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Uncertainty in Annual Energy Resulting from Uncertain Irradiance Measurements

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Abstract

- Uncertainty in measured irradiance contributes to uncertainty in modeled annual energy yield.
- We quantify the uncertainty in annual energy for eight different pyranometers.
- Uncertainty in annual energy is roughly 30% of variability in measured irradiance.
- Pyranometers with higher accuracy class do not necessarily provide less uncertainty in annual yield.

Uncertainty in Annual Yield

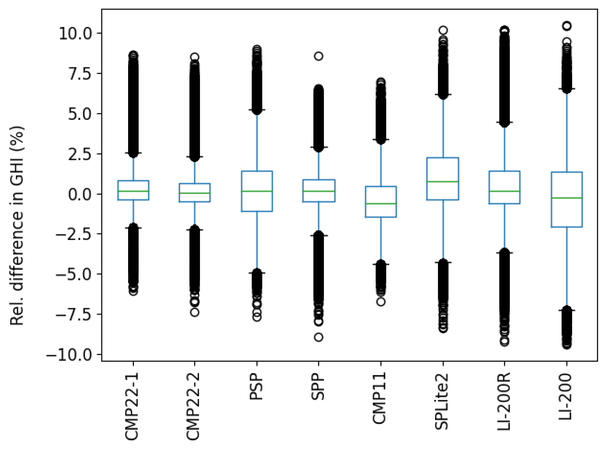
- Base annual yield (Y) from a model f with weather input $\boldsymbol{W}$ and parameters $\boldsymbol{P}$.
- Uncertainty in Y by means of *random factors* Δ, each representing uncertainty in annual yield from data or component of f [1].

$$Y = \left[\sum_t f(\boldsymbol{W}(t), \boldsymbol{P})\right] \times \prod_{i=1}^{M} (1 - \Delta_i)$$

- Here, we quantify a distribution for Δ that corresponds to the uncertainty in irradiance data that is measured by a pyranometer.

Data

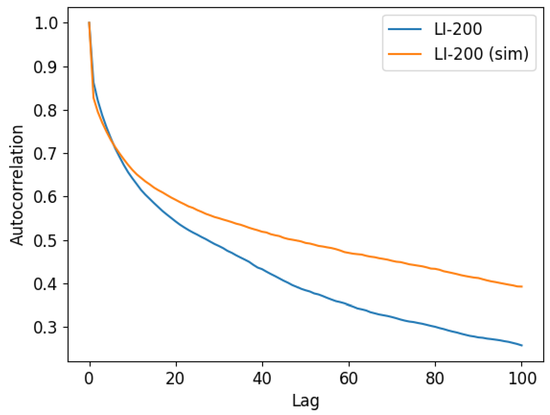
- One reference and eight subject pyranometers at NREL's SRRL in Golden, CO
- One year of GHI, along with DHI, DNI and precipitation for data consistency checks



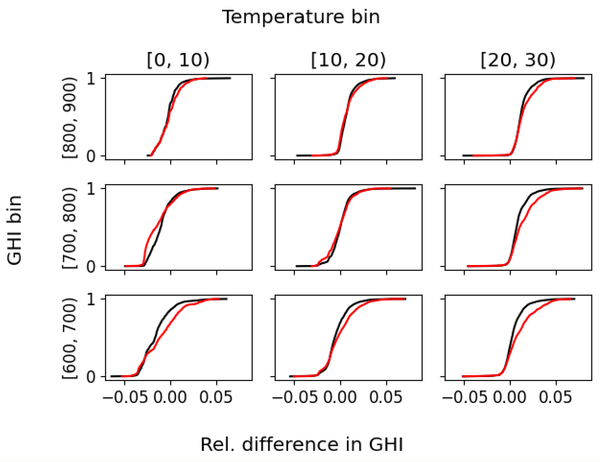
Data Modeling

- Model relative difference from reference GHI for each of eight subject instruments
  - Bin by irradiance, zenith and air temperature
  - Transform to $(-\infty, \infty)$ by rank then logit transformations
  - Fit an ARFIMA model to transformed data
  - Use fitted model to simulate 100 time series of relative difference from reference GHI
  - Use simulated time series to estimate distribution of uncertainty in annual AC energy, for a fixed PV system.

Simulations preserve observed long-memory autocorrelation

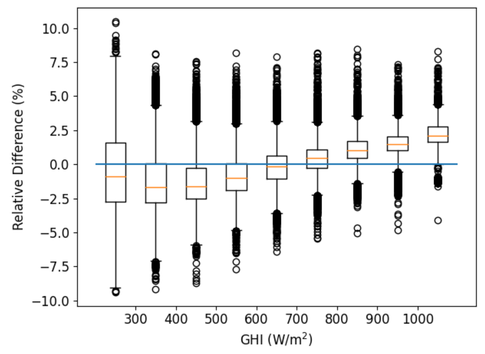


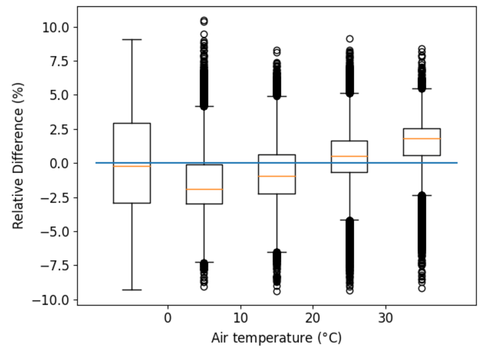
Simulations preserve distributions for each irradiance, temperature and zenith bin

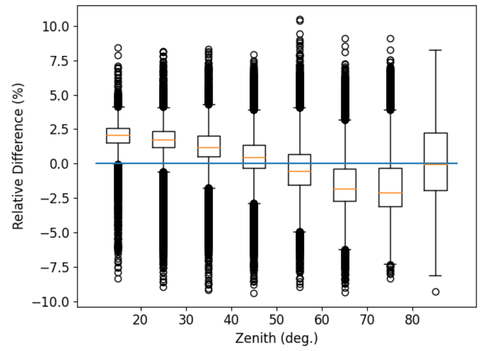


Measured (black) and simulated (red), LI-200

Relative difference from reference GHI for LI-200 pyranometer





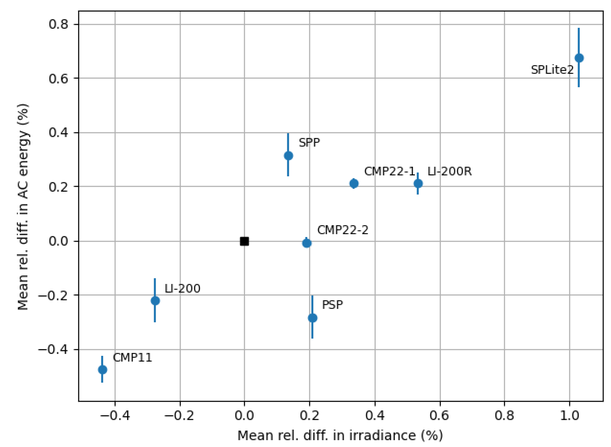


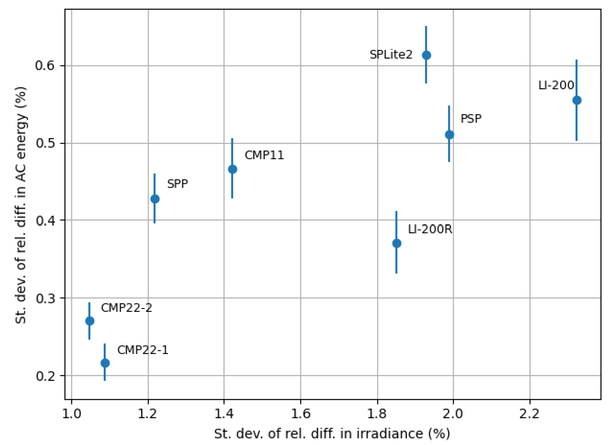
Simulated differences in annual energy yield

Instrument	Mean	St. Dev.
CMP22-1	0.21%	0.22%
CMP22-2	-0.01%	0.27%
PSP	-0.28%	0.52%
SPP	0.32%	0.43%
CMP11	-0.48%	0.47%
SPLite2	0.67%	0.62%
LI-200R	0.21%	0.37%
LI-200	-0.22%	0.56%

Uncertainty Factor Model

- Two-level model: normal distribution with uncertain mean and standard deviation
  - Mean from Uniform [−0.4%, 0.4%]
  - Standard deviation from Uniform [0.35%, 0.6%]
- Distribution does not depend strongly on the specific pyranometer.
- Uncertainty in instrument calibration, rather than instrument make and model, appears to be determinant of the uncertainty factor's distribution.





[1] C. Reise, B. Müller. "Uncertainties in PV System Yield Predictions and Assessments," Intl. Enegy Agency Report IEA-PVPS T13-12:2018, 2018. ISBN 978-3-906042-51-0. 2018..

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