Advancements in Satellite-Ground Tuning: DNI and DHI

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Acknowledgments

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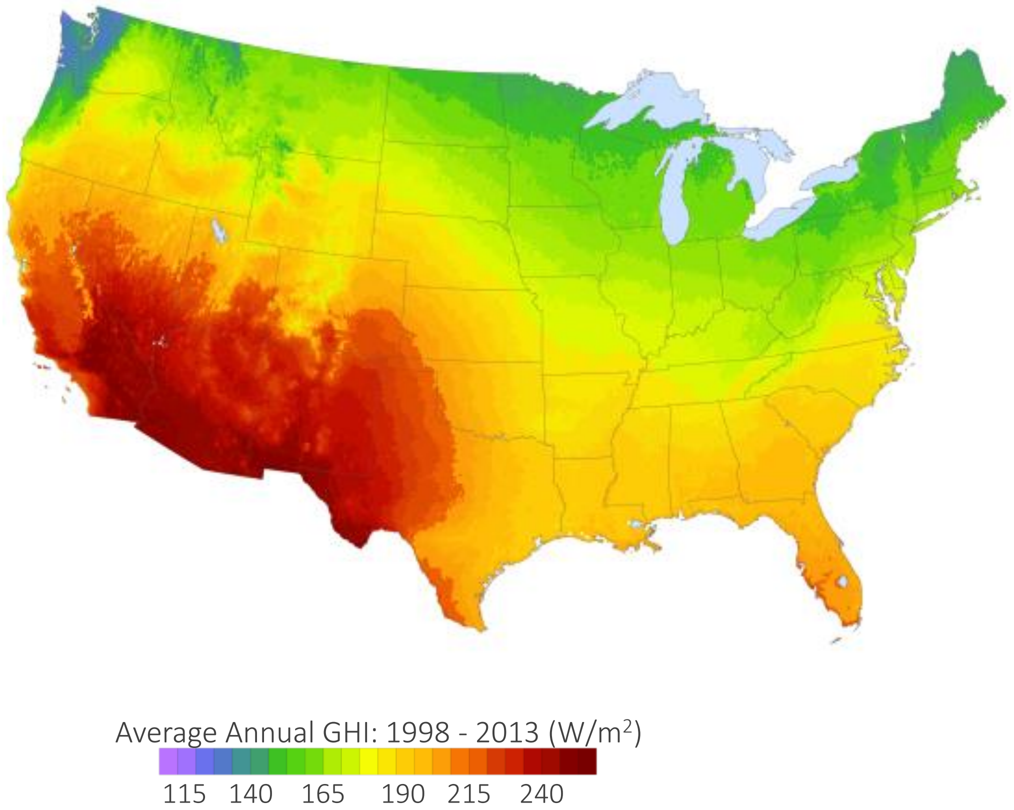
Agenda

- **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

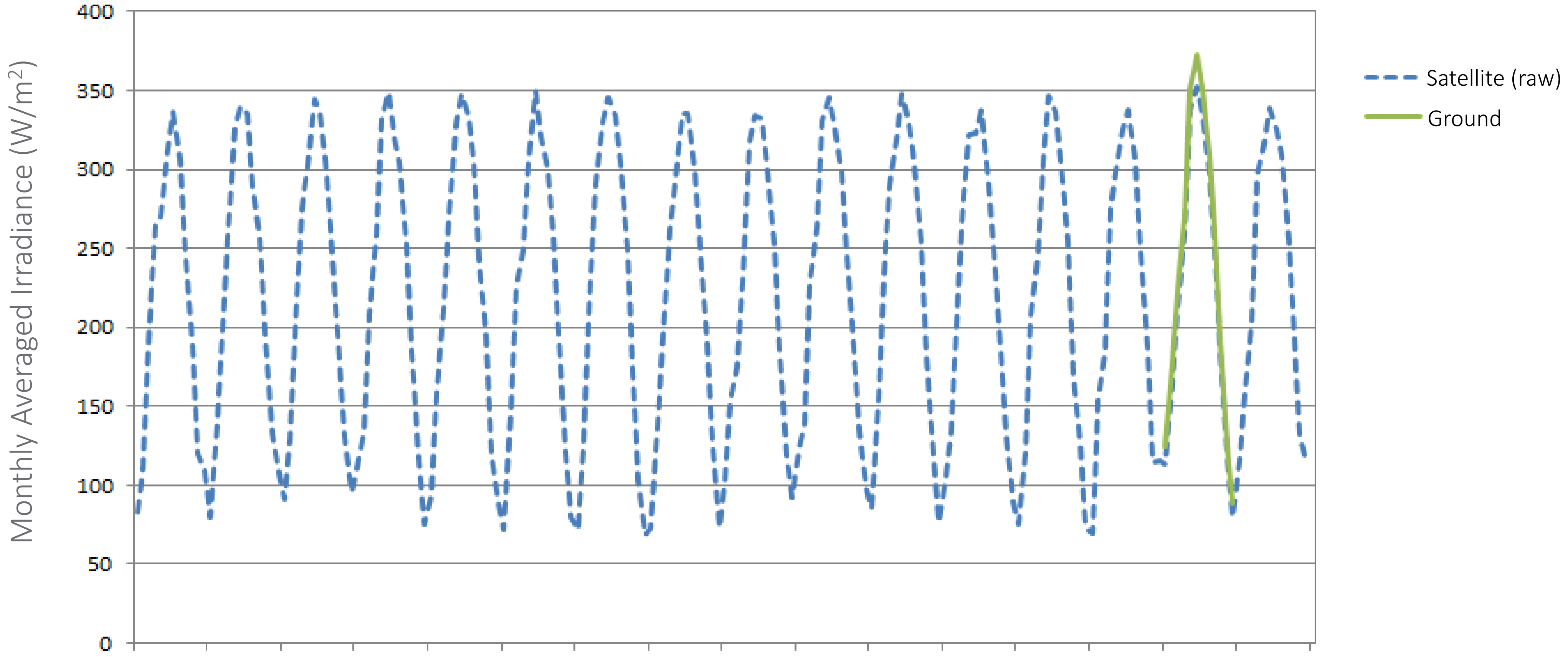
Limitations:

- 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



Satellite data + quality ground data

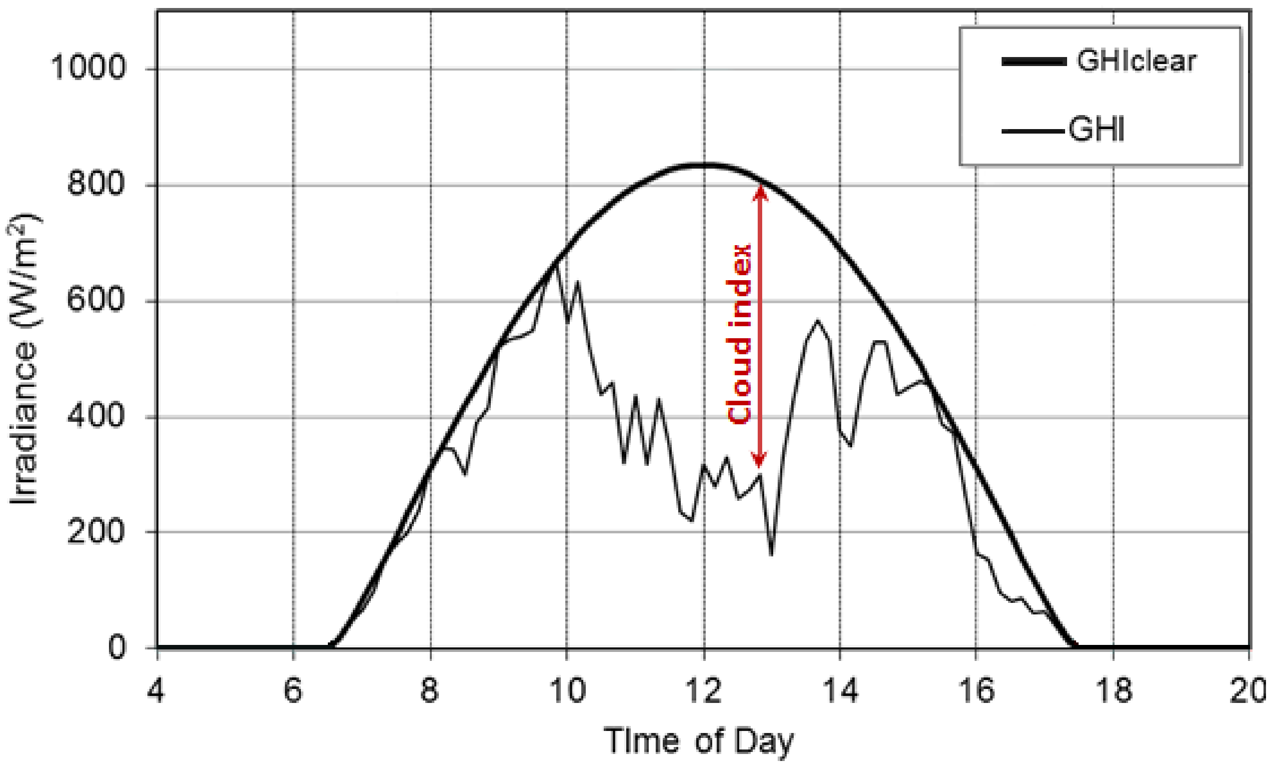
Understanding Differences: Satellite and Ground Datasets

Sources of satellite-model and ground irradiance differences:

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

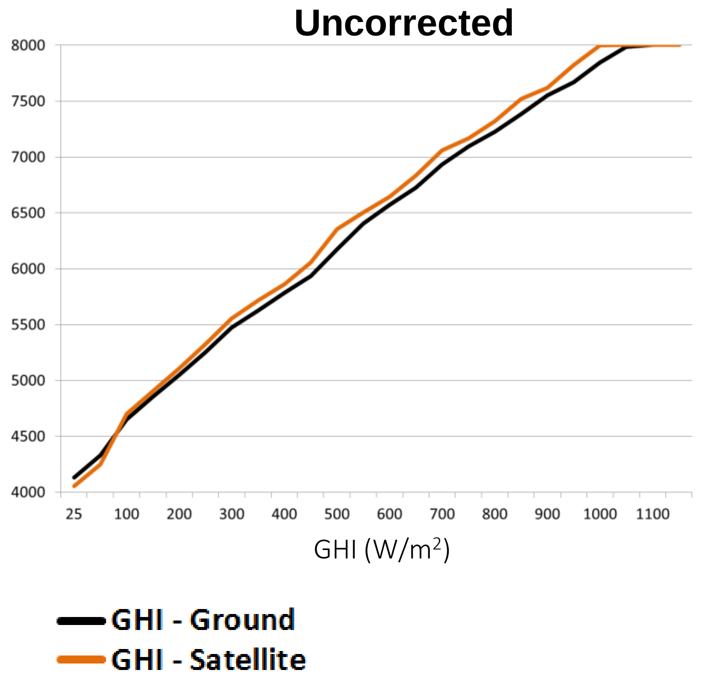
Other considerations:

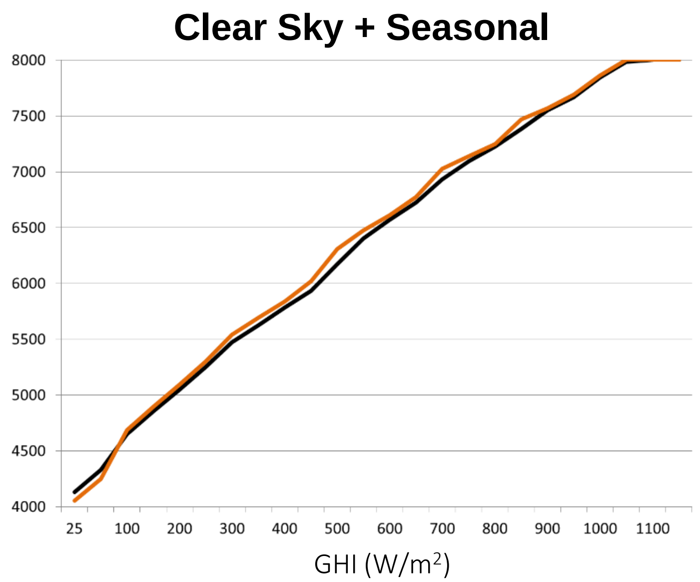
- Ancillary data including wind and temperature
- Irradiance rebalancing (DNI, DHI)

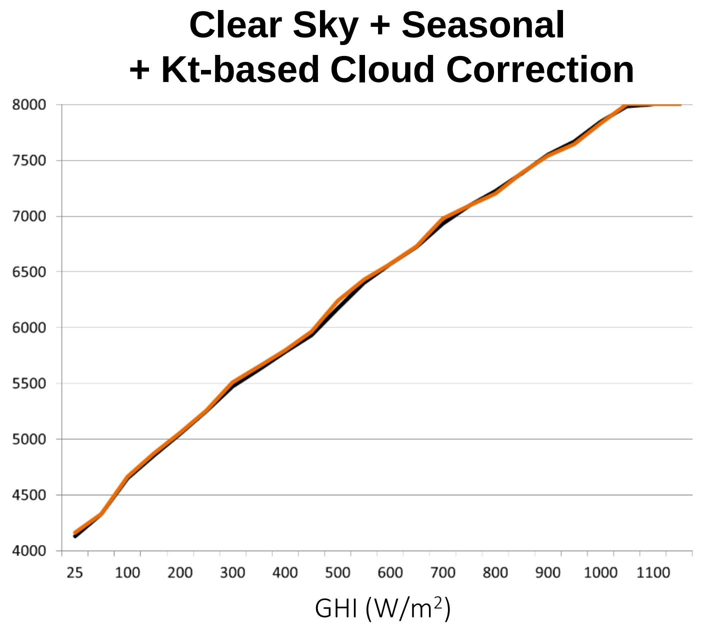


Differences need to be targeted individually during the tuning process

Tuning Satellite Data with Ground: GHI







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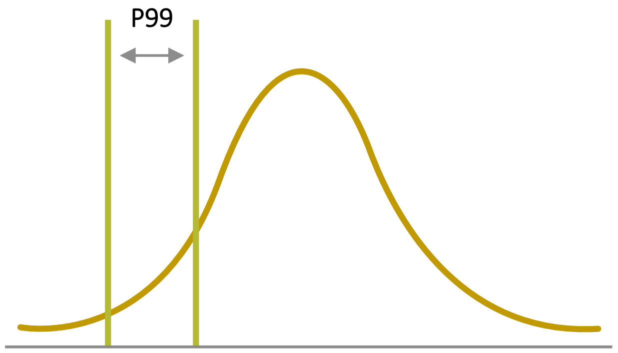
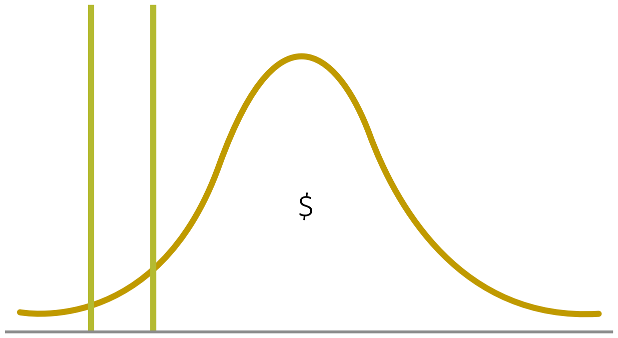
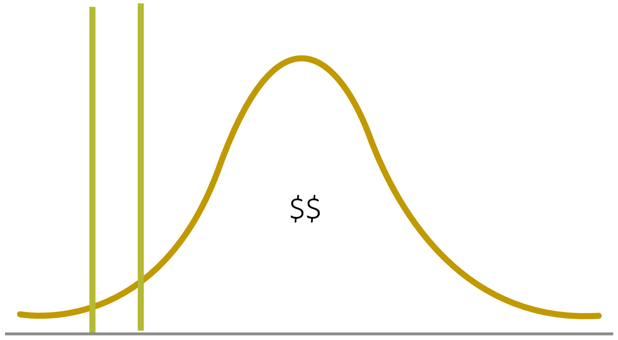
Motivation for Ground Resource Assessment



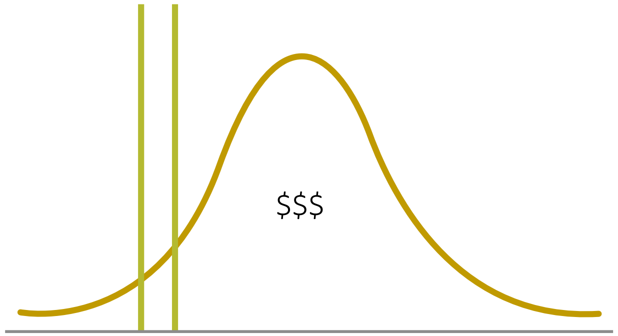
Baseline / Satellite Only



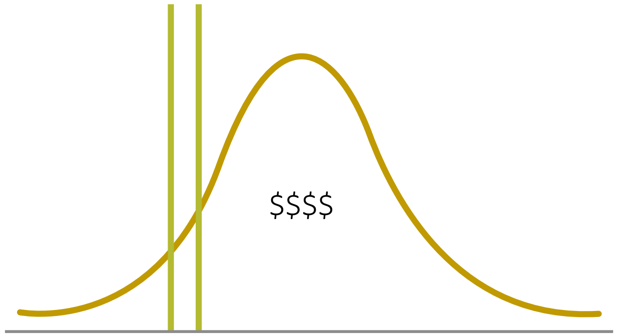
Secondary Standard



Secondary Standard + Soiling



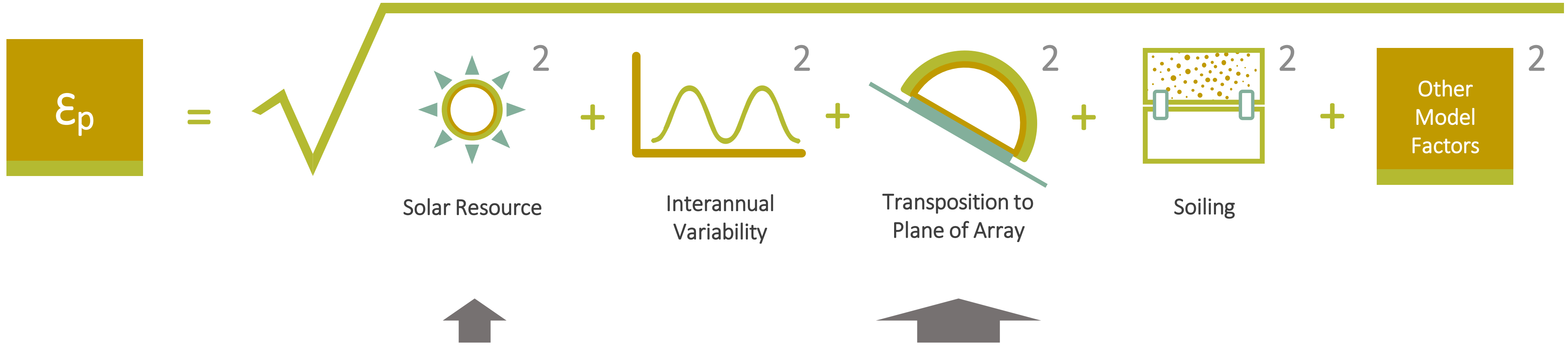
Secondary Standard
+ Diffuse + Soiling



Secondary Standard
+ DNI/Diffuse + Soiling

Investment in Ground Measurements Can Increase P99

Project uncertainty contains a number of factors. Where does DNI/DHI come into play?

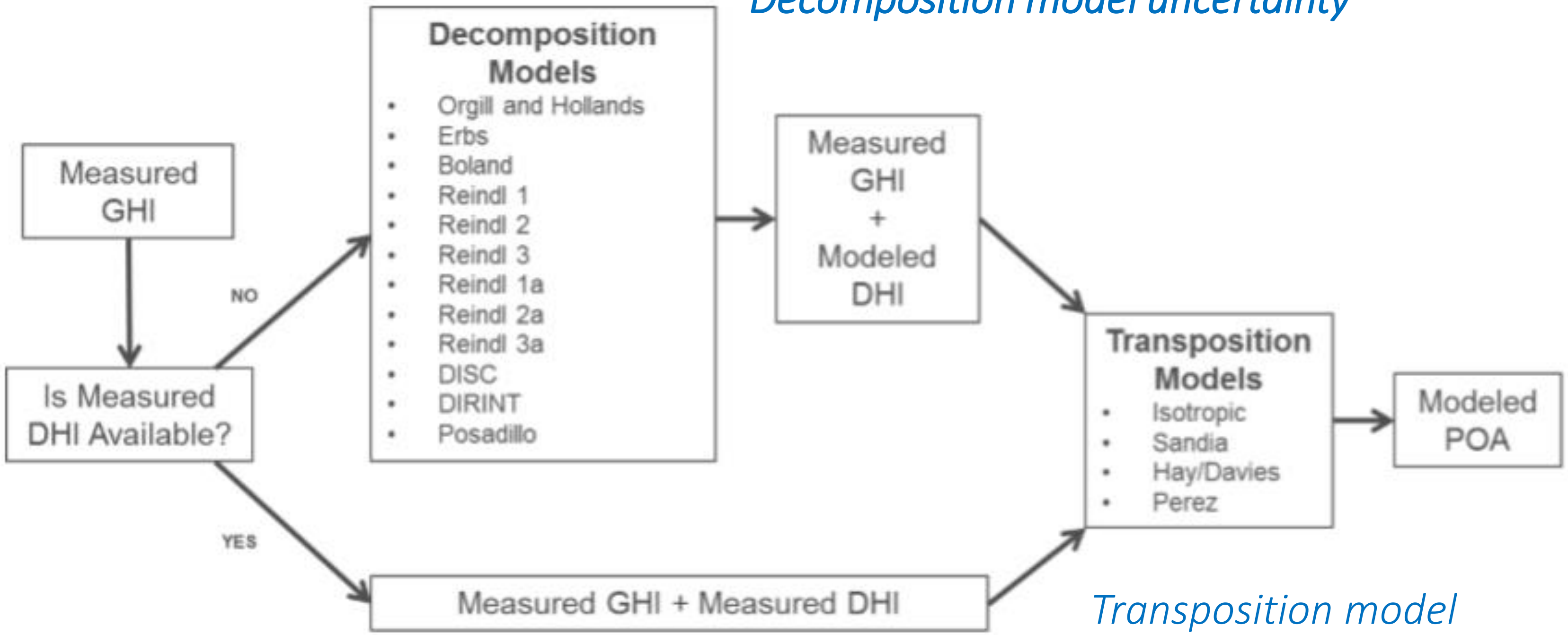


Impacts of high quality DNI / DHI measurement

Root Sum of the Squares

Transposition to Plane of Array

Most common:
Decomposition model uncertainty

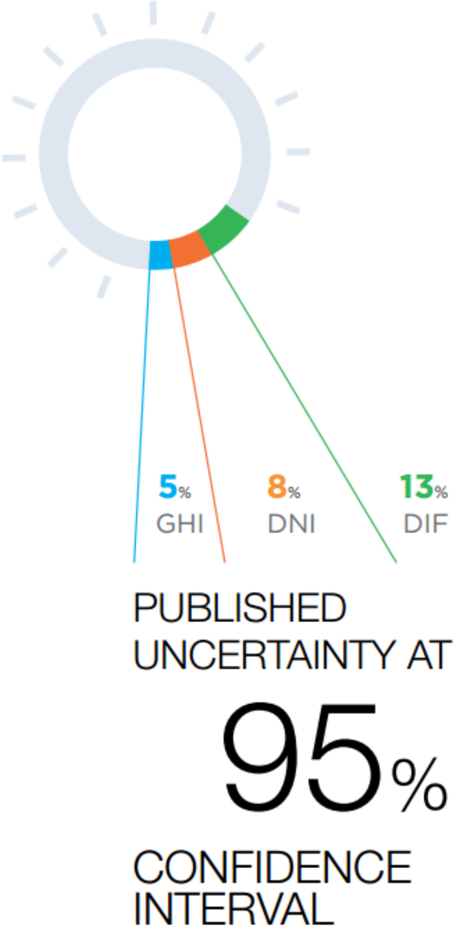


Emerging:
Measurement uncertainty

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

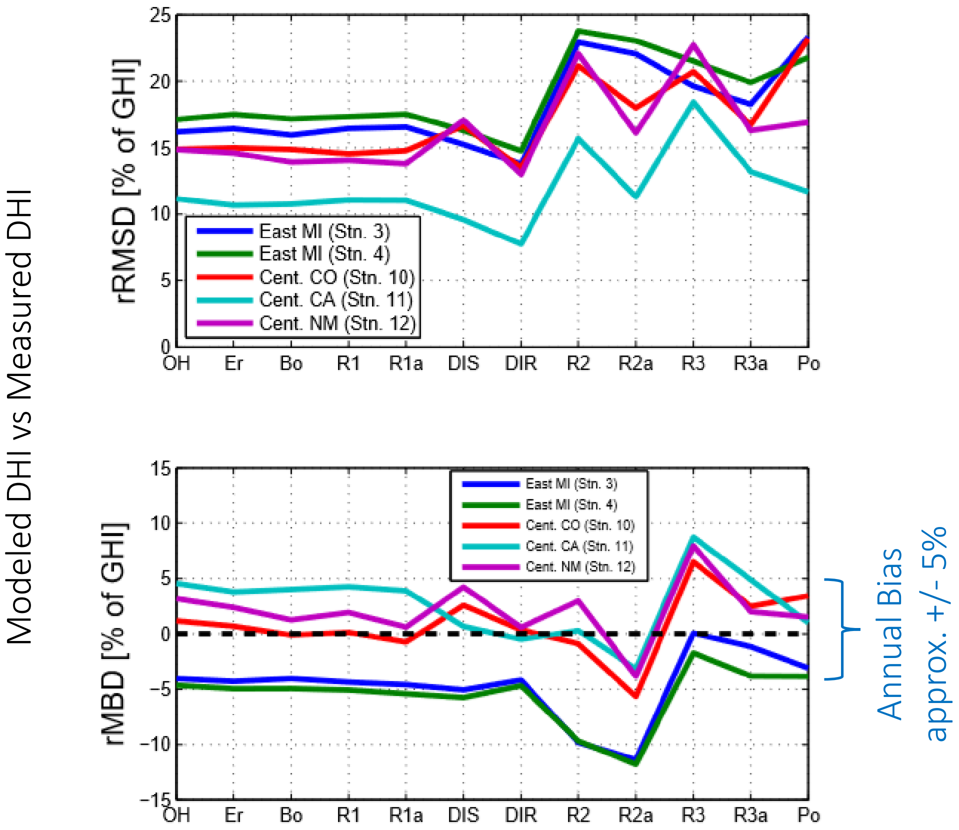
Flow Chart Credit: Lave, M et al., Evaluation of Global Horizontal Irradiance to Plane of Array Irradiance Models at Locations across the United States, Sandia PV Performance Workshop

Decomposition uncertainty (I)



Higher uncertainty for DNI and DHI reflects decomposition uncertainty, and to a lesser degree ground measurement uncertainty

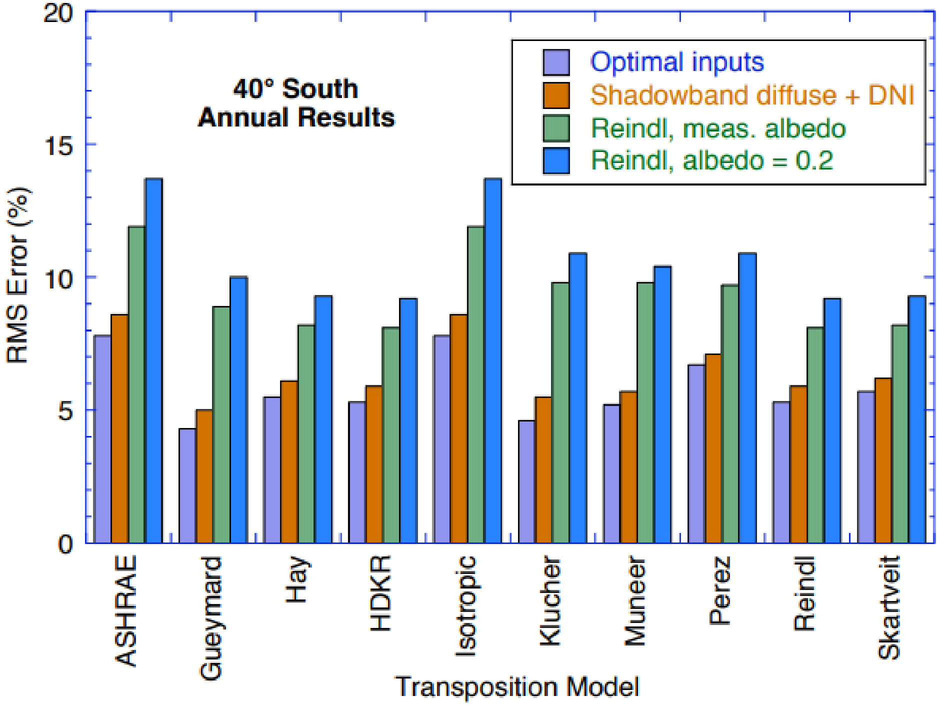
Decomposition uncertainty (II)



Relative (to GHI) root mean squared (rMSD) 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

Modeled POAI vs Measured POAI



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 preferred[1]
- Descriptive metadata

1. Alfi, James, et al. Importance of Input Data and Uncertainty Associated with Tuning Satellite to Ground Solar Irradiation, Photovoltaic Specialists Conference (PVSC) 2016 IEEE 43rd.

High quality instrumentation

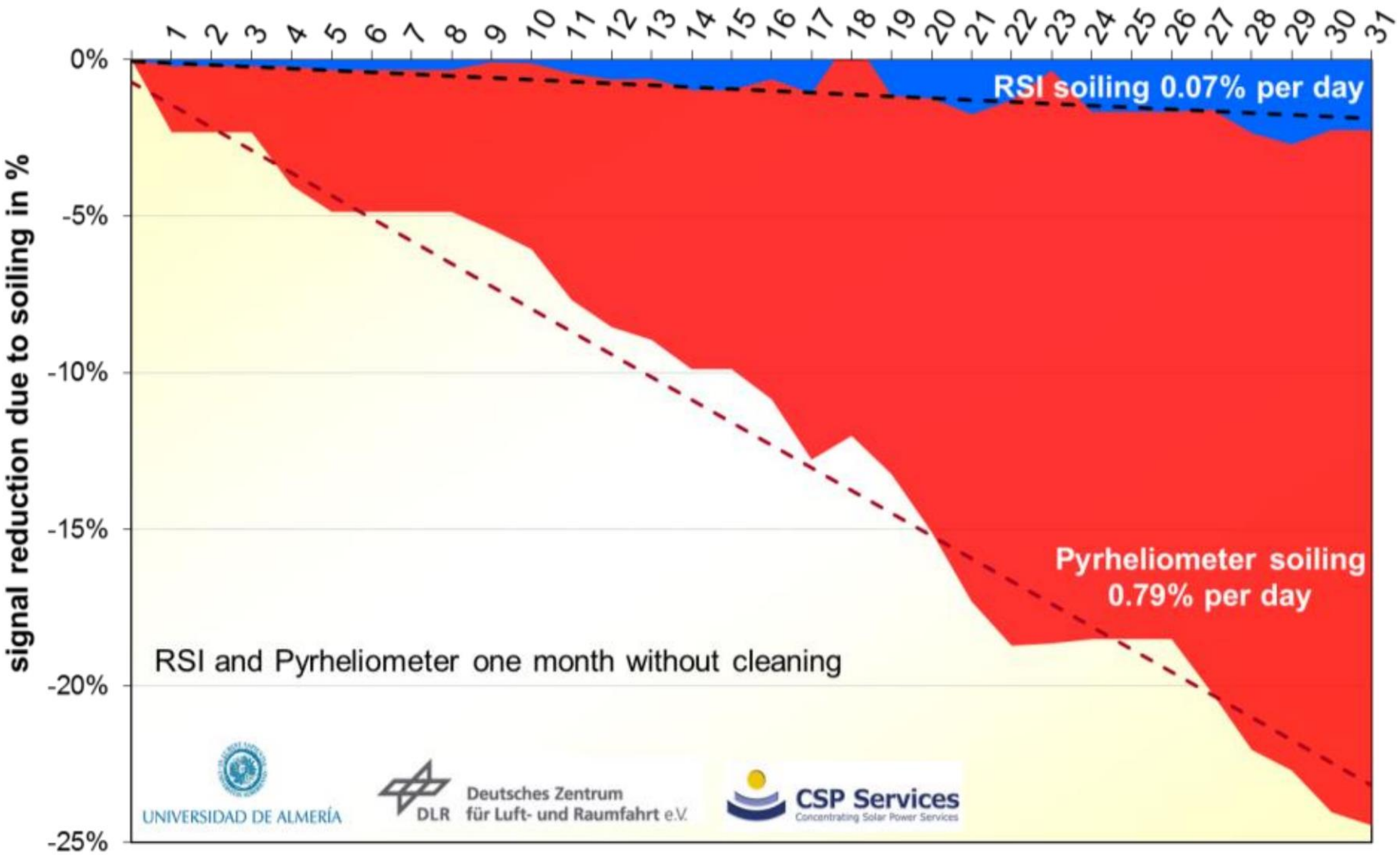
Secondary Standard GHI & DHI + DNI

→ 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)

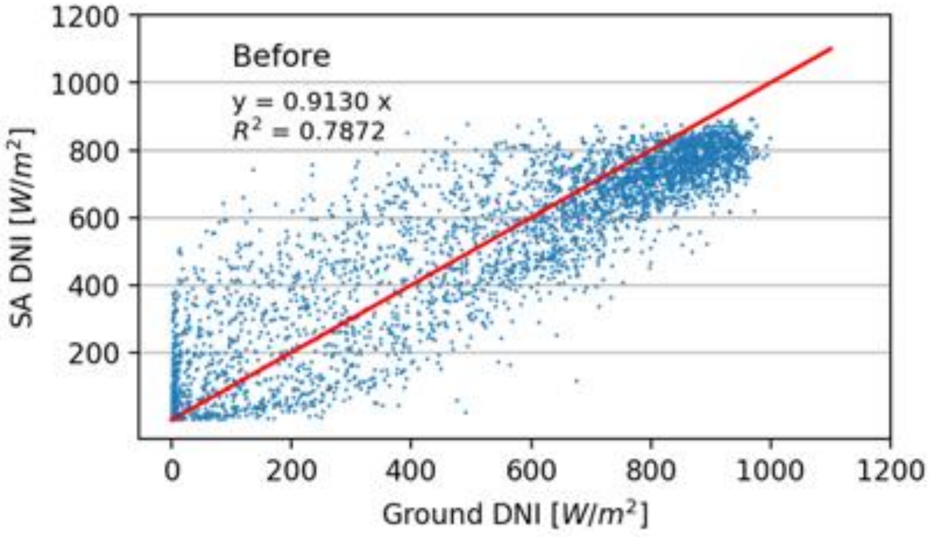
http://www.cspservices.de/media/csps/CSPS-RSI-1510.pdf

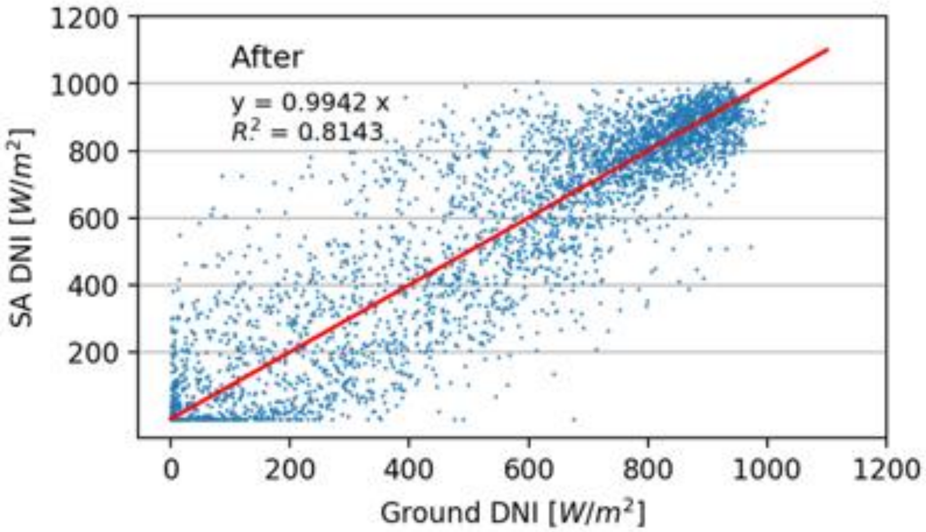
DNI / DHI measurement uncertainty

Source	Uncertainty
Modeled Diffuse	12.7%[1,2]
Measured Diffuse	8.0%[3]
Measured Tracking DNI/Diffuse	2.3%[4]

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
3. Badosa, J. et al., Solar Irradiances measured using SPN1 radiometer, *Atmospheric Measurement Techniques*
4. Habte, A. et al., Method to Estimate Uncertainty in Radiometric Measurement Using the Guide to the Expression of Uncertainty in Measurement (GUM) Method, NREL, March 2015 ASR Science Team Meeting

Tuning Satellite Data with Ground Data: DNI





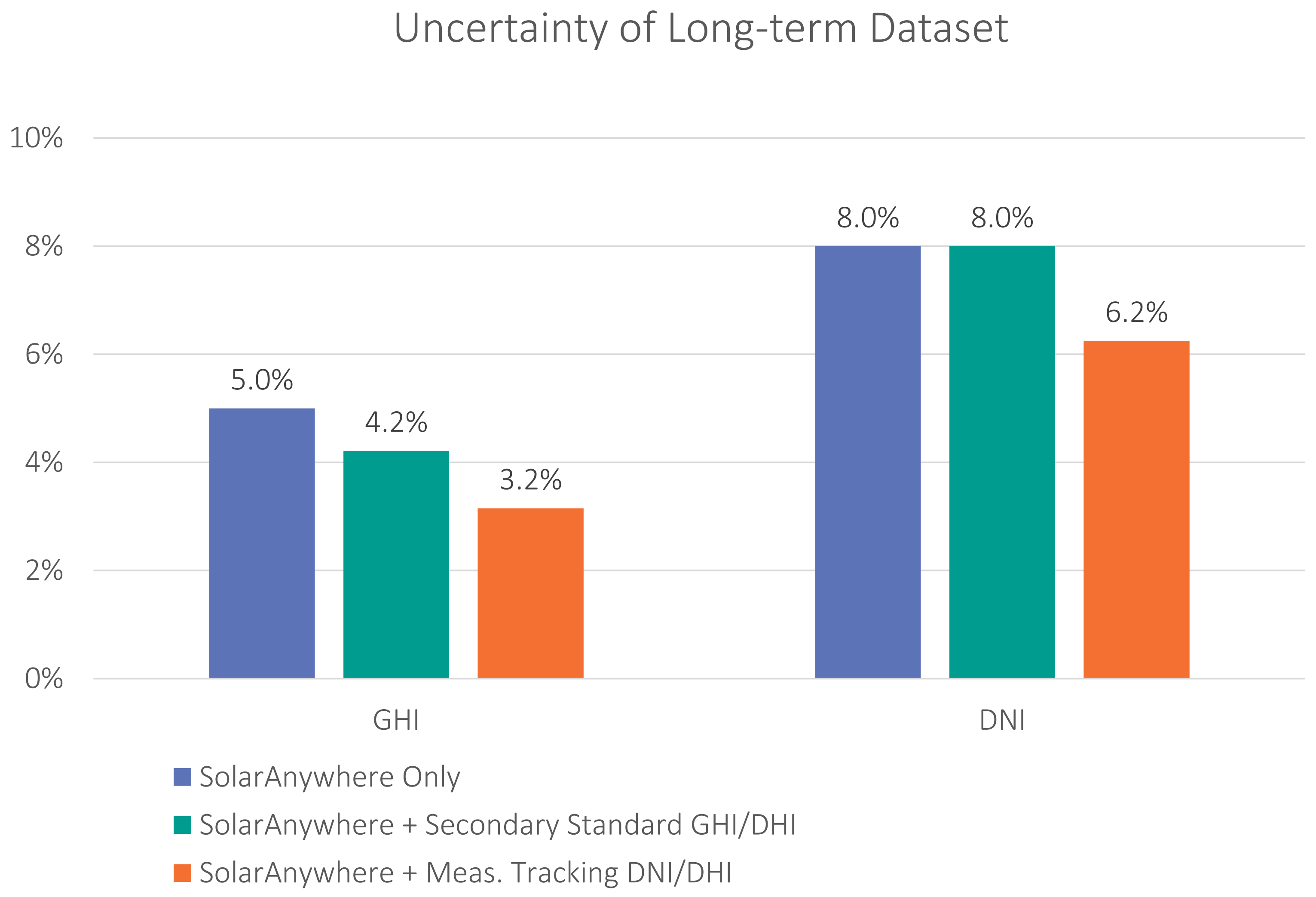
Process:

- *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*

DNI / DHI measurement uncertainty



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.

References: Alfi, James, et al. Importance of Input Data and Uncertainty Associated with Tuning Satellite to Ground Solar Irradiation, Photovoltaic Specialists Conference (PVSC) 2016 IEEE 43rd.

Thank you

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