SOLAR RENEWABLE ENERGY DATA SETS FROM NASA SATELLITES AND RESEARCH

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ABSTRACT

Improvements to NASA Surface Meteorology and Solar Energy (SSE) web site are now being made through the Prediction of Worldwide Energy Resource (POWER) project under NASA Earth Science Applications Energy Management Program. The current status of SSE and research towards upgrading estimates of total, direct and diffuse solar irradiance from NASA satellite measurements and analysis are discussed. Part of this work involves collaborating with the National Renewable Energy Laboratory (NREL) to upgrade the National Solar Radiation Database (NSRDB). POWER plans including historic, near-term and forecast datasets are also overviewed.

1. INTRODUCTION

NASA's Earth Science Enterprise (ESE) has long supported satellite systems and research providing data important to the study of climate and climate processes. These data include long-term estimates of meteorological quantities and surface solar energy fluxes. Satellite based products have been shown to be accurate enough to provide reliable solar resource data over regions where surface measurements are sparse or nonexistent (1, 2). NASA supported the development of the Surface Meteorological and Solar Energy (SSE) dataset providing internet based access to parameters designed for the solar power and other renewable energy system design needs (3). Now, NASA has established Energy Management theme within the ESE Applications Program. Under this program the Prediction of Worldwide Energy Resource (POWER) project has been initialized to improve upon the SSE dataset and create datasets from new satellite systems and forecast modeling directly applicable to the energy sector decision support systems (DSS) (4). The POWER project continues and expands upon government and industry partnerships including the Department of Energy (National Renewable Energy Laboratory) and the Natural Resources Canada (NRCan) organization of the Canadian government. This paper gives an overview of the NASA POWER activities related to the development of parameters for the solar power renewable energy industries.

First, the current status of the SSE dataset is reviewed. SSE has now been upgraded to version 4 and now includes direct links to RETScreen™ (5) and SolarSizer™ (6) design tools. Global parameters of solar energy fluxes including estimates of direct and diffuse fluxes are provided at the web site along with information regarding solar geometry, cloudiness, and clearness indexes. Current accuracies of the parameters are available on line. Secondly, we present future plans for upgrades to the SSE dataset including upgraded resolution of the solar flux parameters and improvements to methods of estimating diffuse/direct and tilted surfaces fluxes. Preliminary results for comparing new higher resolution data to current SSE version are presented for solar irradiance information. Lastly, the vision of POWER towards the development of future long-term datasets including near-term and forecasted products will be presented. These plans include the derivation of parameters from many of NASA's most recent satellite missions including the Terra and Aqua polar orbiting platforms. The plans also include development of datasets from forecasts of short to long-term weather and climate from NASA and NOAA modeling.

2. SSE CURRENT STATUS

Chandler et al. (7) describes the current version of SSE available through the internet at <http://eosweb.larc.nasa.gov/sse/> and presents an

assessment of data quality. SSE 4 now contains over 200 parameters computed from a period spanning from July 1983 through June 1993. Most parameters are available for the 10 year average of each month, but daily averaged and 3-hourly averaged variables are available for some parameters (i.e., cloudiness, surface insolation). The current version includes a large number solar parameters including broadband total, direct normal, diffuse, and equator-facing tilted fluxes. Multiple algorithms are used for the diffuse, direct normal and tilted surface fluxes to obtain a range of estimates. The web site now supports downloading of regional data into tabular formats. A summary of the all the algorithms used to generate the current SSE dataset and a data quality assessment is available in the methodology section of the web site.

Chandler et al. (3) describes the form of the web site emphasizing the direct linkages with several governmental and industry partners. POWER is continuing the efforts, through its partnerships, to provide improved datasets to solar power users in convenient and accessible ways to aid in the design and implementation of solar power systems. Work is underway to add direct links to other Solar power data system support tools such as NREL's HOMER.

Under the NASA POWER project, several of the algorithms used to produce direct, diffuse, and tilted irradiances are being refined. Research has been progressing on studying improvements to the Erbs et al. (8) method for the estimation of the diffuse (and thus, direct) irradiance poleward of 45^o. Also, maps of surface albedo are being developed and being compared to observations and analysis of measurements from NASA's Terra and Aqua satellite platforms using the MODIS and CERES instruments that measure spectral and broadband radiances. The surface albedos are a key input to the tilted irradiance calculations.

3. NEAR FUTURE SSE UPDATES

While methods of improving the calculation of parameters are studied, the inputs of the solar energy parameters are currently being upgraded with newly processed solar data from the NASA/Global Energy and Water Cycle Experiment (GEWEX) Surface Radiation Budget (SRB) project (9). These solar fluxes are now derived from the International Satellite Climatology Cloud Project (ISCCP) DX data (10) that is processed to derive satellite radiance and cloud properties on 1^o latitude by 1^o longitude grid without interpolation. This dataset will now include the time period from July 1983 through October 1995. The NASA/GEWEX SRB dataset includes solar fluxes from two algorithms, the SW (Shortwave) algorithm based on Pinker and Laszlo (11) and the SWQC (Quality Check) algorithm based upon Darnell et al (12) and updated by Gupta et al (13). All the cloud and solar parameters will be computed using the new cloud and solar flux data applying the same methodologies as described on the web site.

A validation strategy is currently being refined to compare the previous version of SSE (interpolated 1^{o}x1^o) to the newly derived fluxes. Since the large majority of surface

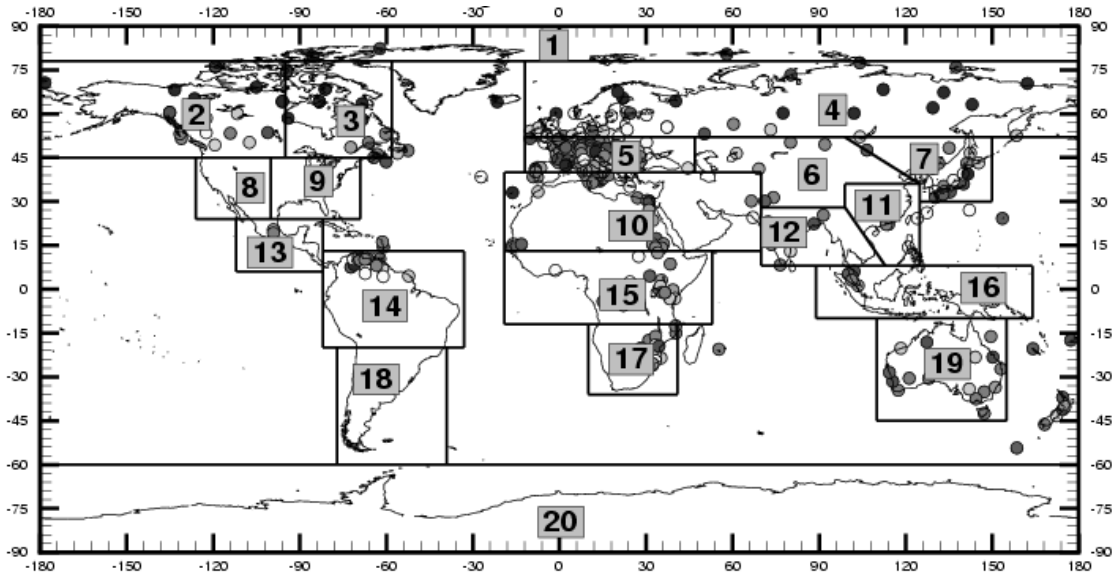

Figure 1: Map of the regions used for validation of the satellite solar irradiance estimates. Surface sites within each region are given by the circles. No Western United States or Antarctic measurements were obtained for this study, but subsequent versions will include any well calibrated available measurements.

sites available for validation occur in Europe the new validation strategy divided the world's major land masses into 20 separate regions for analysis and intercomparison. These regions, shown in Figure 1, are chosen to have relatively similar surface climatological surface type. Monthly averages of original SSE fluxes are being compared with the new fluxes finding that RMS differences relative to surface sites are similar but bias errors are improved. In this first attempt monthly surface observations from the World Radiation Data Centre in St. Petersburg, Russia are used. More observations will be integrated into the analysis. However, the preliminary results of the flux assessment by region are given in Table 1. Averaged over time (i.e. 10 years) and space (i.e. regions), the three data sets yield similar statistics with the overall RMS difference remains just over 15% with a bias (<1%). A qualitative comparison of the daily averaged solar estimates from the higher spatial resolution SRB SW data shows significant improvement relative to the current SSE data since localized features are now better represented in the solar irradiance maps. A quantitative assessment of these differences is still being completed. The upgrade of SSE version 4 to the new resolution version 5 data products is scheduled for completion in summer 2004.

4. NASA POWER VISION AND PLANS

Besides upgrading the SSE dataset, the long-term vision of POWER is to support the solar resource assessment research by providing improved long-term databases, faster updates to those databases from new NASA observations and analysis and the development of the solar resource forecasts from NASA and NOAA models. Figure 2 presents this vision in schematic form. This supports the integrated systems approach central to all the national applications of the Earth Science Applications program. This approach is to move scientific knowledge and methodology directly to decision makers through partnering with governmental and other entities in matters of national interest. POWER supports decision makers in the energy sector in which the solar power renewable technologies reside. For instance, in addition to upgrading the SSE web site database, POWER is directly supporting the updating of the NREL National Solar Radiation Data Base (14). This work is being performed under the current Memorandum of Understanding between NASA and the National Renewable Energy Laboratory (NREL).

Table 1: Percent RMS and bias differences relative to surface observations by region. NASA/GEWEX SRB runs two solar radiative flux algorithms operationally (denoted SW and SWQC – see text). Regions 8 (Western US) and 20 (Antarctica) currently have no surface measurements that were obtained for this assessment. Regions containing less than 6 ground sites on average from 1984 – 1992 are shaded since these regions are more susceptible to instrument error.

Region	Number of Ground Sites	Site Avg H (W/m^2)	RMS (% H)			Bias (% H)		
			SRB SW	SRB SWQC	SSE	SRB SW	SRB SWQC	SSE
1	2.7	115	29	27	24	-15	-3	-12
2	14.3	114	14	15	15	-2	0	-8
3	9.4	116	18	18	26	-8	-3	-18
4	53.3	107	18	19	17	2	4	-4
5	115.5	138	18	19	18	1	4	-3
6	5.2	176	20	21	20	-2	8	1
7	18.3	146	15	20	14	7	15	8
9	2.8	151	8	7	7	-5	1	-4
10	29.8	207	17	17	17	5	7	7
11	3.1	160	16	20	20	12	17	14
12	7.9	221	12	11	12	2	2	-4
13	1.8	230	12	10	14	-7	-3	-3
14	15.2	194	19	20	17	11	13	10
15	17.5	234	16	17	16	-1	0	-2
16	3.7	193	13	13	10	9	9	5
17	10.2	231	14	13	13	-7	-6	-5
18	1	182	6	8	7	-3	0	-5
19	17.9	220	12	11	11	-3	-1	-2

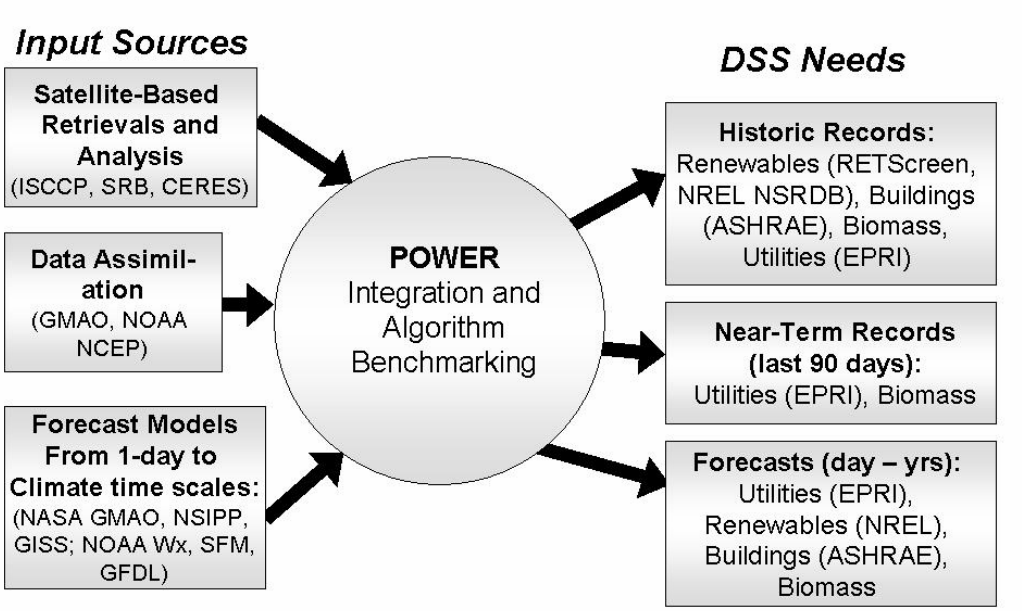

Figure 2: NASA Energy Management POWER project plans for providing datasets and improved algorithms for historic and forecasted solar resource information. CERES is the Clouds and Earth Radiant Energy Systems instrument and science team producing solar irradiance from several NASA polar orbiting satellites. The NASA GMAO (Global Modeling and Analysis Office) and NOAA NCEP (National Center for Environmental Prediction) have atmospheric data analysis projects that produce long-term simulations of global weather and climate by assimilating surface, radiosonde, and satellite observations. NOAA produces operational ensemble weather forecasts (Wx), seasonal forecasts (SFM – Seasonal Forecast Model) and climate forecasts (GFDL – Geophysical Fluid Dynamics Laboratory). NASA has developmental seasonal (NSIPP – NASA Seasonal-to-Interannual Prediction Project) and climate forecast model teams (GISS – Goddard Instititute of Space Studies). ASHRAE is the American Society of Heating, Refrigeration and Air-Conditioning Engineers. EPRI is the Electric Power Research Institute.

4.1 Historic Datasets

As Figure 2 suggests POWER is actively improving and developing historic solar resource data from the last 20 years. NASA supported projects such as ISCCP and SRB are collaborating with NASA and non-NASA investigators to improve the historic representation of cloud and aerosol properties. Aerosols are being improved through scientific collaboration with the GOCART models (Georgia Tech/Goddard Ozone, Chemistry, Aerosol and Radiation Transport model (15). Also, the Global Modeling and Analysis Office (GMAO) at NASA Goddard Space Flight Center is in the midst of processing a 20+ year meteorological dataset GEOS (Global Earth Observing System) 4.0.3 that will feature much improved column water vapor. POWER will process satellite observations from ISCCP with GEOS 4.0.3 to develop a dataset to support the NSRDB upgrade for the years 1995 – 2001 (14). Solar irradiance values from this time period will be validated against more reliable surface observations during this period. Overlap of this dataset with the improved cloud, aerosol and radiation datasets being developed from the NASA Terra and Aqua systems will lead ultimately to a reduction in the uncertainty of solar irradiance values since these instruments are calibrated to accuracies far exceeding conventional weather observing platforms. After isolation of errors in the methodology and inputs a reprocessing of all the solar irradiance values using satellite systems for the last 20-25 years is planned.

4.2 Near-Term Records

POWER is also collaborating with a team of investigators endeavoring to develop global gridded solar irradiance estimates within one week of observation from NASA satellite platforms. The advantage of this dataset is globally gridded data and the transfer of cross-calibration of the NASA instruments to geosynchronous platforms. These datasets termed “Near-term” are important for a variety of applications where the recent past is relevant for maintenance and statistical forecasting methods.

4.3 Solar Resource Forecasts

Improved weather and air quality forecasting will lead to the opportunity to improve predictions of the solar resource at a

variety of time scales. POWER is partnering with modelers in NASA and NOAA to begin to evaluate methods of forecast the solar resource from weather and climate model output. In many cases, conventional output from these models will have to be changed or supplemented to improve computation of total, direct, and diffuse fluxes. The potential benefit of these forecasts is high within the energy sector. This work will become an increasing focus for the POWER project.

5. CONCLUSIONS

This paper briefly reviewed the status of the current Surface Meteorology and Solar Energy web site database as now being improved under the POWER project of the NASA's Earth Science Application Energy Management Program. POWER is improving historic datasets by adapting improved satellite measurements and analysis from NASA satellite missions, meteorological analysis and aerosol transport modeling to produce more reliable direct and diffuse solar fluxes. POWER is working towards developing datasets and methodologies of producing solar resource estimates within a week of the actual satellite measurement. Lastly, POWER is beginning partnerships to evaluate methods of estimating solar resource from atmospheric model output from short-term to climate time scales. All this work is being performed through partnerships in government and industry with the purpose of improving decision support systems and design tools needed to optimize solar power systems.

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