A GLOBAL PERSPECTIVE ON RENEWABLE ENERGY RESOURCES: NASA's Prediction of Worldwide Energy Resources (POWER) Project

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ABSTRACT

The Prediction of the Worldwide Energy Resources (POWER) Project, initiated under the NASA Science Mission Directorate Applied Science Energy Management Program, analyzes, synthesizes and makes available data parameters on a global scale. These data have proved to be reliable and useful to the renewable energy industries, especially to the solar energy sectors. The POWER project derives its data primarily from NASA's World Climate Research Programme (WCRP)/Global Energy and Water cycle Experiment (GEWEX) Surface Radiation Budget (SRB) project (Version 2.9) and the Global Modeling and Assimilation Office (GMAO) Goddard Earth Observing System (GEOS) assimilation model (Version 4).

The latest development of the NASA POWER Project and its plans for the future are presented in this paper.

1. INTRODUCTION

The POWER data are available to users through NASA's Surface meteorology and Solar Energy (SSE, Version 6.0) website (http://earth-www.larc.nasa.gov/power/). The number of parameters available is over 200 and the resolution is 1 degree by 1 degree. The time span now covers 22 years from July, 1983 to June, 2005 and continues to grow, and the data are presented as 3-hourly, daily and monthly means. The SSE website has now had over 5 million hits and 1 million data document downloads.

The radiation data are systematically validated against data from the Baseline Surface Radiation Network (BSRN), the World Radiation Data Centre (WRDC), the Global Energy Balance Archive (GEBA), and National Solar Radiation Data Base (NSRD). The GEOS-4 data are results of reanalyses that have incorporated land/ocean surface- and satellite-based observations[1][2]. Other meteorological parameters, such as minimum, maximum, daily mean and dew point temperatures, relative humidity, and surface pressure, are validated against the National Climate Data Center (NCDC) data. SSE feeds data through an interface directly to the National Renewable Energy Laboratory's (NREL) Hybrid Optimization Model for Electric Renewables (HOMER) and the RETSCreen International.

The POWER data, for its high-resolution global coverage and long continuous record, are not only of immediate value to industrialists, architects of sustainable buildings, and agriculturists, but have great potential to facilitate analysis and prediction of worldwide energy from the climatological as well as economic points of view.

2. DATA AND SOURCE

The POWER project derives its data mainly from two sources: the GEWEX/SRB project for radiation data; GEOS-4 for temperature and humidity data [3][4]. The time span of the currently available data is from July 1983 to June 2005, and the resolution is 1^{o}x1^{o}.

Figures 1 and 2 show the 22-year average of monthly means of surface solar insolation for July and October, respectively, from 1983 to 2004. And Figure 3 is the 22-year average of annual means of the surface solar insolation. Figure 4 shows the seasonally (JJA for June-July-August; DJF for December-January-February) and annually averaged zonal means of surface solar insolation.

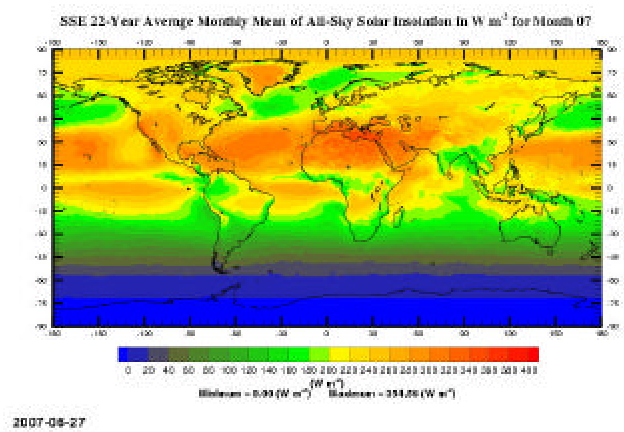

Fig. 1: 22-year average of July surface solar insolation from 1983 to 2004 at 1°x1° resolution. . (The color bar ranges from 0 to 400 W m^{-2}.)

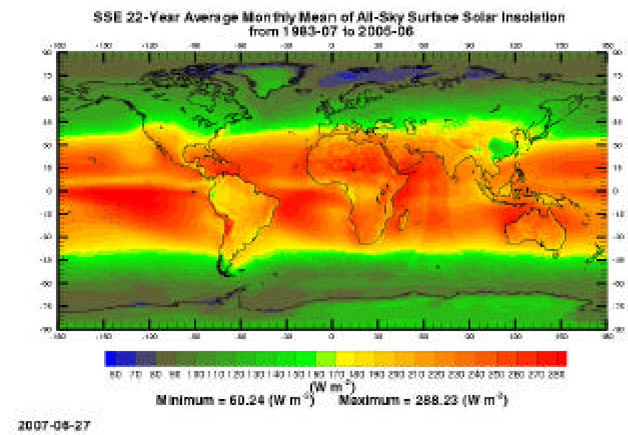

Fig. 3: 22-year average of the annual mean of surface solar insolation from July 1983 to June 2005. (The color bar is from 60 to 300 W m^{-2}.)

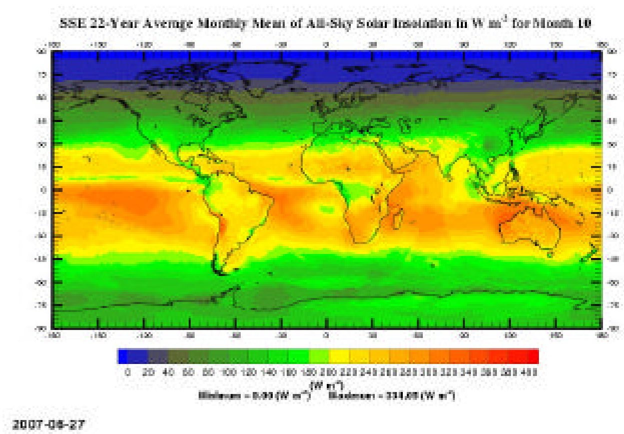

Fig. 2: 22-year average of October surface solar insolation from 1983 to 2004 at 1°x1° resolution. . (The color bar ranges from 0 to 400 W m^{-2}.)

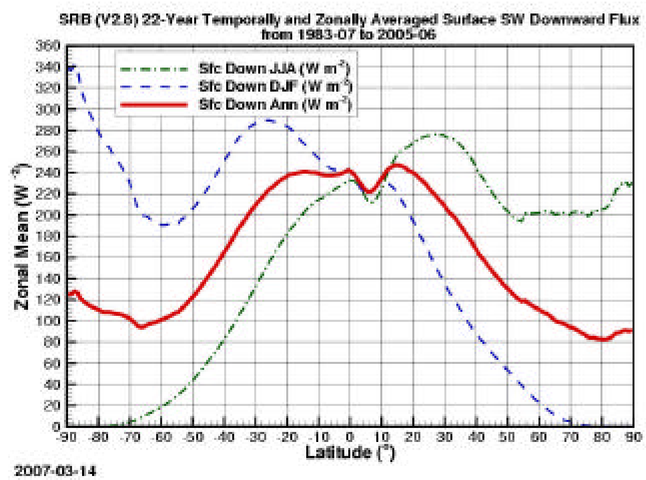

Fig. 4: 22-year averages of seasonally (JJA for December-January-February ; DJF for December-January-February) and annually averaged zonal means of surface solar insolation.

3. VALIDATION

In order to establish the validity of the SSE data, massive validation has been conducted. The ground observations used for the validation include the BSRN, WRDC, GEBA and NSRDB databases.

Figure 6 shows the scatter plot of the SSE monthly mean surface solar insolation along with its BSRN counterpart. The statistics are computed globally, 60° poleward, and 60° equatorward. As the figure indicates, the global bias based on 2981 site-months of data is about –8 W m^{-2} (4.57% of the mean) and the RMS is about 24 W m^{-2} (13.69% of the mean).

Figure 7 shows the monthly mean SSE surface solar insolation in comparison with the WRDC data from 1983 to 1993. The total number of site-months is 39,343, and the bias is as small as about 3 W m^{-2} (1.93% of the mean).Though the data points are widely spread, the scatter density shows that the majority of the SEE data are in good agreement with the WRDC data.

Figure 8 compares the SSE monthly surface solar insolation with that of the GEBA. The time span is about 20 years from July 1983 to September 2003. The scatter density plot shows that the 82,977 site-months of SSE-GEBA pairs compared favorably with each other (bias of 3.10 W m^{-2} which is 1.93% of the mean).

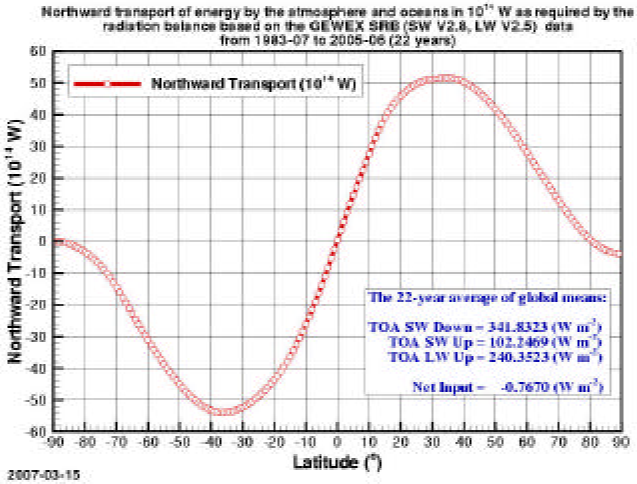

Fig. 5: Total northward transport of energy by the atmosphere and oceans based on both shortwave and longwave radiation at the top of the atmosphere and the Earth'surface

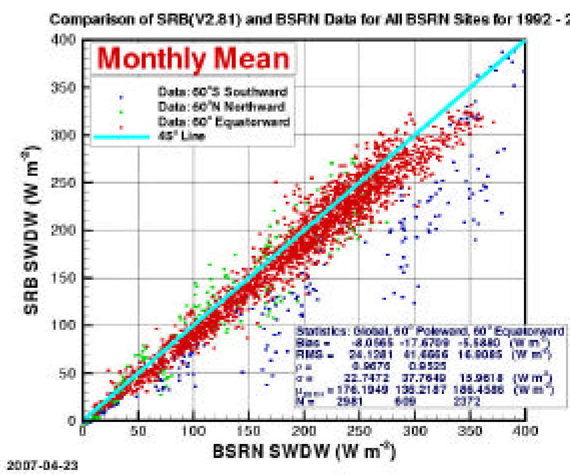

Fig. 6: The SSE surface solar insolation in comparison with its BSRN counterpart from January 1992 to June 2005.. The overall bias based on 2981 site-months of data is about –8 W m^{-2}.

The availability of the solar energy varies as the global climate system varies. The prediction of the solar energy is thus closely related to the understanding and simulation of the dynamics of the global climate system. Figure 9 shows the coefficient of the first empirical orthogonal function (EOF) of the SSE monthly mean surface solar insolation from July 1983 to June 2005 over the Pacific region in comparison with the Southern Oscillation Index (SOI) of the same period. The data has been deseasonalized before computing the EOF.

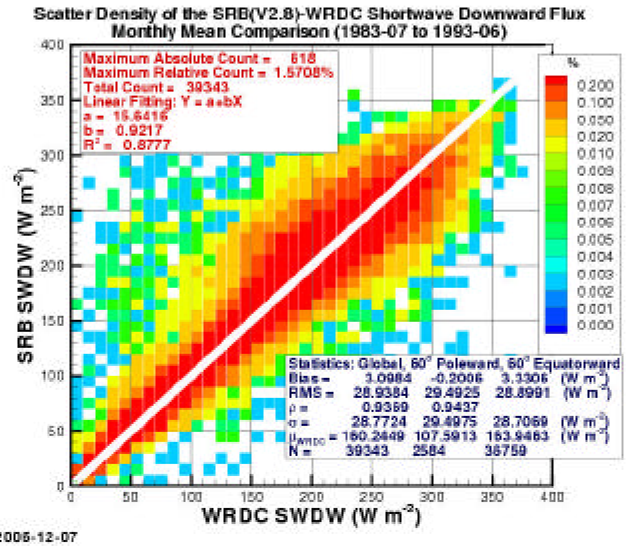

Fig. 7: The SSE surface solar insolation in comparison with its WRDC counterpart from July 1983 to June 1993. The overall bias based on 39,343 site-months of data is about 3 W m^{-2}.

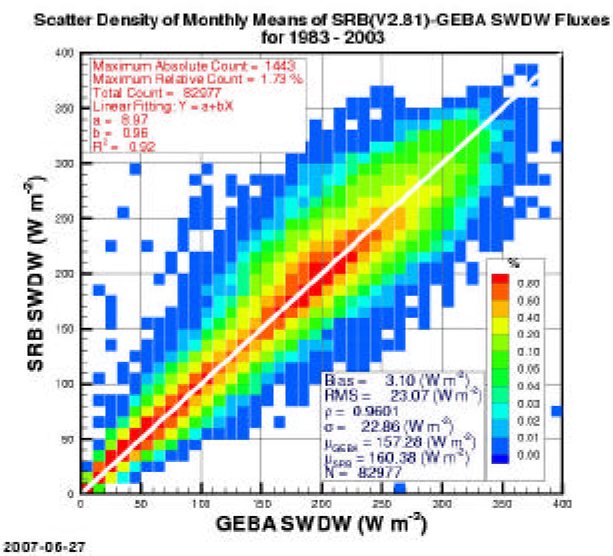

Fig. 8: The SSE surface solar insolation in comparison with its GEBA counterpart from July 1983 to September 2003. The bias based on 82977 site-months of data is 3 W m^{-2}.

The range of the region is from 120^{o}E to 180^{o} to 120^{o}W and from 20^{o}S to 20^{o}N. The corresponding EOF represents 21% of the total variance of the deseasonalized solar insolation. The correlation between the EOF coefficient and the SOI is 0.6978.

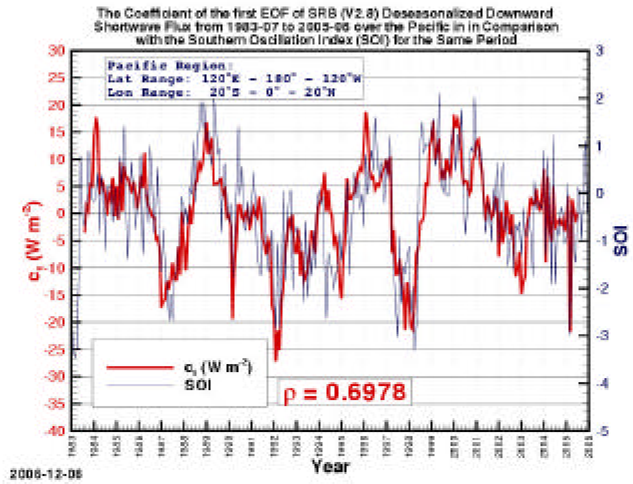

Fig. 9: The coefficient of the first EOF of the monthly mean surface solar insolation from July 1983 to June 2005 over the Pacific region in comparison with the Southern Oscillation Index. The correlation coefficient is as high as 0.6978.

4. VISION OF THE POWER PROJECT

To date, the POWER project has made available 22 years of historical solar and meteorological data parameters from 1983 to 2005. The record is planned to be extended past at least the last 25 years. New improvements to the historic representation of cloud and aerosol properties are being made. This research involves collaboration with the International Satellite Cloud Climatology Project and the GOCART models (Georgia Tech/Goddard Ozone, Chemistry, Aerosol and Radiation Transport model [7].

Additionally, the NASA GMAO's upcoming analysis, called MERRA, will feature a horizontal resolution of $(1/2)^o x (2/3)^o$. Consequently, the SSE resolution can be increased to $(1/2)^o x (1/2)^o$

The POWER has also developed new prototypes more specifically designed to meet the needs of the sustainable building engineers and architects as well as agricultural applications, included in which are clear-sky data in building design.

FLASHFlux (Fast Longwave and Shortwave Radiative Fluxes from CERES and MODIS) is another project from which POWER provides renewable energy products. This project produces global gridded solar irradiance estimates within one week of observation from NASA's Terra and Aqua satellites [8].

Lastly, the POWER is now also collaborating with others for short-term forecast of solar insolation.

5.CONCLUSION

The POWER project and its latest development is reviewed in this paper. POWER has produced 22 years of solar radiation and other related meteorological data of great value, especially to the renewable energy, architectural and agricultural industries. POWER is also actively working toward short-term forecasting of solar irradiance.

More information can be found at http://eosweb.larc.nasa.gov/sse/ and http://earth-www.larc.nasa.gov/solar/power.

6. REFERENCES

(1)Schubert, S.D., R.B. Rood, and J.W. Pfaendtner, (1993). An Assimilated Dataset for Earth Science. *Bull. Amer. Meteor. Soc*., **74**, 2331-2342.

(2) Bloom, S.A. da Silva, and D.Dee, (2005). Documentation and Validation of the Goddard Earth Observing System (GEOS) Data Assimilation System—Version 4. NASA Technical Report Series on Global Modeling and Data Assimilation, Max J. Suarea, Editor, NASA/TM-2005-104606, **26**.

(3) Stackhouse, P.W., Jr., R.S. Eckman, C.H. Whitlock, W.S. Chandler, J.M. Hoell, T. Zhang, J. C. Mikovitz, G.S. Leng, P. Lilienthal: Supporting Energy-Related Societal Applications Using NASA's Satellite and Modeling Data, IEEE International Geoscience and Remote Sensing Symposium, Geoscience and Remote Sensing, Denver, CO, 2006.

(4).Cox, S.J., P.W. Stackhouse, Jr., S.K. Gupta, J.C. Mikovitz, M.Chiacchio and T. Zhang: The NASA/GEWEX Surface Radiation Budget Project: Results and Analysis, International Radiation Symposium, Busan, Korea, 2004.

(5). Kann, D.K., S. Yang, and Miller, A.J., 1994. Mean meridional transport of energy in the earth-atmosphere system using NMC global analyses and ERBE radiation data. *Tellus*, **46A**, 553-565.

(6) Peixoto, J.P. and A.H. Oort, 1992. *Physics of Climate*. American Institute of Physics, New York, New York.

(7) Chin, M., P. Ginoux, S. Kinne, O. Torres, B. Holben, B.N. Duncan, R.V. Martin, J.A. Logan, A. Higurashi, T. Nakajima, 2002. Tropospheric Aerosol Optical Thickness from the GOCART Model and Comparisons with Satellite and Sun Photometer Measurements. *J. Atmos. Sci*., **59**, 461-483.

(8) Stackhouse Jr., P.W., D.P. Kratz, G.R. McGarragh, S.K. Gupta and E.B.Geier, 2006: Fast Longwave and Shortwave Radiative Flux (FLASHFlux) Products from CERES and MODIS Measurements. *Proceedings of the 12th Conference on Atmospheric Radiation*. Madison, WI, July 10-14, American Meteorological Society.