disease, and pest infestation. Variability in the Northern Hemisphere (many continental heat islands and industries) is much different than Southern Hemisphere regions (large oceans and sparsely settled land).

4. REFERENCES

(1) Brunger, A. and Thevenard D., Evaluation of Models for Natural Illumination on Horizontal Surfaces, Proceedings of the North Sun 1999 Conference, Solar Energy Society of Canada, Inc., 1999.

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(3) Wilber, A. C., Smith, G. L. and Stackhouse, P. W., Jr., Regional Climatology and Surface Radiation Budget, Proceedings of the 10th Conference on Atmospheric Radiation, American Meteorological Society, 1999.

(4) Smith, G. L., Wilber, A. C., Gupta, S. K., and Stackhouse, P. W., Jr., Surface Radiation Budget and Climate Classification, (accepted Journal of Climate), 2002.

(5) Haeffelin, M, Kato, S., Smith, A. M., Rutledge, C. K., Charlock, T. P., and Mahan, J. R., Determination of the Thermal Offset of the Eppley Precision Spectral Pyranometer, Applied Optics, 2001.

TABLE: SATELLITE-BASED SSE ESTIMATES OF UNCERTAINTY

DATA SET	INSOLATION		DIFFUSE HORIZONTAL	
Ground-Site Measurements	Bias	RMS	Bias	RMS
10-yr SSE vs 30-yr WRDC (courtesy NREL)	+1.8%	13.3%	0.0%	20.0%
1988-1989 SSE vs 1988-1989 GEBA	0.0%	9.5%	+5.6%	22.5%
1985-1988 SSE vs 1985-1988 NREL (mostly university data)	+0.8%	10.4%	-6.0%	18.9%
Ground-Site Mostly Modeled				
10-yr SSE vs TMY2 (courtesy NREL)	-3.0%	9.0%	-5.0%	15.0%

Notes:
1. Positive bias indicates that SSE values are higher than ground site data.
2. RMS values include bias.

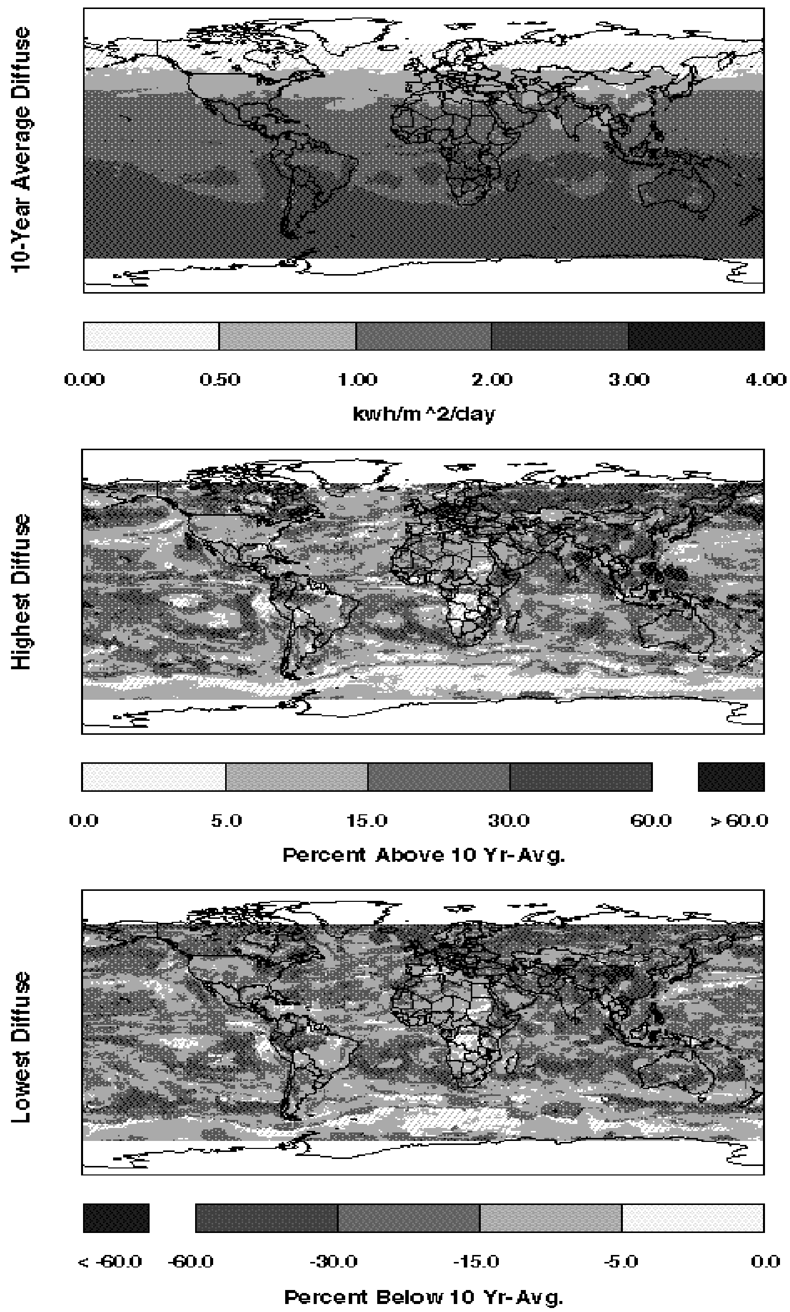

Fig. 1 January maps of 10-yr diffuse irradiance.

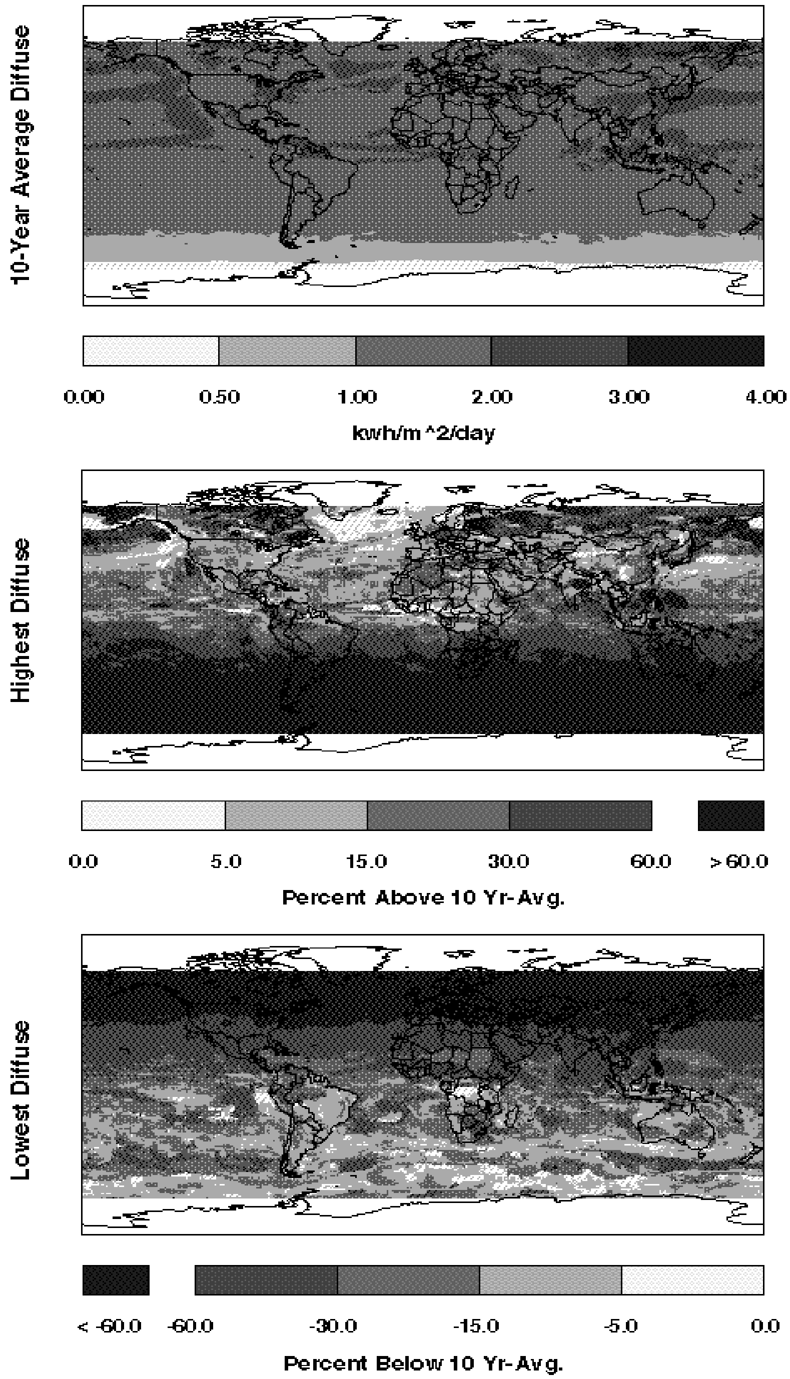

Fig. 2 April maps of 10-yr diffuse irradiance.

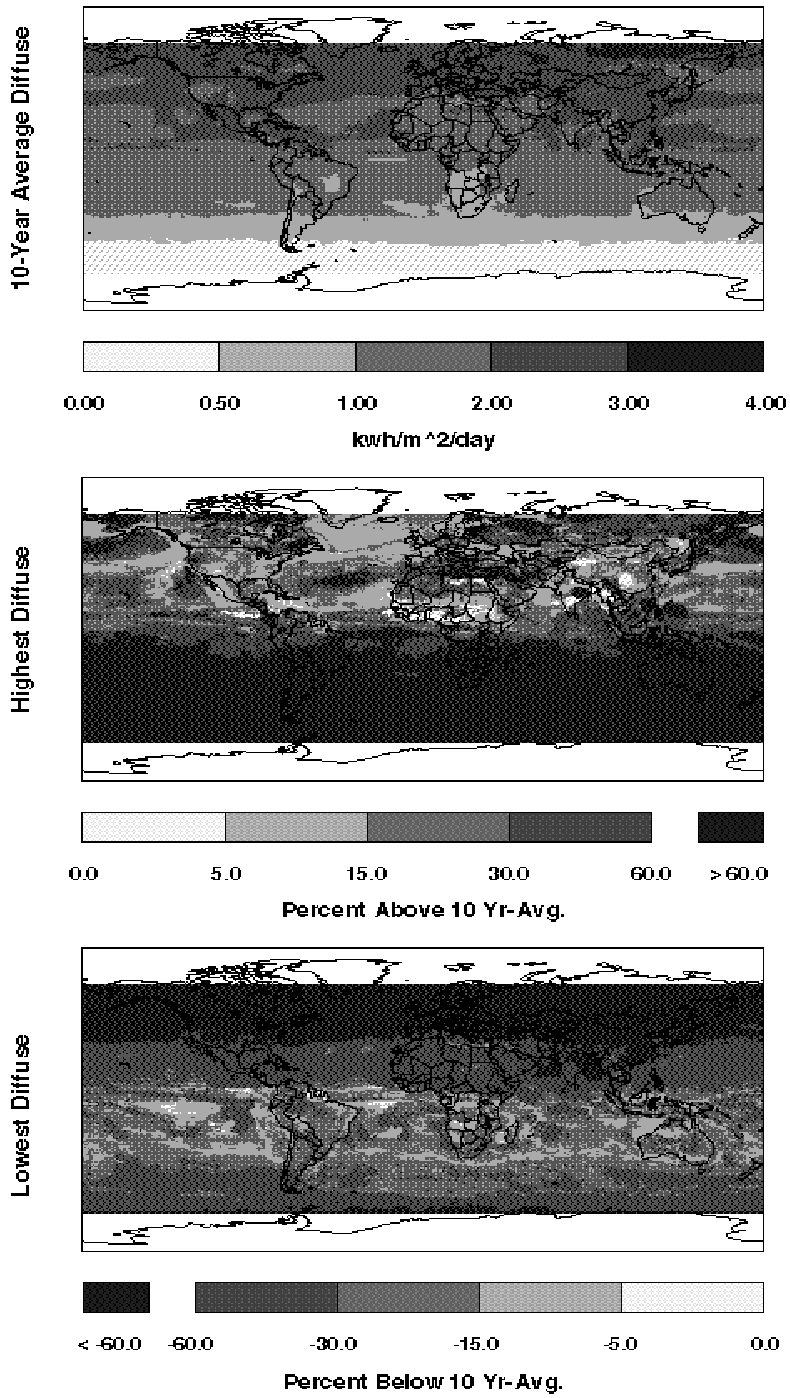

Fig.. 3 July maps of 10-yr diffuse irradiance.

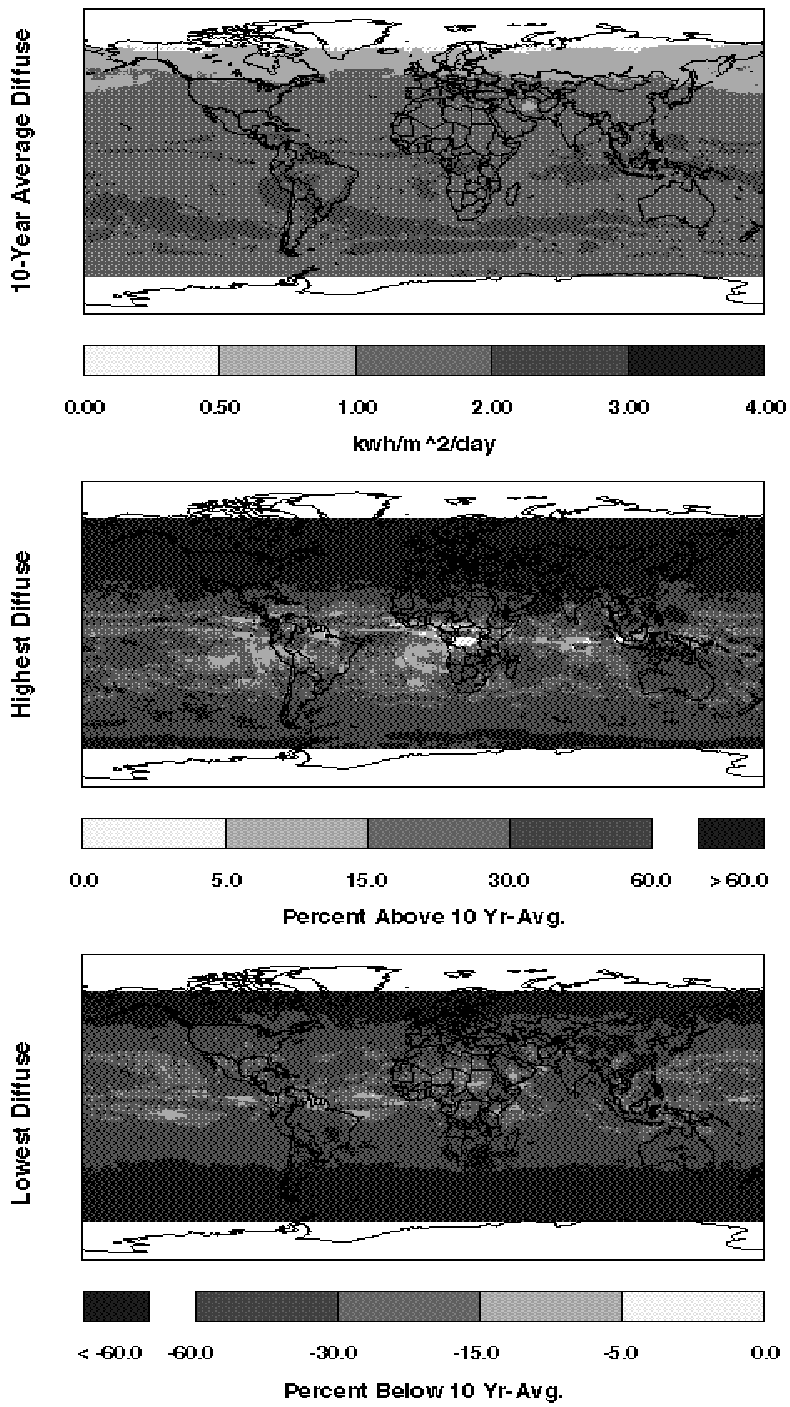

Fig. 4 October maps of 10-yr diffuse irradiance.