Angular Response Correction Factors for Comparing PV Reference Cells and Thermopile Pyranometers

Michael Gostein, Atonometrics, Austin, TX

ATONOMETRICS

Introduction

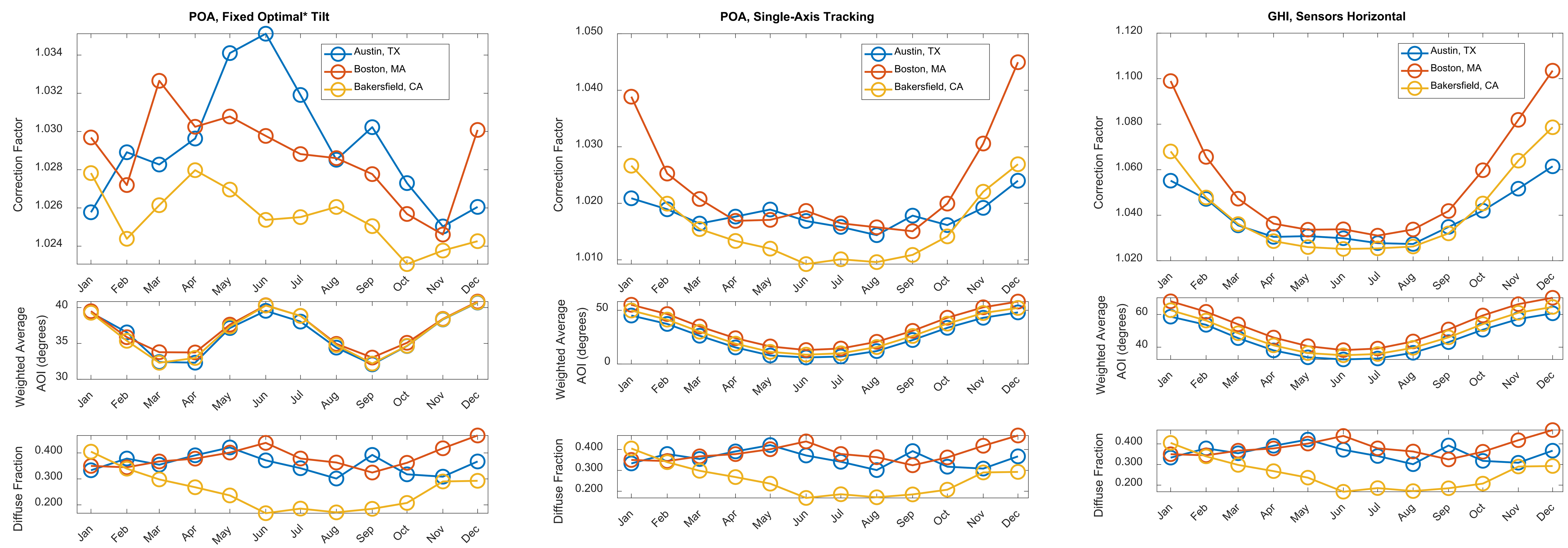
- PV reference cells and thermopile pyranometers have different spectral and angular responsivities
- PV performance analysts may be confused when comparing data from reference cells to pyranometers
- Discrepancies are often attributed to spectral effects while angular effects are under-appreciated
- In this work we calculate estimated angular response correction factors for comparing reference cells and pyranometers in exemplary systems

Simulation Method

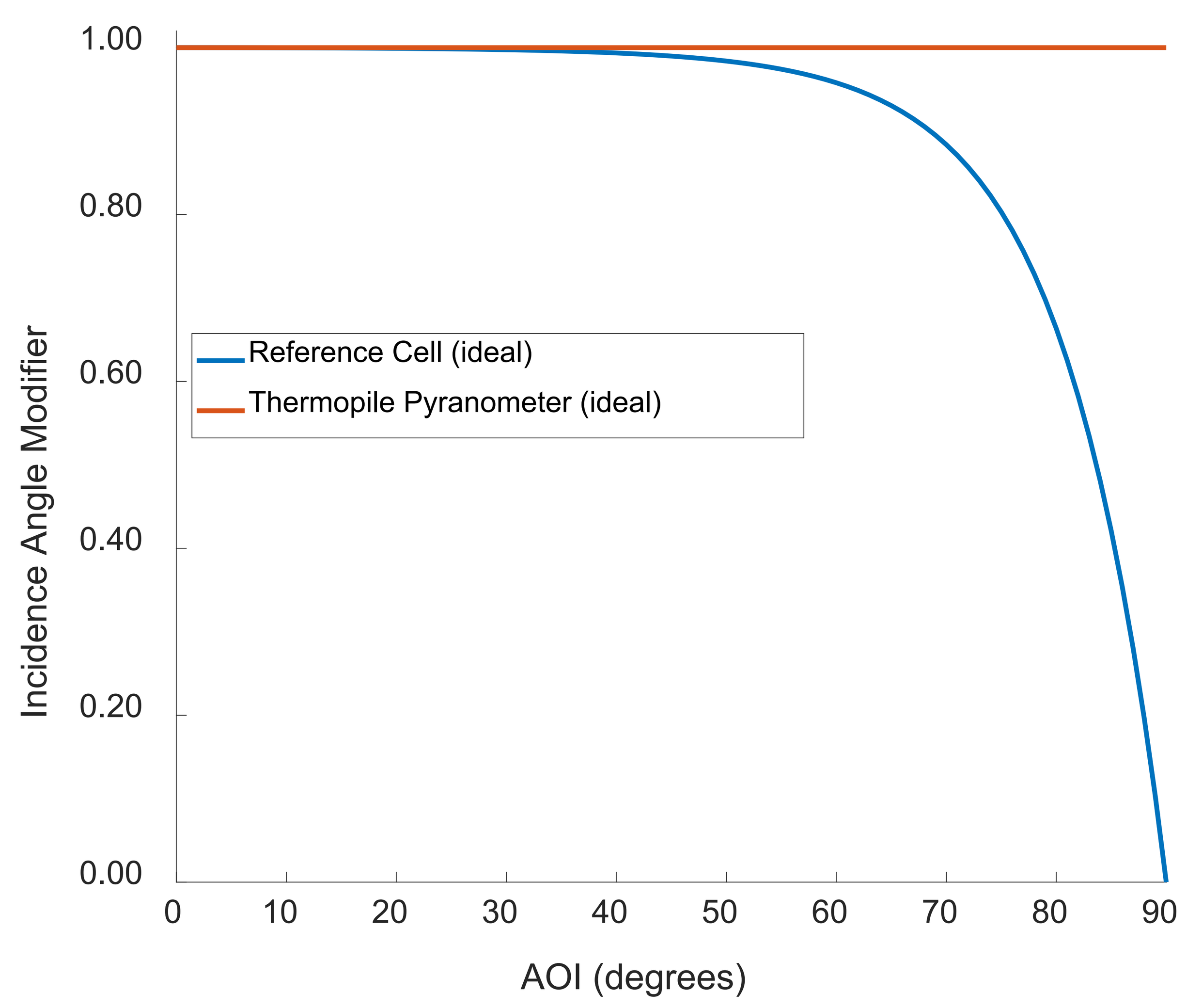
- Calculations are performed using Sandia's PVLIB in MATLAB
- We use Typical Meteorological Year (TMY) data for 3 sites from the National Solar Radiation Database (NSRDB)
- The calculation is performed for three different geometries: fixed optimal* tilt, single-axis tracking, and horizontal (GHI sensor orientation)
- Optimal* tilt taken as 0.8 x latitude (simplification)
- For each data set and geometry, we use DNI, DHI, and albedo from the TMY data to calculate POA
- The calculation uses the Perez model for diffuse irradiance translation and the isotropic model for ground-reflected light
- For the pyranometer: POA sensor response is calculated assuming ideal cosine response (incidence angle modifier (IAM) = 1)
- For the reference cell: POA sensor response is calculated using an ideal IAM from the Martin-Ruiz model, including weighted-average IAM values for diffuse and ground-reflected light

$$POA = DNI \cdot \cos(aoi) \cdot IAM(aoi) + f_{Perez}(DNI, DHI) \cdot IAM_{diff} + GHI \cdot \alpha \cdot \left(\frac{1-\cos\beta}{2}\right) \cdot IAM_{ground}$$

Simulation Results



Incidence Angle Modifier (IAM)



Correction Factor

$$CF = \sum POA_{pyranometer} \Big/ \sum POA_{refcell}$$

Multiply reference cell POA by CF to get estimate for pyranometer POA

Diffuse Fraction

$$k_d = DNI/GHI$$

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Discussion

- Assume reference cell and pyranometer calibrated identically at normal incidence
- Considering only angular response, the reference cell will measure lower irradiance than the pyranometer
- This is not a spectral effect
- In winter months at high latitudes differences can reach 2-4% for single-axis tracking
- Differences correlate with weighted-average AOI
- High diffuse fraction also increases the discrepancy, because IAM diffuse averages over high AOI
- Reference cell angular response is similar to modules, while pyranometer angular response is flat
- The correction factors presented here can be used as a first estimate to explain observed behavior