Advancements in Satellite-Ground Tuning: DNI and DHI

Patrick Keelin
Clean Power Research

Julie Chard
GroundWork

May 1st, 2018
Presented at PVPMC 2018

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Acknowledgments

Skip Dise
Dir. Product Management

Justin Robinson
Technical Director
Agenda

- **Data Tuning Overview**
- **DNI: Why it matters**
- **DNI: Case Study**
  - Best practices for measuring DNI
  - DNI Tuning
  - Results
Solar Resource: Foundation for PV System Simulations

Satellite-based solar irradiance models

Advantages:
- Continuous geographical coverage (1 km resolution)
- Temporally solid and consistent (19+ years)
- Up to 15 minute frequency observations
- Site-specific historical weather observations
- Available on-demand

Limitations:
- Lower accuracy than highest quality ground observations
Value of Ground-based Solar Resource Monitoring

- High accuracy if properly maintained (dust, frost, snow, birds, event logging, etc.)
- Necessary to understand local variability effects
- Requires meticulous data QC
- Ground truth for tuning process
- Have to place into long term reference frame for proper resource context!
Low-Uncertainty, Long-term Solar Resource Dataset

Monthly Averaged Irradiance (W/m$^2$)

- Satellite (raw)
- Ground
Sources of satellite-model and ground irradiance differences:

- Clear sky bias (AOD, etc.)
- Seasonal
- Cloudy sky measurement error (satellite/ground mismatch, etc.)

Other considerations:

- Ancillary data including wind and temperature
- Irradiance rebalancing (DNI, DHI)

Differences need to be targeted individually during the tuning process.
Tuning Satellite Data with Ground: GHI

Uncorrected

Clear Sky + Seasonal

Clear Sky + Seasonal + Kt-based Cloud Correction

GHI - Ground
GHI - Satellite
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Motivation for Ground Resource Assessment

Investment in Ground Measurements Can Increase P99
Project uncertainty contains a number of factors. Where does DNI/DHI come into play?

\[ \varepsilon_p = \sqrt{\text{Solar Resource}^2 + \text{Interannual Variability}^2 + \text{Transposition to Plane of Array}^2 + \text{Soiling}^2 + \text{Other Model Factors}^2} \]

Impacts of high quality DNI / DHI measurement
Transposition to Plane of Array

Most common:
Decomposition model uncertainty

Emerging:
Measurement uncertainty

Transposition model uncertainty; depends on PV configuration, e.g. Tracker, Bi-facial modules...

Flow Chart Credit: Lave, M et al., Evaluation of Global Horizontal Irradiance to Plane of Array Irradiance Models at Locations across the United States, Sandia PV Performance Workshop
Decomposition uncertainty (I)

Higher uncertainty for DNI and DHI reflects decomposition uncertainty, and to a lesser degree ground measurement uncertainty.
Decomposition uncertainty (II)

Relative (to GHI) root mean squared (rMSE) and mean bias (rMBD) difference (modeled minus measured) for each of the 12 decomposition models (x-axis) at each of the five stations with DHI measurements.

Credit: Lave, M et al., Evaluation of Global Horizontal Irradiance to Plane of Array Irradiance Models at Locations across the United States, Sandia PV Performance Workshop

Dependence of the RMS error for ten transposition models on the quality of input data for 40 deg tilt at SRRL.

Credit: Gueymard, C.A., From Global Horizontal To Global Tilted Irradiance, Solar 2008 ASES
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Best Practices for Ground Measurement

• High quality instrumentation
• Weekly or more frequent maintenance
• Redundant irradiance measurements
• Actionable data quality program
• 1 year minimum campaign, 2 preferred¹
• Descriptive metadata

High quality instrumentation

Secondary Standard GHI & DHI + DNI

⇒ DNI Measurement Uncertainty 2.3%
Not high quality instrumentation

“First Class” Measured GHI & DHI + Calculated DNI
→ DNI Measurement Uncertainty ~10%" for the RSR (LI-200) and SPN1
Importance of frequent maintenance

Sensor soiling test at the University of Almería in May 2008. The DNI measured by an RSI showed a ten times lower sensitivity to soiling (0.07 % per day) as a pyrheliometer (0.79 % per day)
DNI / DHI measurement uncertainty

<table>
<thead>
<tr>
<th>Source</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeled Diffuse</td>
<td>12.7%\textsuperscript{1,2}</td>
</tr>
<tr>
<td>Measured Diffuse</td>
<td>8.0%\textsuperscript{3}</td>
</tr>
<tr>
<td>Measured Tracking DNI/Diffuse</td>
<td>2.3%\textsuperscript{4}</td>
</tr>
</tbody>
</table>

1. Gueymard, C.A., From Global Horizontal To Global Tilted Irradiance, Solar 2008 ASES
2. Lave, M et al., Evaluation of Global Horizontal Irradiance to Plane of Array Irradiance Models at Locations across the United States, Sandia PV Performance Workshop
Tuning Satellite Data with Ground Data: DNI

Process:

- Tune GHI
  - Clear sky
  - Seasonal
  - Cloudy sky
  - Ancillary data

- Tune DNI
  (similar to GHI)

- Rebalance in order of priority GHI, DNI, DHI to eliminate unlikely values
The tuned dataset may move up or down (for this project bias between SolarAnywhere and ground was -0.7% GHI and -3.2% DNI), however the primary benefit of tuning and more sophisticated ground measurement is reduced uncertainty.

Notes: This data is from a recent project “Project A” which included measured tracking DNI/DHI. The bar for secondary Standard GHI/DHI is included to illustrate the difference in uncertainty had a common setup been used.

Thank you