UPDATE OF THE NATIONAL SOLAR RADIATION DATABASE (1998-2016) : VERSION 3

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Support the U.S. Department of Energy (DOE) SunShot goal of reducing solar deployment and financing costs through improving accuracy in solar resource modeling. Funded by the SI subprogram of DOE EERE Solar Energy Technology Program

### Application of Solar Resource Information

<table>
<thead>
<tr>
<th>Phase</th>
<th>Data</th>
<th>System</th>
</tr>
</thead>
</table>
| 1. Pre-Feasibility           | • Spatial variability  
• Annual values  
• Uncertainty          | Legal subsidies  
Technology selection       |
| 2. Feasibility               | • Hourly values  
• Annual variability  
• Preliminary TMY      | Design optimization  
Yield assessment         |
| 3. Due Diligence & Acceptance| • Minutely values  
• Daily variability  
• Final TMY            | Final design  
Detailed profitability assessments |
| 4. Operation & Management    | • High quality values  
• Forecast data  
• Uncertainty        | Real energy yield  
Operation strategies     |

Source: [https://www.nrel.gov/docs/fy18osti/68886.pdf](https://www.nrel.gov/docs/fy18osti/68886.pdf)
Outline

• Evolution of NSRDB
• The Physical Solar Model (PSM)
• What’s new in PSM Version 3
• Validation of the NSRDB
• GOES East and West Comparisons
• Typical Meteorological Year (TMY)
• Accessing NSRDB and available parameters
• Future Work
Evolution of the National Solar Radiation Database

- **SOLMET 1977–80**: 248 weather stations with 26 Solar measurement stations [ERDA, NOAA, 1979]
- **NSRDB 1961–1990**: 239 modeled stations with 56 partial measurement stations [DOE, NOAA, 1994]
- **NSRDB 1991–2010**: 1,454 modeled locations [DOE, CPR, 2012]
- **NSRDB 1998–2016**: Satellite-based, gridded, 4 km x 4 km, half-hourly [DOE, NOAA, UW, SCS 2016]

[http://nsrdb.nrel.gov](http://nsrdb.nrel.gov)
Physical Solar Model (PSM) Framework

- GOES: Cloud Properties
- MERRA2: Atmospheric Profile
- MODIS: Aerosol Properties
- IMS: Surface Albedo
- Snow Albedo

FARMS

- GHI
- DNI
- DHI
NSRDB (PSM-V3): What’s New

- Snow-free Surface Albedo from MODIS (2001-2015) (MCD43GF CMG Gap-Filled Snow-Free Products from University of Massachusetts, Boston).
- Snow cover from Integrated Multi-Sensor Snow and Ice Mapping System (IMS) daily snow cover product (National Snow and Ice Data Center).
- GOES-East time-shift applied to cloud properties instead of solar radiation.
- Ancillary data (pressure, humidity, wind speed etc.) from MERRA2.
NSRDB Version 2 and 3 Comparison

DNI Version 2

GHI Version 2

DNI Version 3

GHI Version 3
Validation of NSRDB Using Surface-Based Measurements

Surface Radiation (SURFRAD) Network, NREL’s Solar Radiation Research Laboratory (SRRL), and the Atmospheric Radiation Measurement (ARM) Southern Great Plains locations

Uncertainty estimation includes:
- MBE
- RMSE
- Surface measurement uncertainty.
Validation of NSRDB Using Surface-Based Measurements

**Difference between the two versions:**
- MERRA-2 AOD vs climatological AOD
- Precipitable water vapor from MERRA2
- Surface Albedo from MODIS and Snow Cover from IMS
- Some of downscaling calculations for ancillary variables
- Time shifting method on GOES East.
GOES East and West Comparison

Global Horizontal Solar Irradiance
National Solar Radiation Database Physical Solar Model

About the Data
This map includes all available data for the years 1981 through 2010, excluding any data from 1983.

For more information, visit https://nrel.gov/solar/solarpro.html.
GOES East and West Comparison

West Satellite Minus East Satellite

GHI KWH/M2/DAY
- < -0.2
- -0.1
- -0.05
- 0.05
- 0.1
- > 0.2
GOES East and West Comparison with Surface Measurements

### West

- **MBE All**: -1%
- **MBE Clear**: 2%
- **MBE Cloudy**: -6%

### East

- **MBE All**: 0%
- **MBE Clear**: 0%
- **MBE Cloudy**: 1%

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**Hourly GHI NSRDB West vs Surface Measurements at Eugene: 2015**

- **NSRDB West All Sky R**: 0.97 RMSE: 15% MBE: -1%
- **NSRDB West Clear R**: 0.98 RMSE: 9% MBE: 2%
- **NSRDB West Cloudy R**: 0.92 RMSE: 24% MBE: -6%

**Hourly GHI NSRDB East vs Surface Measurements at Eugene: 2015**

- **NSRDB East All Sky R**: 0.95 RMSE: 17% MBE: 0%
- **NSRDB East Clear R**: 0.99 RMSE: 5% MBE: 0%
- **NSRDB East Cloudy R**: 0.9 RMSE: 27% MBE: 1%
## GOES East and West Comparison with Surface Measurements

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
<th>All</th>
<th>Clear</th>
<th>Cloudy</th>
<th>All</th>
<th>Clear</th>
<th>Cloudy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashland</td>
<td>42.19</td>
<td>-122.7</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>-5</td>
</tr>
<tr>
<td>Burns</td>
<td>43.52</td>
<td>-119.02</td>
<td>0</td>
<td>2</td>
<td>-1</td>
<td>-1</td>
<td>2</td>
<td>-7</td>
</tr>
<tr>
<td>Eugene</td>
<td>44.05</td>
<td>-123.07</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>2</td>
<td>-6</td>
</tr>
<tr>
<td>Silverlake</td>
<td>43.12</td>
<td>-121.06</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>1</td>
<td>-7</td>
</tr>
</tbody>
</table>

![Graph showing MBE% comparison between GOES East and West with surface measurements for Ashland, Burns, Eugene, and Silverlake stations.](image-url)
COV ($\sigma/\mu$) using 5x5 pixels. Each NSRDB pixel is 4km x 4km.

COV is higher in regions with terrain impacts: closest pixel to location should be used. Measurements should be taken as close as possible to actual location.
Calculation of PV generation using TMY after converting to single-axis tracking solar resource using Perez transposition model.

TMY represents median for horizontal but does not represent the median for other orientation.

Do we need tilt-specific TMY?
USA and North and South America:

- Current product (4-km, half-hourly) available from 1998–2016 (Model V3)
- Typical meteorological year (TMY) product is also available.
- Multiple summary products are available with current data sets.

https://nsrdb.nrel.gov
15 Variables are Delivered Publicly:

<table>
<thead>
<tr>
<th>Dataset in the NSRDB</th>
<th>Publicly available datasets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MERRA-2</strong></td>
<td>Global horizontal irradiance (GHI)</td>
</tr>
<tr>
<td>Atmospheric pressure</td>
<td>Direct normal irradiance (DNI)</td>
</tr>
<tr>
<td>Surface albedo</td>
<td>Diffuse horizontal irradiance (DHI)</td>
</tr>
<tr>
<td>Aerosols</td>
<td>Clear-sky GHI, DNI, and DHI</td>
</tr>
<tr>
<td>Aerosol optical thickness</td>
<td>Cloud type</td>
</tr>
<tr>
<td>Single scattering albedo</td>
<td>Dew point**</td>
</tr>
<tr>
<td>Aerosol Angstrom parameter.</td>
<td>Air temperature*</td>
</tr>
<tr>
<td>Total ozone</td>
<td>Atmospheric pressure</td>
</tr>
<tr>
<td>Precipitable water.</td>
<td>Relative humidity**</td>
</tr>
<tr>
<td><strong>GOES (PATMOS-X retrievals)</strong></td>
<td>Solar zenith angle</td>
</tr>
<tr>
<td>Cloud effective radius</td>
<td>Precipitable water*</td>
</tr>
<tr>
<td>Cloud optical depth</td>
<td>Wind direction**</td>
</tr>
<tr>
<td>Cloud type.</td>
<td>Wind speed.**</td>
</tr>
<tr>
<td><strong>Moderate Resolution Imaging Spectroradiometer/National Snow and Ice Data Center</strong></td>
<td></td>
</tr>
<tr>
<td>Surface albedo.</td>
<td></td>
</tr>
</tbody>
</table>

* From MERRA-2
** Recalculated from MERRA-2
Future Work

- Improved identification and use of high albedo surfaces (sand and snow).
- Spectral data sets in the plane of array.
- Improved cloud retrievals from GOES-16.
- Aerosol retrieval from GOES-16.
- 5-min. data from GOES-16.

http://nsrdb.nrel.gov
Thank You!

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NSRDB: http://nsrdb.nrel.gov