Supporting Energy-Related Societal Applications Using NASA's Satellite and Modeling Data

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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 Science Mission Directorate Applied Science Energy Management Program. The purpose of this project is to tailor NASA Science Mission results for energy sector applications and decision support systems. 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 partners such as the National Renewable Energy Laboratory (NREL) and the Natural Resources Canada (NRCan). Energy Management and POWER plans including historic, near-term and forecast datasets are also overviewed.

Keywords-component; energy; solar energy; decision support systems

I. INTRODUCTION

NASA's Earth System Science 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 such as datasets from the NASA/GEWEX Surface Radiation Budget project. Within the last 10 years, it was found that these data could potentially benefit the energy-sector related systems design by providing environmental and climate data. This data is required for the optimization of energy production from renewable energy systems and the integration of the technology into structures that traditionally depend upon fossil fuels. To meet this need, NASA supported the development of the Surface Meteorological and Solar Energy (SSE) dataset providing internet based access to parameters designed for the photovoltaic and renewable energy system design needs [1]. Through SSE, it was shown that satellite-based products were accurate enough to provide reliable solar resource data over regions where surface measurements are sparse or nonexistent [2,3]. Now, NASA has established Energy Management theme within the NASA Science Mission Directorate Applied Science National Application 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 energy sector decision support sectors [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. The purpose of this presentation is to give an overview of the NASA POWER activities related to the development of parameters from long-term dataset from atmospheric datasets for energy sector industries including renewable energy technologies.

First, the current status of the SSE dataset is reviewed. 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. Lastly, the vision of POWER towards the development of future long-term

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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. The time frame of availability of such parameters will be discussed.

II. SSE Current Status

SSE has now been upgraded to version 5 that includes direct links to RETScreen™ [5], SolarSizer™ [6], and HOMER 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. Reference [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 5.1 now contains over 200 parameters computed from a period spanning from July 1983 through June 1993 on a 1^{o}x1^{o} grid. All 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, etc.). Example global fields of each parameter are given in Figure 1.

The solar parameters are computed using a modified version of the Pinker and Laszlo algorithm [8] as processed under the NASA/Global Energy and Water Cycle Experiment (GEWEX) Surface Radiation Budget (SRB) project (Release 2.0, [9], [10]). The International Satellite Cloud Climatology Program (ISCCP) DX data are used as input into the algorithm and to derive the cloud information including cloud diurnal cycle [11]. Additional parameters available to the user and calculated on the fly via the SSE web interface also inherit these improvements. The current version includes a large number solar parameters including broadband total, direct normal, diffuse, and equator-facing tilted fluxes. It should be noted that the direct and diffuse components as well as the titled components are not provided directly from the SRB project. Instead, the total irradiance from SRB is used in conjunction with multiple algorithms, accepted by the solar energy researchers, to compute the diffuse, direct normal and tilted surface fluxes to obtain a range of estimates.

The data set also contains several other new supporting parameters designed to useful for system design. These include a new wind parameter called the "Monthly Averaged Wind Speed Adjusted For Height And Vegetation Type" can be calculated for 17 different surface vegetation types and for any height from 10 to 300 meters. The location, vegetation type and height are specified by the user. The Gipe Power Law [12] is used to calculate a new wind speed from the wind speed at 50 meters above the surface that is computed from output of the Goddard Earth Observing System (GEOS) version 1 analysis [13]. Validation of surface winds using this approach at airports and other surfaces is provided in the SSE Accuracy and Methodology sections. Global/regional plots for wind speed at 100 and 150 meters are also available. When using this data it is important to note that these are coarse resolution data meant to fill gaps where conventional wind data is unavailable. High resolution wind maps may be preferred depending on the specific application. However, these gross winds are adjustable depending upon the surface roughness and the web site does give quick access to wind profile estimates.

In addition to the parameter changes some aspect of the web itself were also upgraded. For instance, 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.

III. 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/GEWEX SRB project. The project has just recently completed a 21.5 year run spanning from July 1983 through December 2004 using the GEOS-4 reanalysis meteorology [14]. All the cloud and solar parameters will be computed using the additional years cloud and solar flux data applying the same methodologies as described on the web site.

The validation strategy shown in [15] is currently being repeated to compare the previous version of SSE to the newly derived fluxes. This new analysis will be available upon release of the data set. The longer version will also provide the opportunity to compare to 10 years of Baseline Surface Radiation Budget Data (BSRN). The remaining meteorological parameters are being validated using the National Climate Data Center global database of surface measurement sites include surface temperature, dewpoint and winds. The validation against both the both the radiometer network and the NCDC database will be available upon release of the latest SSE version. The upgrade of SSE version 5.1 to the new resolution version 5 data products is scheduled for completion in summer 2006.

IV. 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. 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 collaboration

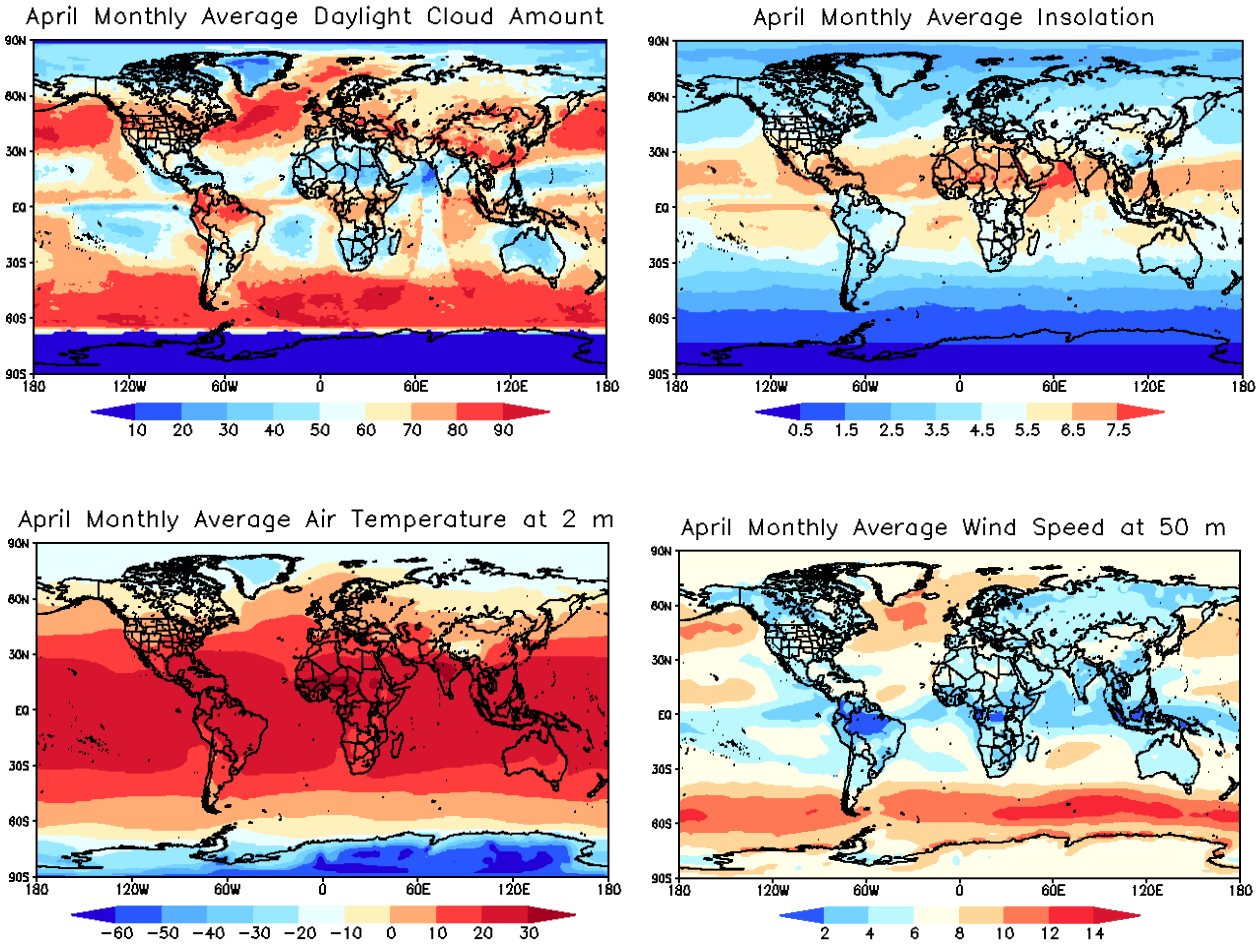

Figure 1: Sample global fields for the 10-year averaged (1984-1993) April as tailored from the ISCCP, GEWEX SRB, and GMAO GEOS 1 projects for applications in the renewable energy sectors. The parameters are clockwise from upper left: a) daylight cloud amount, b) global solar insolation (kWh/m^2/day), c) surface air temperature at 2 m (K), and d) average wind speed at 50 m above the surface (m/s).

between the National Renewable Energy Laboratory (NREL) under the current Memorandum of Understanding between NASA and NREL.

A. Historic Data Sets

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 [16]. Also, NASA GMAO has completed and is still processing the GOES-4 assimilation from 1980 through present. This product will feature much improved column water vapor and surface skin temperatures. POWER will be collaborating with NASA/GEWEX SRB to produce the first 21+ year record of these quantities. This longer data set will play a increased role in the NREL effort to upgrade the National Solar Radiation Database (NSRDB). 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.

B. New More Focused Prototypes

The POWER project has also released two new prototypes more specifically designed to meet the needs of sustainable building engineers and architects as well as agricultural applications. These prototypes can be found currently at the web site:

http://earth-www.larc.nasa.gov/solar/power

This is an active site with regularly updated data products for evaluation of the community. Some of the 21 year solar energy and meteorological data that will eventually be

released in SSE Release 6 are found at this page. Included is the daily averaged time series from the entire period.

C. Near-Term Records

POWER is also collaborating with a team of investigators for a project called FLASHFlux (Fast Longwave and Shortwave Radiative Fluxes from CERES and MODIS) eto develop global gridded solar irradiance estimates within one week of observation from NASA satellite platforms Terra and Aqua. The system is now operationally producing orbital data and the gridded data sets are expected to be operational without a couple months. The processing system will eventually be modified to use geosynchronous data with the advantage of increased temporal resolution and 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.

D. Energy Management Forecasting

Part of the usefulness of the near-real time products will be realized in longer term forecasts. Seasonal forecasts require initialization data sets such as from FLASHFlux to improve ensemble forecasts for seasonal to 1-2 year forecasts. POWER is also collaborating with a Pacific Northwest Regional Laboratory to support long-term parameters required for energy market forecasts. Lastly, POWER has begun collaborative work to evaluate the usefulness of operational weather forecasts for renewable energy applications.

V. 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 Applied Science 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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