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ÅPENT

Impact of albedo variations and sensor positions on rear irradiance for bifacial power plants

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Bifacial PR

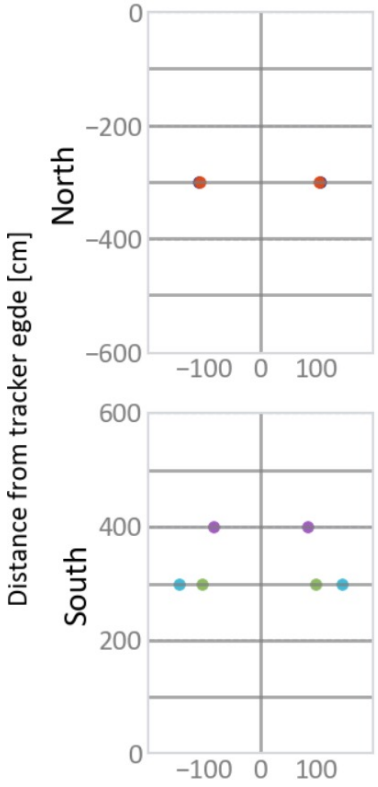
$$PR'_{STC} = \frac{P_{out} G_{ref}}{P_0 G_i (1 + \gamma (T_{mod} - T_{25^oC}))}$$

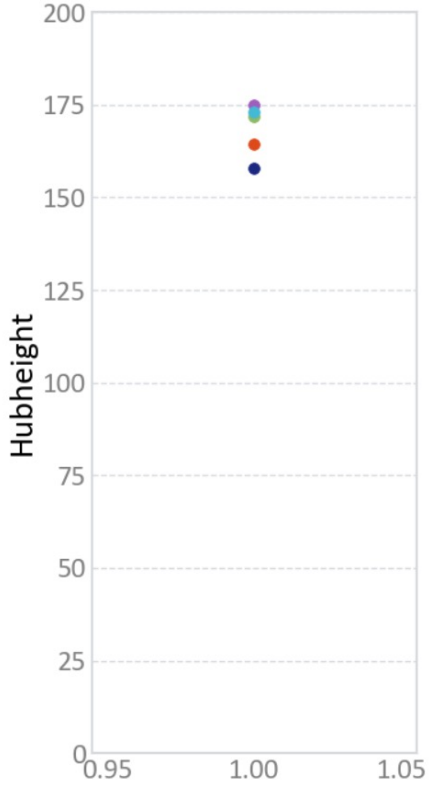
$$G_i = G_{POA,front} + \varphi \, G_{POA,rear}$$

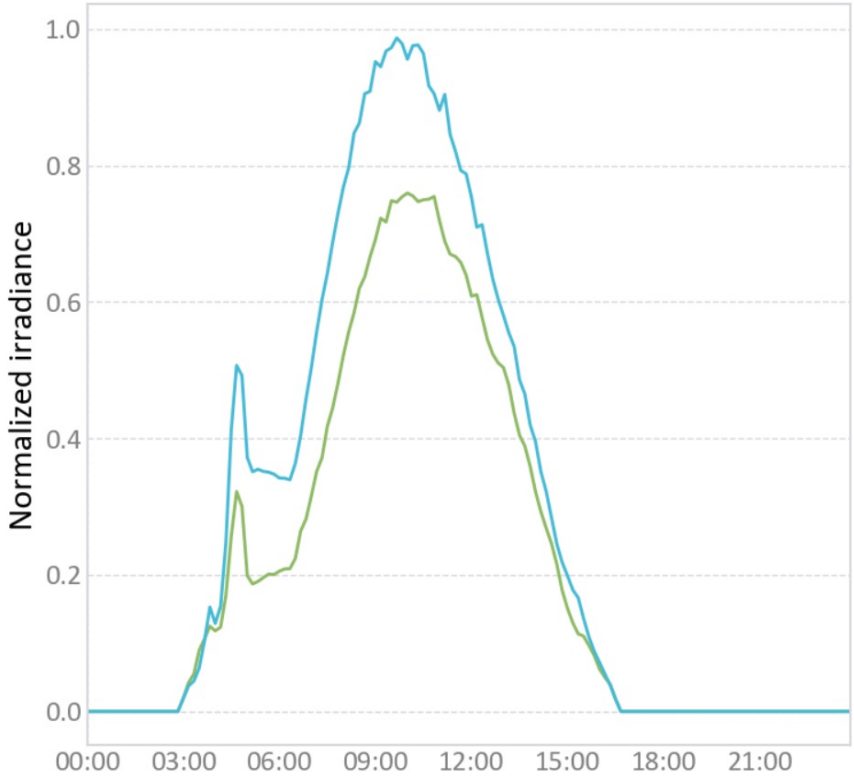
- ISO 61724-1
  - Measure albedo, GHI (and DHI) + optical model.
    - View factor or ray tracing
  - Measure rear in-plane irradiance,
    - Broadband or spectrally matched
    - No specification of rear side sensor positions

Bifacial PV plant

Rear side pyranometers

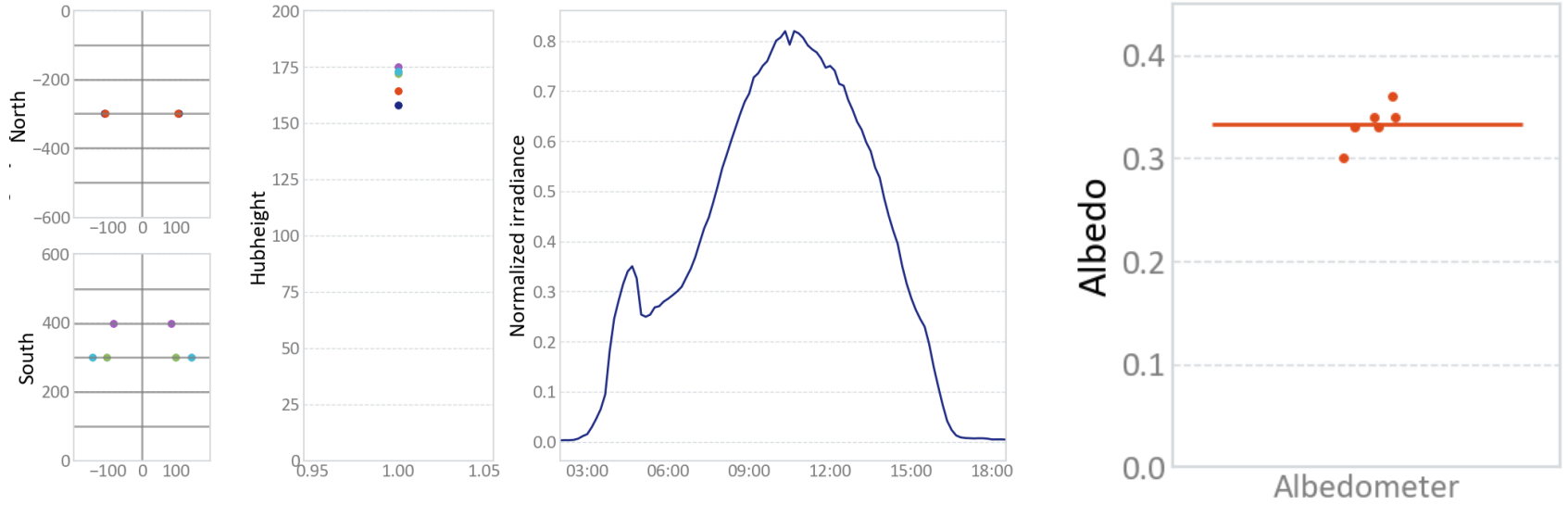




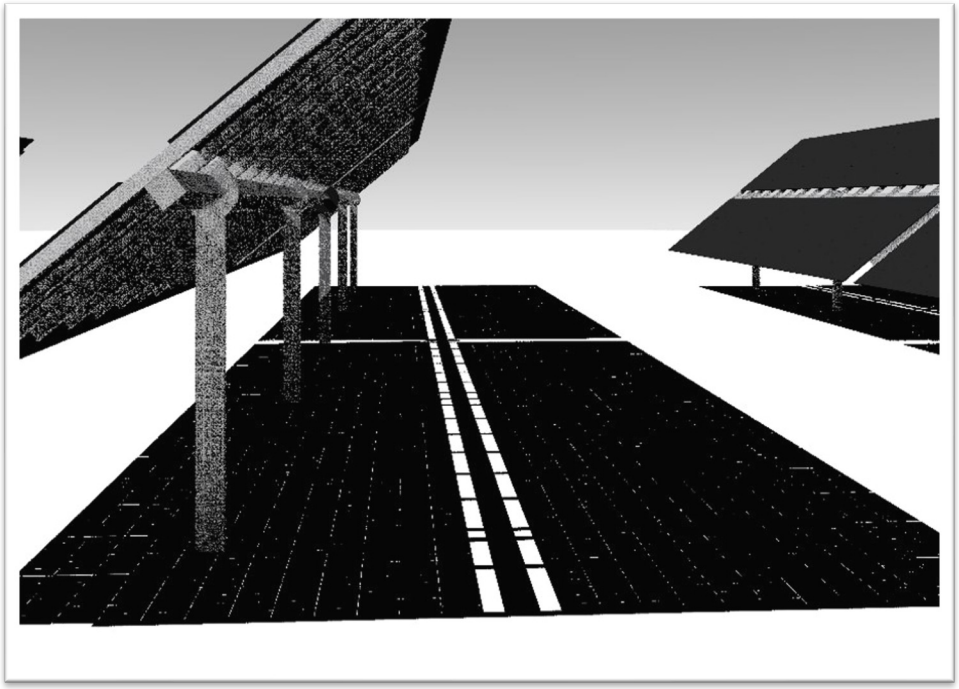


Model irradiance at sensor position – Average albedo

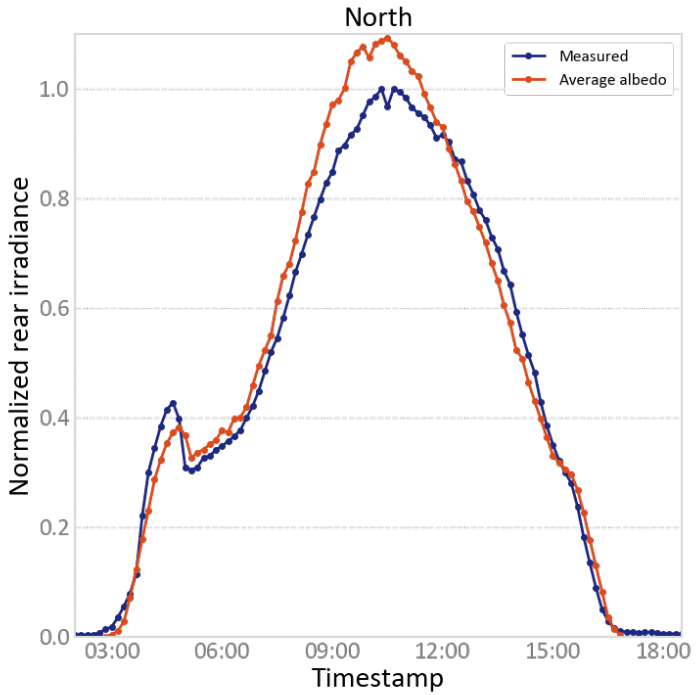
- Desert
- Non-seasonal, albedo
- Input GHI and DHI
- Measured tracker angles

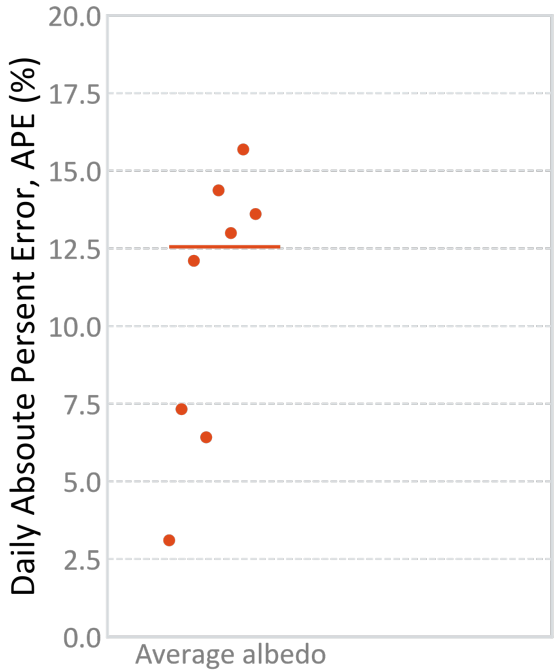


Building a detailed shading scene in bifacial radiance



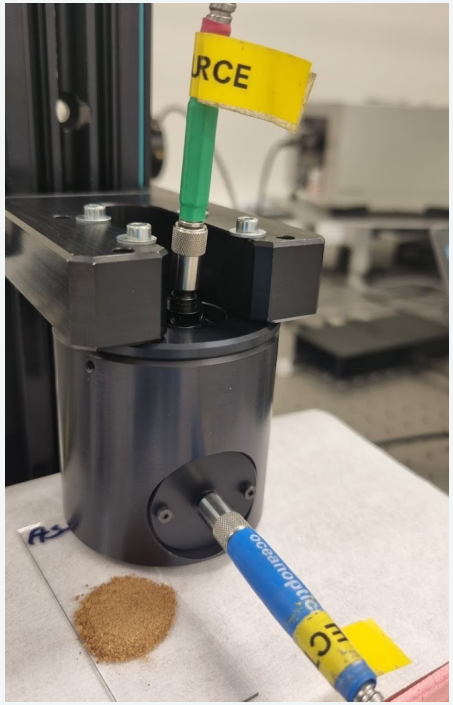
Modeling the pyranometer positions



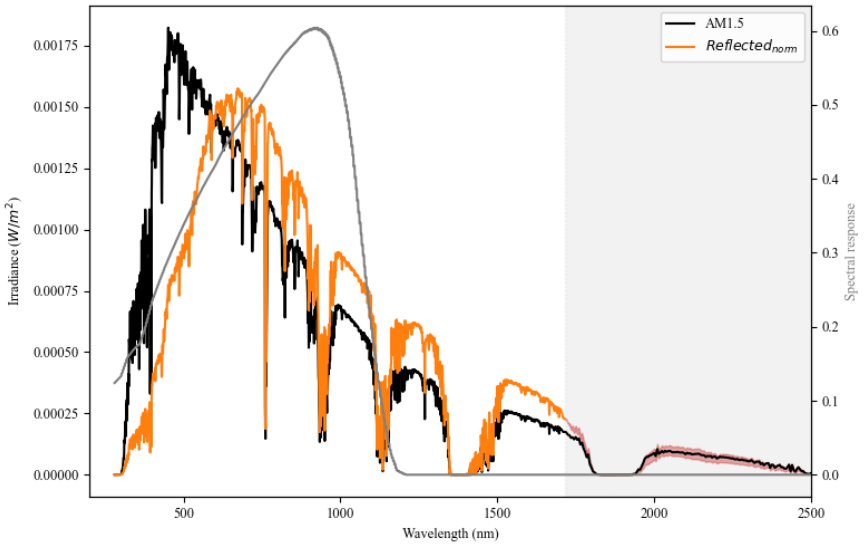


Albedo variations

Spectral impact on effective albedo

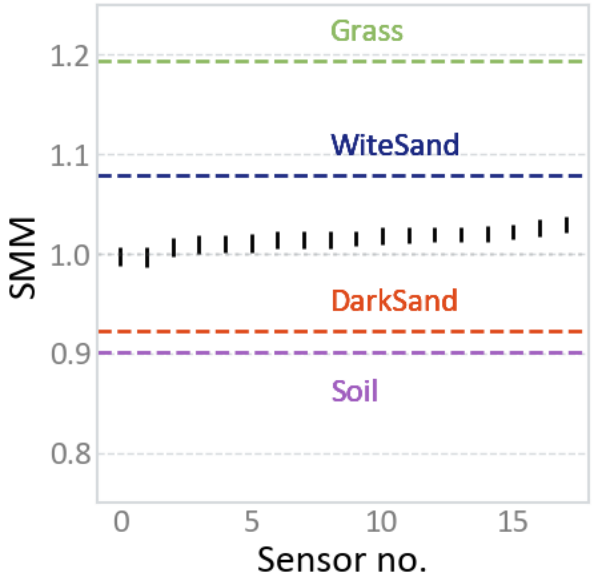


$$\mathrm{SMM} = \frac{\frac{\int E(\lambda) SR(\lambda) d\lambda}{\int E(\lambda) d\lambda}}{\frac{\int E(\lambda)_{AM1.5g} SR(\lambda) d\lambda}{\int E(\lambda)_{AM1.5g} d\lambda}}$$



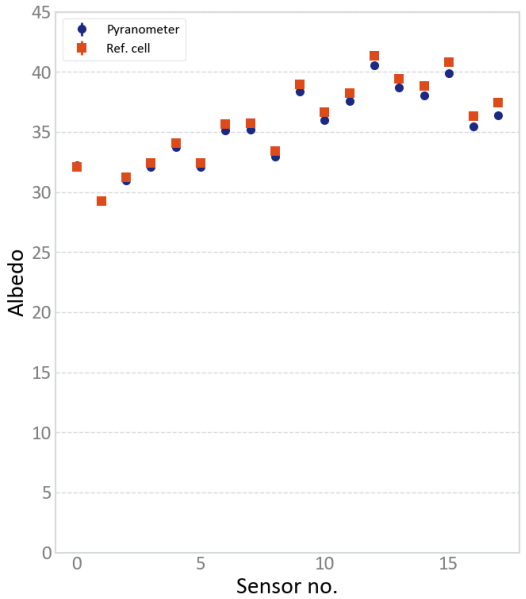
Spectral impact on effective albedo

- SMM intermediate of WiteSand and DarkSand from SMARTS
- SMM 1-1.03

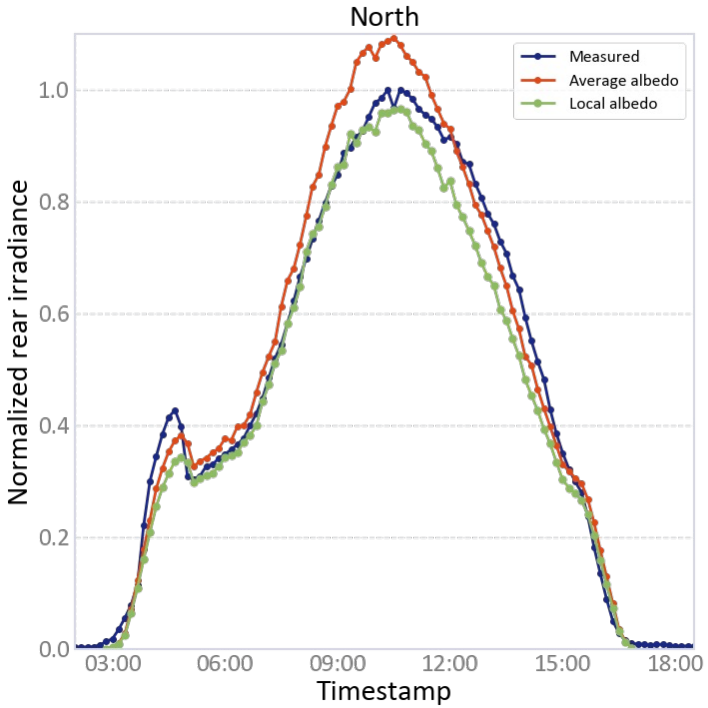


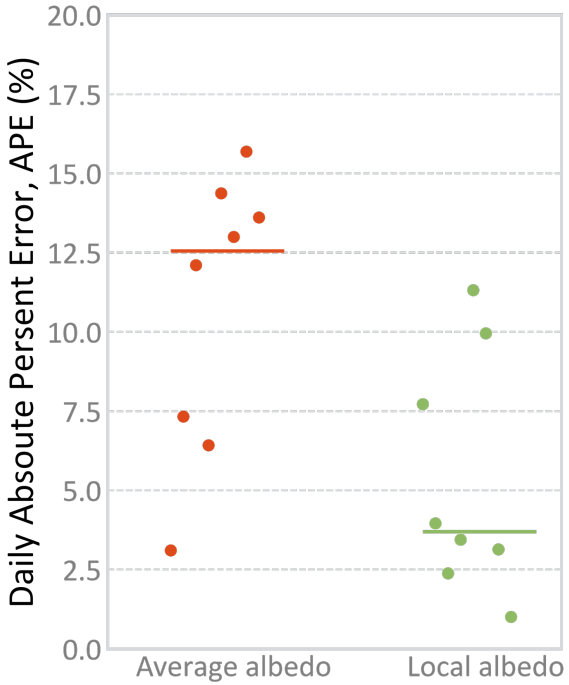
Local variations in albedo

- SMM intermediate of WiteSand and DarkSand from SMARTS
- SMM 1-1.03
- The local albedo below the rear sensors varies from 29-41%.

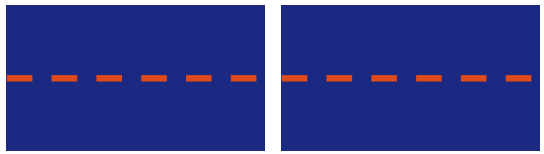


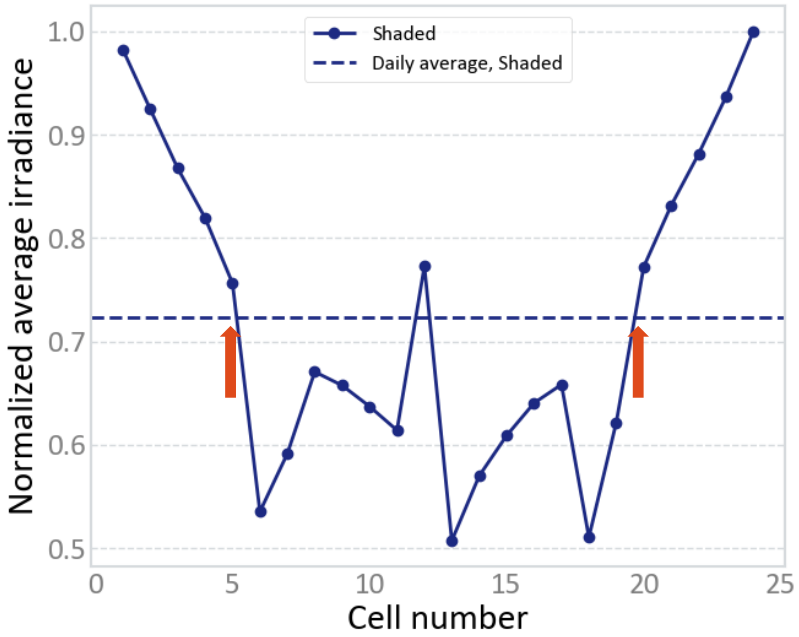
Modeling the pyranometer positions





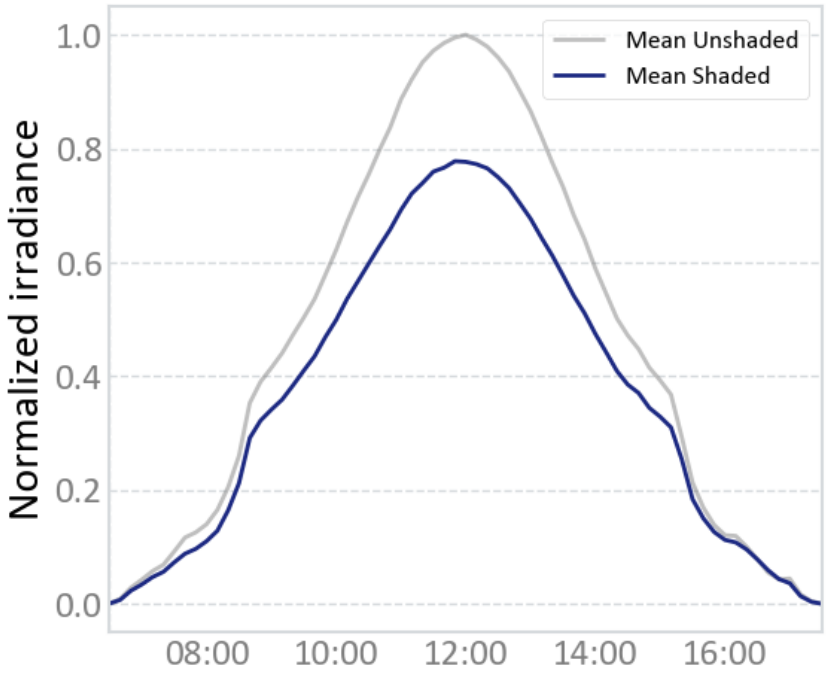
Modeled irradiance across module cord

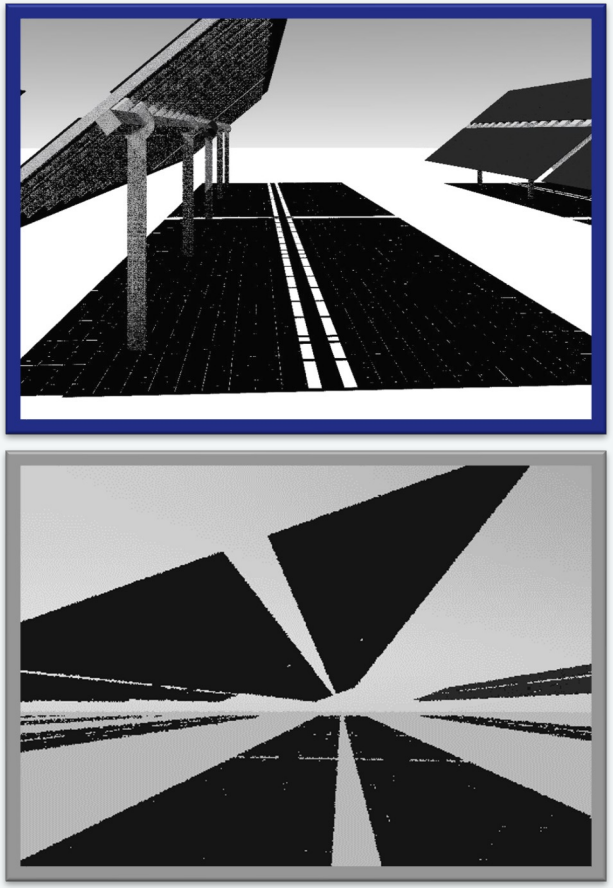




- The rear irradiance varies a lot from cell to cell and is strongly influenced by the rear side shading pattern.

Removing the shading elements

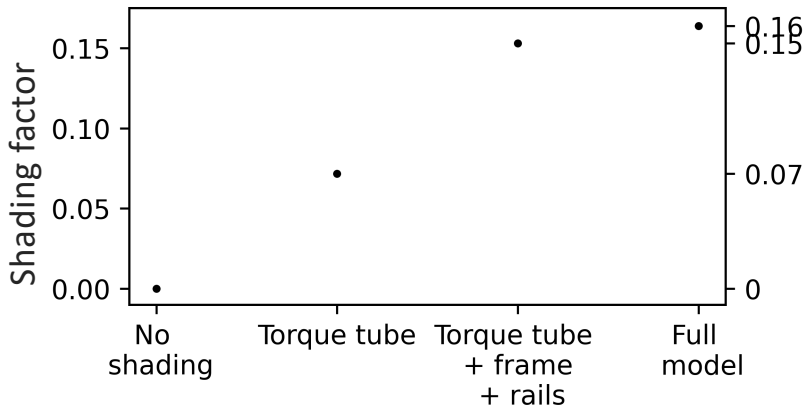




Shading factor, yearly simulation

$$f_{shading} = \frac{\frac{1}{N}\sum_{n=1}^{N} G_{rear,shaded}}{\frac{1}{N}\sum_{n=1}^{N} G_{rear,unshaded}}$$

$$SF = \left(1 - f_{shading}\right)$$



Summary

- Low spectral impact
  - POA from Pyranometer and reference cell are equivalent
- Local albedo has a strong impact on individual sensor measurements
- $G_{POA,rear}$ is very sensitive to the sensor position.

- No sensor position will at all times give a good estimate for the average rear irradiance, hence bifacial PR will have higher noise levels compared to monofacial PR.

- Modeled rear irradiance requires a detailed model of the structures causing rear side shading.
- More efficient tools are required for online monitoring

Thank you for your attention

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