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IMPROVING SURFACE RADIATION IN A SATELLITE-BASED PHYSICAL MODEL

Manajit Sengupta, Aron Habte, and Peter Gotseff
National Renewable Energy Laboratory
15013 Denver West Parkway, Golden, CO 80401, USA

MOTIVATION

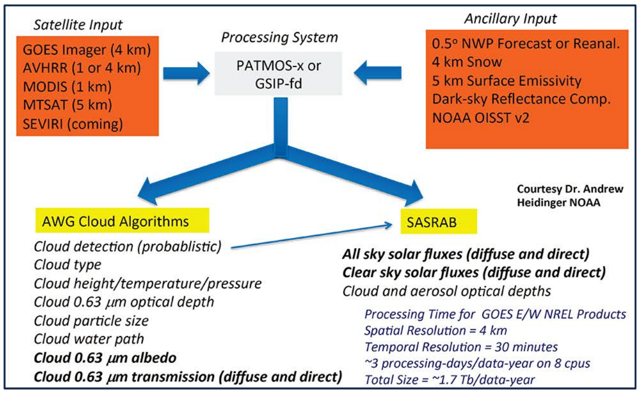
Solar resource assessment is needed to achieve high penetrations of concentrated solar power or photovoltaic on the grid. This requires -

- **Accurate information about the availability of the solar resource**
- **Information about factors that influence the solar resource**
- **Spatial and temporal variability of the solar resource**

GOALS

- **Develop physics-based method to improve solar resource assessment**
- **Validate satellite product with ground measurements**
- **Improve satellite product**

PHYSICAL METHOD FOR REAL-TIME PROCESSING OF CLOUDS AND SOLAR RADIATION



RESULTS: PRODUCTS DERIVED FROM PHYSICAL METHOD FROM GOES-11 (WEST) GEOSTATIONARY SATELLITE

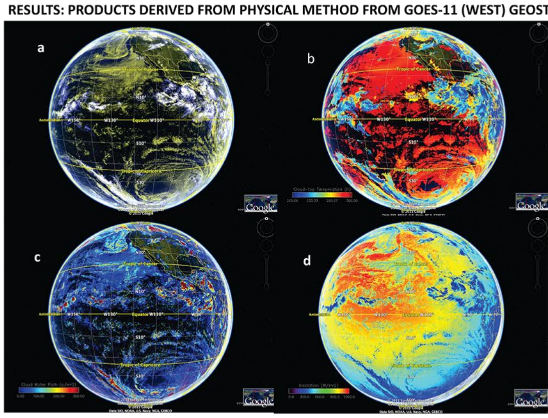
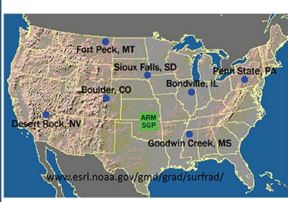


Figure 1: Output from GOES-11 (West) for physical method—
(a) 0.65 + 11 μm false color image;
(b) Cloud-top temperature in K;
(c) Cloud integrated water path (g/m²); and
(d) Global horizontal irradiance (W/m²).
Note that information from (a), (b), and (c) can be used in a radiative transfer model to produce the results in (d).

VALIDATION: GROUND MEASUREMENT STATIONS FOR PRODUCT VALIDATION – NOAA SURFRAD



DATA STREAMS:
Global horizontal irradiance (GHI), direct normal irradiance (DNI), diffuse, wind speed and direction, temperature, pressure, relative humidity, aerosol optical depth

Code							
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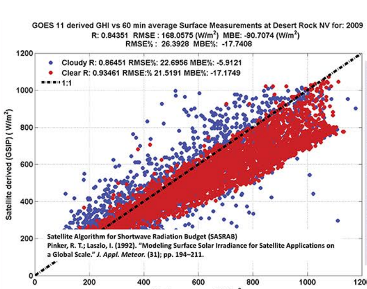


Figure 2: Comparison of surface measurements from Desert Rock, Nevada, with satellite retrievals using the physical model. Data from GOES-11 for 2009 was used. The satellite pixel resolution was 4 km and the temporal resolution was 30 min. Clear-sky periods from the satellite retrieval are in red; the cloudy periods are in blue. The radiative transfer model used is the SASRAB (Pinker and Laszlo 1992) model. During clear-sky periods, the satellite product has a clear low bias (-17%). The cloudy-sky periods have a much lower bias (-5%).

POSSIBLE REPLACEMENTS FOR THE SASRAB MODEL:

1. BIRD Model – (Bird and Hulstrom): Bird, R.E.; Hulstrom, R.L. (1981). A *Simplified Clear-Sky Model for Direct and Diffuse Insolation on Horizontal Surfaces*. SERI/TR-642-761. Golden, CO: Solar Energy Research Institute.

1. SOLIS – (Ineichen): Ineichen, P.; Perez, R. (2002). "A New Air Mass Independent Formulation for the Linke Turbidity Coefficient." *Solar Energy* (73); pp. 151–157.

1. REST2 – (Gueymard): Gueymard, C.A. (2008). "REST2: High-Performance Solar Radiation Model for Cloudless-Sky Irradiance, Illuminance, and Photosynthetically Active Radiation—Validation with a Benchmark Data Set." *Solar Energy* (82); pp. 272–285.

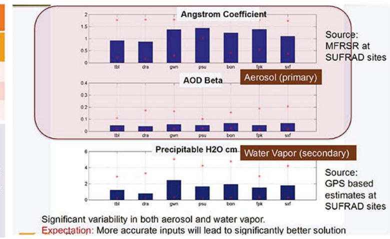
EXPERIMENTAL SETUP

Two goals:

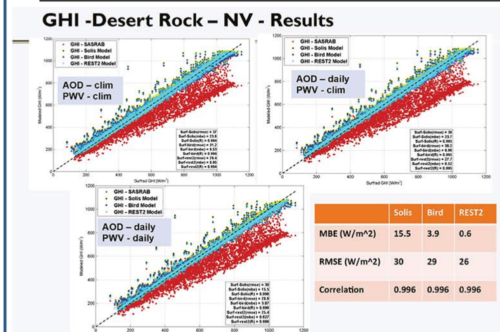
- Choose the best-performing radiative transfer model (speed and accuracy)
- Determine the need for high-resolution primary and secondary inputs

	Inputs to Radiative Transfer Models	
Cases	Aerosol (primary)	Water Vapor (secondary)
Case 1	Climatological	Climatological
Case 2	Daily	Climatological
Case 3	Daily	Daily

Fig. 3. Plot showing aerosol and water vapor properties from each of the seven SURFRAD stations. The blue bars show the annual means for 2009, and the red stars represent the ranges. Note that aerosols are the primary drivers of solar radiation in clear-sky situations.

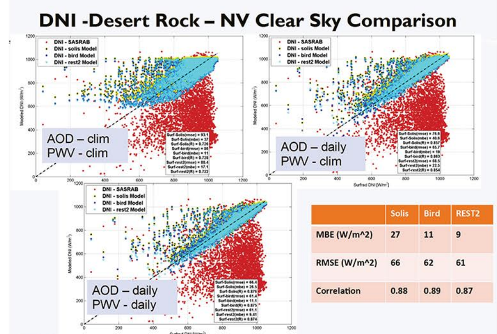


RESULTS: COMPARISON OF RADIATIVE TRANSFER MODEL ACCURACY



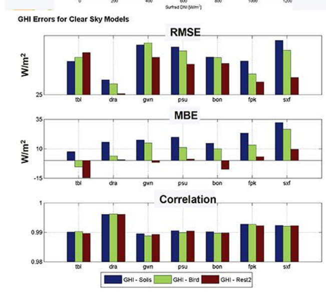
	Solis	Bird	REST2
MBE (W/m^2)	15.5	3.9	0.6
RMSE (W/m^2)	30	29	26
Correlation	0.996	0.996	0.996

Fig. 4. Comparison of the three models for the three cases for GHI are shown here. Note the slight improvement from using daily input values. Resulting statistics are shown in the table.



	Solis	Bird	REST2
MBE (W/m^2)	27	11	9
RMSE (W/m^2)	66	62	61
Correlation	0.88	0.89	0.87

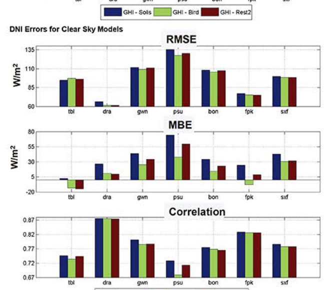
Fig. 5. Comparison of the three models for the three cases for DNI are shown here. Note the significant improvement from using daily input values. Resulting statistics are shown in the table.



	Solis	Bird	REST2
MBE (W/m^2)	20	9	-1
RMSE (W/m^2)	39	37	33
Correlation	0.99	0.99	0.99

Fig. 6. Comparison of GHI from the three models for the daily input case for seven SURFRAD stations. Note that the REST2 model has the lowest bias error (MBE) when all stations are considered.

Model	Timing (μsec)
Solis	3.95
Bird	4.12
REST2	6.23



	Solis	Bird	REST2
MBE (W/m^2)	40	14	22
RMSE (W/m^2)	100	96	97
Correlation	0.80	0.78	0.78

Fig. 7. Comparison of DNI from the three models for the daily input case for seven SURFRAD stations. Note that the BIRD model has the lowest bias error (MBE) when all stations are considered.

CONCLUSIONS

- **SOLIS, BIRD, and REST 2 significantly reduce errors created by the SASRAB model.**
- **High-temporal-resolution aerosol and water vapor information is important especially for accuracy in DNI.**
- **GHI is best estimated by REST2, whereas DNI is best estimated by the BIRD model.**
- **BIRD has significantly faster performance than REST2.**
- **The BIRD model has been chosen for other analysis, but the capability to use any of the three models has been developed.**

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