Renewable Energy Data Sets From NASA Satellites And Research

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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. The Surface Meteorological and Solar Energy (SSE) dataset provides internet-based access to parameters tailored for renewable energy system design needs including solar and wind power systems (1). These parameters have been shown to be accurate enough to provide reliable solar resource data over regions where surface measurements are sparse or nonexistent (2, 3). Now, NASA has established the Energy Management theme within the ESE Applications Program. Under this program, the Prediction of Worldwide Energy Resource (POWER) project has been initiated 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 initiated while developing the SSE-dataset, including the Department of Energy National Renewable Energy Laboratory (NREL) and the Natural Resources Canada (NRCan) organization of the Canadian government. This paper gives an overview of the NASA POWER/SSE activities related to the development of parameters for the renewable energy industries.

2. SSE CURRENT STATUS

Chandler et al. (1) describes the SSE Release 4 dataset available through the internet at <http://eosweb.larc.nasa.gov/sse/> and presents an assessment of data quality. SSE Release 4 now contains over 200 parameters computed from a period spanning July 1983 through June 1993. Most parameters are available for the 10-year average of each month, but daily averaged and monthly averaged 3-hourly variables are available for some parameters (i.e., cloudiness, surface insolation, and winds). 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 features of the web site emphasizing the direct linkages with several governmental and industry partners such as RETScreen® (6) and SolarSizer™ (7). POWER is continuing the efforts, through its partnerships, to provide improved datasets for decision support tools in convenient and accessible ways to aid in the design and implementation of renewable energy systems.

POWER's partnership with NREL has led to providing data to the United Nation Environmental Programme (UNEP) Solar and Wind Energy Resource Assessment (SWERA) data project archive, participation in upgrading the National Solar Radiation Database (8) and an effort to add direct links from the web site to NREL's HOMER. POWER continues to search for decision support tools and databases for which inclusion of NASA data and modeling can lead to systematic improvements.

3. NEAR FUTURE SSE UPDATES

3.1 *Improvements to Solar Energy Parameters*

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. (9) method for the estimation of the diffuse (and thus, direct) irradiance poleward of 45°. Surface albedos are a key input to the tilted irradiance calculations. Accordingly, maps of surface albedo are being developed and 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. Results from the tilted irradiance calculations along with the surface albedo maps will soon be available on the POWER web site.

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 (10). These solar fluxes are now derived from the International Satellite Climatology Cloud Project (ISCCP) DX data (11) that is processed to derive satellite radiance and cloud properties on a 1° latitude by 1° longitude. The cloud and fluxes properties on a 1°x1° grid represents a major upgrade to SSE Release 4 because this version has cloud, precipitable water and solar flux data bi-linearly interpolated to 1°x1°. The new SRB dataset spans the time period from July 1983 through October 1995 and includes solar fluxes inferred using two different algorithms (9). One SW (Shortwave) algorithm is based on Pinker and Laszlo (12) and the other SWQC (Quality Check) algorithm is based upon Darnell et al (13) as updated by Gupta et al (14). Note, that the solar fluxes in the SSE- release 4 dataset are inferred from an earlier version of the SWQC algorithm. All the cloud and solar parameters currently available in the SSE-dataset will be re-computed using the new cloud and solar flux data applying the same methodologies as described on the SSE-web site. Figure 1 gives an example of the new SRB surface solar flux in terms of industry units for January 1986.

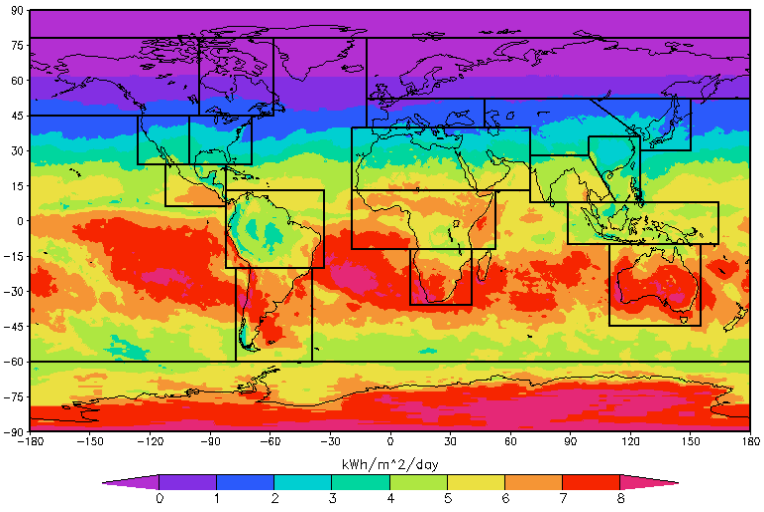

Figure 1: Surface solar insolation for January 1986 from the latest run of the GEWEX SRB SW algorithm converted to SSE format. Outlined in black are land surface regions within which surface measurements are compared to the satellite based estimates for validation and assessment.

Ground site observations from World Radiation Data Centre, supplemented by other more local networks, are being compared to original SSE fluxes and new GEWEX SRB fluxes to evaluate the new products. This comparison is being performed within geographical regions as shown in Figure 1. Averaged over time (i.e., 10 years) and space (i.e. regions), the three datasets (GEWEX SRB – SW and SWQC and SSE-4) yield similar statistics with the overall monthly averaged 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 show 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.

3.2 *Improvements to Wind Energy Products*

SSE Release 4 dataset provides wind products (speed, direction, etc.) at an altitude of 50m using GEOS-1 surface parameters (pressure, temperature, surface layer thickness and wind speed and direction) averaged every 3 hours. Under the POWER Project, these products are being extended to higher altitudes to support the design of wind turbines installed 100 m or more above the surface of the earth. Preliminary work has been completed using the Gipe power law equation (15) to estimate wind speeds at 110 m from the 50 m wind estimates. Winds at various altitudes can be computed using the Gipe power law (15) as given by:

$$V = V_o * (H / H_o)^{\alpha},$$

where V_o is the wind speed at the original height H_o, α is the surface roughness exponent specified as a function of surface vegetation (15), V is the wind speed at the new height H. As an example, Figure 2 shows the global wind for January 1986 computed at a height H of 110m corresponding to a pressure of 1000 mb for an underlying grassland surface, which tends to be characteristic of airports sites where wind data for model validation is more readily available. The GEOS-1 data set also gives upper air prognostic fields including horizontal wind components at 18 levels every six hours (00Z, 06Z, 12Z, 18Z)(16). As first order validation, wind fields such as from Fig. 2 were compared to GEOS-1 1000 mb wind fields for all months of 1986 using surface types identified by GEOS-1 excluding areas with surface pressures greater than 1000 mb. The resulting wind speed exhibited an average bias of –0.3 m/s with an RMS of 1 m/s

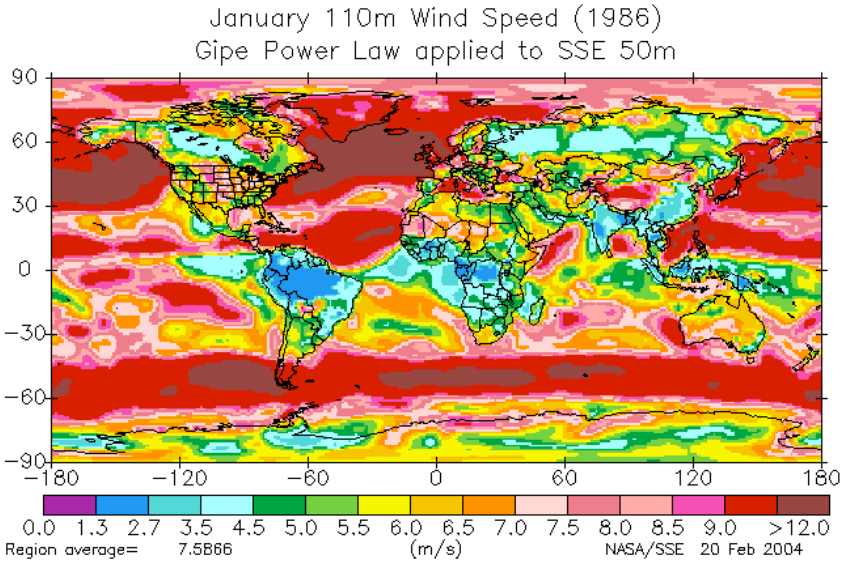

Figure 2: Gipe power law applied to the SSE 50-meter wind speed to elevate it to 110 meters over grassland surface representative of airports.

representing errors of approximately –4% and 12% respectively. Other methods are also being tested against this data. This work will be extended and refined with new GEOS 4.0.3 as it becomes available from the NASA Goddard Space Flight Center. SSE release 5.5, scheduled for the latter part of calendar year 2004, will incorporate the new wind products.

4. NASA POWER VISION AND PLANS

The NASA Earth Science National Applications program aims to move scientific data and knowledge directly to decision makers through partnering with governmental and other organizations. The long-term vision of the POWER project is to support this objective by providing improved long-term databases, faster updates to those databases from new NASA observations and analysis, and the development of the forecasted parameters from NASA and NOAA models. Table 1 presents this vision in schematic form for the next 5 years. 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 parameters such as direct and diffuse solar fluxes and winds for larger wind generation systems. POWER is also working towards developing datasets and methodologies of producing renewable energy resource quantities within a week of the actual satellite measurement and meteorological analysis (near-term datasets in Table 1). Lastly, POWER is beginning partnerships to evaluate methods of estimating renewable energy parameters from atmospheric model output from short-term to climate time scales. All this work is being performed through partnerships in

Table 1: NASA Energy Management POWER project plans for providing datasets and improved algorithms for historic and forecasted renewable energy information. Undefined acronyms: GMAO - Global Modeling and Analysis Office; CERES - NASA Clouds and Earth Radiant Energy Systems instrument and science team; MODIS - Moderate Imaging Spectrometer; LaRC (Langley Research Center) RAQMS – Regional Air Quality Forecast Model; NOAA NCEP SFM - National Center for Environmental Prediction Seasonal Forecast Mode; GFDL – Geophysical Fluid Dynamics Laboratory. NSIPP - NASA Seasonal-to-Interannual Prediction Project and climate forecast model teams; GISS - Goddard Institute of Space Studies.

POWER Historic, Near-term and Forecasted Datasets			
Data Sets/ Prototypes	**Timetable:**		
	2004	**2005-2006**	**2007-2008**
Historic SSE datasets	**SSE 5** (1983 – 1995; 1°x1° clouds and fluxes, refined solar, new winds) **SSE 5.5** (1995 – 2001; GEOS-4 meteorology, 1°x1°)	**SSE 6** (1983 – 2004, GEOS-4 add precip.)	**SSE 7** (1983 – 2004, GEOS-5, ½° x ½°, upgraded algorithms, aerosols, and precip.)
Near-term (within 1 week of real time; 6 month archival)		Prototype (global 1x1 from GMAO/CERES/MODIS + geosynchronous)	Operational (1-3 hourly, ½° x ½° degree)
Weather Scale (2, 7 day)	Prototype from NASA LaRC RAQMS model (2-day forecast)	Prototype from NOAA NCEP ensemble Wx forecasts	Operational prototype from NWS forecasts 2 and 7 days
Seasonal Scale (Month, 90 day, 1 yr)		Prototype from NASA NSIPP and NOAA NCEP SFM	Operational prototypes for 1 month and 1 season from NASA/NOAA
Climate Forecast			Prototype from NASA GISS and/or NOAA GFDL

government and industry with the purpose of improving decision support systems and design tools needed to optimize renewable energy systems.

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