PROGRESS TOWARDS DERIVING AN IMPROVED LONG-TERM GLOBAL SOLAR RESOURCE

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ABSTRACT

This paper describes an ongoing project to provide the National Renewable Energy Laboratory (NREL) with a global long-term advanced global solar mapping production system for improved depiction of historical solar resources and to provide a mechanism for continual updates. This new production system is made possible by the efforts of NASA and NOAA to completely reprocess the International Satellite Cloud Climatology Project (ISCCP) data set that provides satellite visible and infrared radiances together with retrieved cloud and surface properties on a 10 km, 3-hourly basis beginning July 1983. We provide a general overview of this project, samples of the new solar irradiance mapped data products, and comparisons to surface measurements. Samples of the use of the SUNY-Albany solar irradiance algorithm applied to the ISCCP data show very good agreement with high quality surface measurements. We identify the next steps in the production of the data set.

1. INTRODUCTION

Considering the possibility of global climate change and the global competition for energy resources, there is an increasing need to provide improved global Earth surface solar resource information. The capability to improve and produce long-term records is needed to better understand and quantify potential shifts in the solar resource with changes in climatic weather patterns. Toward this end a project was funded under the NASA Applied Science program involving the National Aeronautics and Space Administration (NASA), National Renewable Energy Laboratory (NREL), the State University of New York/Albany (SUNY) Atmospheric Science Research Center (ASRC) and the NOAA National Climatic Data Center (NCDC) to provide NREL with a global long-term advanced global solar mapping production system for improved depiction of historical solar resources and variability. An additional goal of the project is and to provide a mechanism for NREL to continually update solar resource information on a global scale. This new production system is made possible by the efforts of NOAA and NASA to completely reprocess the International Satellite Cloud Climatology Project (ISCCP) data set that provides satellite visible and infrared radiances together with retrieved cloud and surface properties on a 3-hourly basis beginning from July 1983. The old version of the ISCCP data provided this information for all the world's available geosynchronous satellite systems and NOAA's AVHRR data sets at a 30 km effective resolution [1]. This information plus additional atmospheric information was used in NASA GEWEX Surface Radiation Budget project to produce the first global long-term maps for solar irradiance at a 1x1

degree resolution which became the basis for the NASA's Surface meteorology and Solar Energy web portal (SSE, [2,3]). This new version will provide a new and improved satellite calibration at an effective 10 km resolution. Unfortunately, the new version of ISCCP has suffered substantial delays now exceeding 2 years and will not be ready for production at NCDC until later in 2013. Therefore, an existing data set, entitled the ISCCP B1U [4] has been used to test the development of the algorithms and the eventual data production system. Additionally, a new reformatted data set has become available from NOAA NCDC entitled GridSat [5]. GridSat also contains all the world's geo-synchronous satellite radiances from 70° N to 70° S. The advantage of GridSat is its gridded structure that also includes the IR channels from those satellites. Thus, working with SUNY, NASA continues to develop and test an improved production system that will enable the longest-term global solar resource database to date at 10 km spatial resolution using these alternative data sets as a first test climatology. Separate efforts to improve and update this preliminary climatology will be attempted once the new version of the ISCCP data set is produced.

   This paper provides an overview of the current status of this project together with early results in the testing and validation of the improved algorithms from SUNY and NASA. Lastly, we will identify the next steps in the production of the data set including some accuracy goals for which the effort is aiming.

2. INITIAL RESULTS WITH ISCCP B1U

To obtain an early test of the eventual data products, the current version of the ISCCP B1U was tested [6]. The ISCCP B1U data set, prepared and archived by NCDC, contains the full ISCCP 8-10 km resolution by satellite for the world's geosynchronous platforms (i.e., US GOES, Japan's GMS, Europe's METEOSATs). This data set does not contain improved inter-calibration, cloud properties nor any polar orbiting data sets from NOAA's AVHRR imager. However, together with ancillary data sets, there was enough data to evaluate the application of the SUNY ASRC solar algorithm [7] to this data set. As a

BSRN Station	Time Period	Satellite Platform
Lauder, New Zealand	2006	MTS-1
Nauru Island	2002-2003	GMS-5, GOES-9
Lindenberg, Germany	1996-1997	MET-5, MET-6
Sede Boqer, Israel	2006-2007	MET-5, MET-7
Carpentras, France	2006-2007	MET-8, MET-9
Florianopolis, Brazil	1995-1996	GOES-8

Fig. 1: Six BSRN surface sites chosen for validation of SUNY ASRC solar algorithm.

MODEL WITH RANKING PROCEDURE APPLIED										
Location / Satellite	Lauder MTS 1	Nauru GOES 9	Nauru GMS 5	Lindenberg MET 6	Lindenberg MET 5	Sede Boqer MET 7	Sede Boqer MET 5	Carpentras MSG 2	Carpentras -- MSG 1	Florianopolis GOES 8
Mean GHI (W/sq.m)	163	239	197	145	109	233	243	190	165	105
unmodified model										
Count model MBE	3.5%	0.2%	8.8%	-3.1%	2.1%	2.4%	1.7%	-1.6%	2.2%	4.4%
Reflectivity model MBE	2.8%	11.8%	11.3%	-3.9%	0.0%	1.5%	1.3%	-1.5%	1.8%	4.4%
Count model MAE	26.1%	18.5%	20.8%	20.1%	22.9%	11.8%	12.4%	9.6%	12.6%	23.1%
Reflectivity model MAE	26.3%	19.3%	22.1%	20.7%	23.2%	12.5%	12.7%	9.4%	12.1%	23.9%

Fig. 2: Validation statistics for SUNY ASRC count and reflectivity models compared to BSRN surface measurements. MBE is Mean Bias Error. MAE is Mean Absolute Error.

further test of the usefulness of this data, solar flux time series were produced at a number of Baseline Surface Radiation Network sites The SUNY algorithm has recently been further validated against several BSRN surface sites, covering a range of geostationary satellites and surface types. The stations are shown in Figure 1 and the results in Figure 2. Mean bias errors in Global Horizontal Irradiance are generally within 3-4% for the version of the model that uses visible counts as primary input.

3. PROPOSED PRODUCTION SYSTEM

The eventual production of a long-term solar resource capability that will be delivered to NREL for production will require a considerable amount of ancillary data besides the ISCCP data sets. Data products such as column water vapor, ozone, snow/ice cover, aerosol optical properties, surface ground cover and reflectivity are important to the quality of the data products. To facilitate this, a production strategy has been devised and is shown schematically in Figure 3. Work to date has aimed at providing these inputs and the development of the production code. For instance, a time series of the Total Solar Irradiance has been constructed using the new finding of the NASA SORCE (Solar Radiation And Climate Experiment) mission that the solar constant is approximately 1361 W m^{-2} [8]. Additionally, a new blended global ozone data product has already been developed for the production. Tests of various sources of column water vapor information are underway. One source being evaluated is the Modern Era Retrospective-analysis for Research and Applications (MERRA, [9]).

Lastly, a global background aerosol climatology has been adapted and tested within the SUNY model. This climatology does span the entire period of the new solar climatology and can be augmented with important aerosol events in time, such as from volcanic aerosol. Prototypes from these various inputs are identified in Figure 3 which also depicts the production flow of the data sets to temporally averaged solar flux data products. The resulting
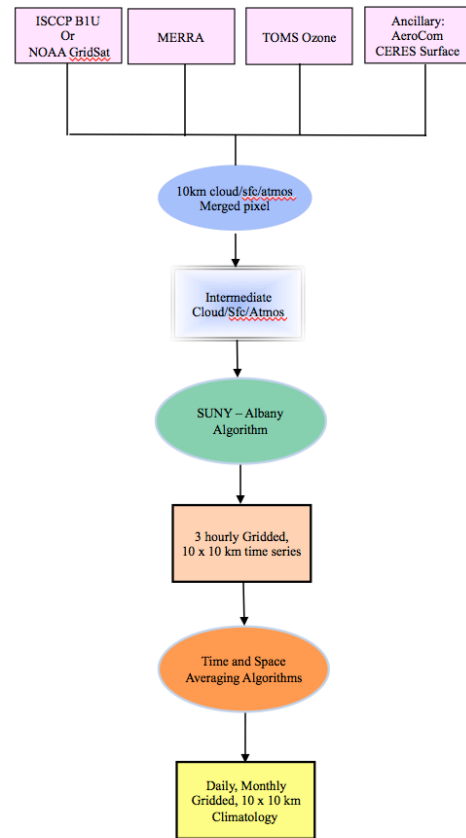

Fig. 3: The proposed production system for the development of solar resource data products for preliminary climatology based upon either the ISCCP B1U or the GridSat data sets. The data product record would commence in July 1983 and span as close to present as possible. Both the B1U and GridSat are available at NCDC and the solar resource production system will assess the SUNY ASRC solar algorithms to derive the new data products.

data will be accessible as a time series for specific latitude longitude coordinates. The final output parameter list will include surface meteorological quantities from the MERRA data set, as identified above.

4. FUTURE WORK

Results to date are preliminary but show promise for using NOAA GridSat data set to produce the first long-term nearly global surface solar irradiance data set at 10 km to span nearly 30 years. Subsequent, improvements will be attempted once the next improved version of the ISCCP data set is released. More specifically, the next steps are planned during the course of this project are outlined below:

- Continued testing of the ISCCP B1U/GridSat data set using the SUNY ASRC model and comparing both to surface measurements and currently available data sets from SRB and SUNY.
- Evaluation of the merged ISCCP B1 geostationary product known as GridSat as primary input. GridSat produces 3-hrly data on an 10 km grid, using all available geostationary satellites, and preferentially selecting the satellite with most favorable view angle where there is overlap. If this product proves viable for our purposes, it would greatly simplify pre-processing. A sample GridSat image is shown in Figure 4.
- Finalization of the ancillary input required for the long-term production of the data products
- Completion of the production system by adapting current production systems in collaboration with SUNY.
- NASA/SUNY and NCDC collaborate to assess new ISCCP data products and incorporate into the production system. Testing of both SUNY and NASA solar algorithms using the new data sets via comparison to surface measurements
- Evaluation of the new products by comparing against currently available solar irradiance products available from the National Solar Radiation Data Base (NSRDB) and surface measurements.

The goal of this work is the complete production and delivery to NREL of the most advanced global solar resource data products and capability possible. Allowing for the continual production of the solar resource should provide the means to continue to update these solar resource databases into the future.

5. ACKNOWLEDGEMENTS

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Visible reflectance near 0.6 microns: Jan. 1, 2006 00 UT

Visible reflectance

0.00   0.20   0.40   0.60   0.80   1.00
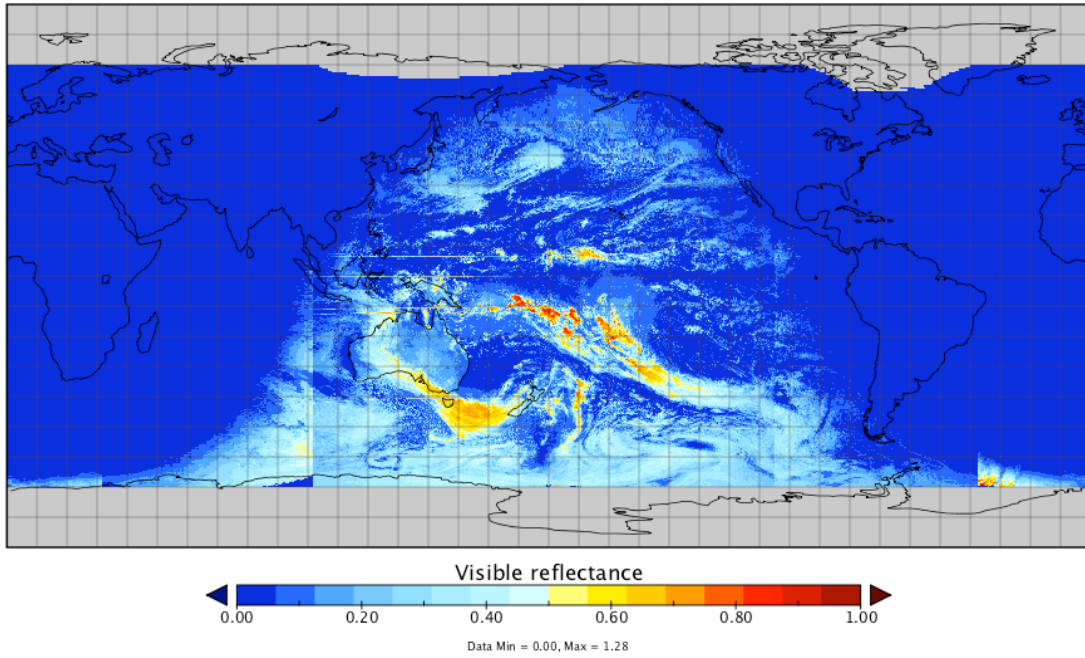
Data Min = 0.00, Max = 1.28

Fig. 4: Sample image of visible reflectance from GridSat project, which merges all available geostationary data into a 3-hrly, 8 km gridded product. GridSat is currently being evaluated as an input source for the algorithms described here.