

Sandia National Laboratories Bifacial Performance Optimization Studies using Bifacial Radiance and High Performance Computing



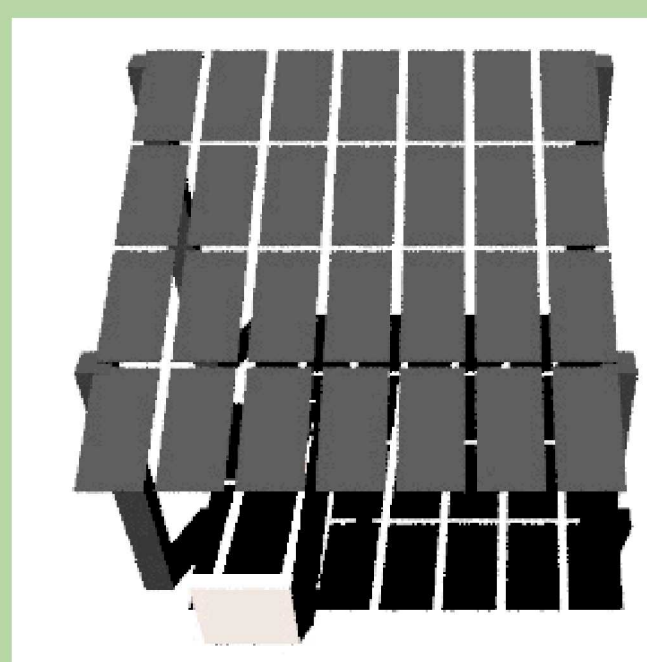
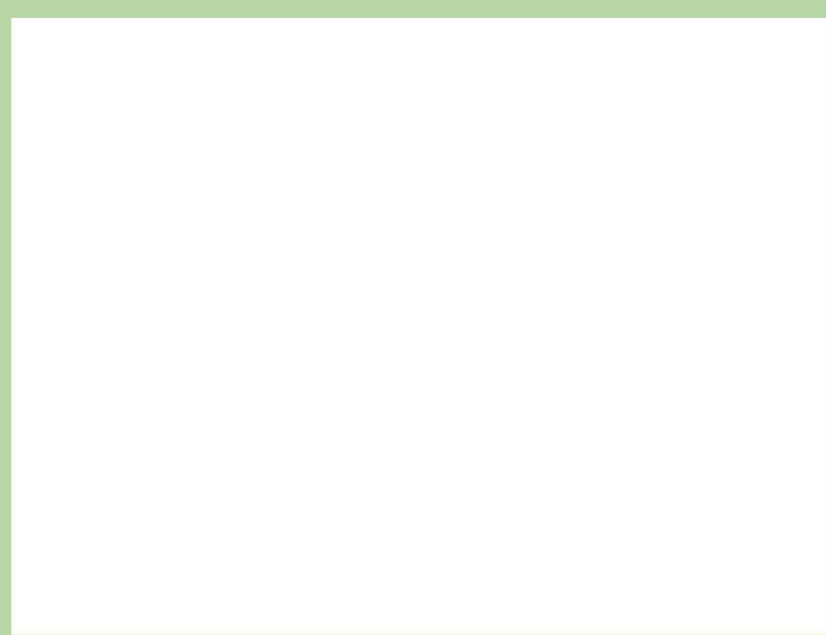
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Problem Statement

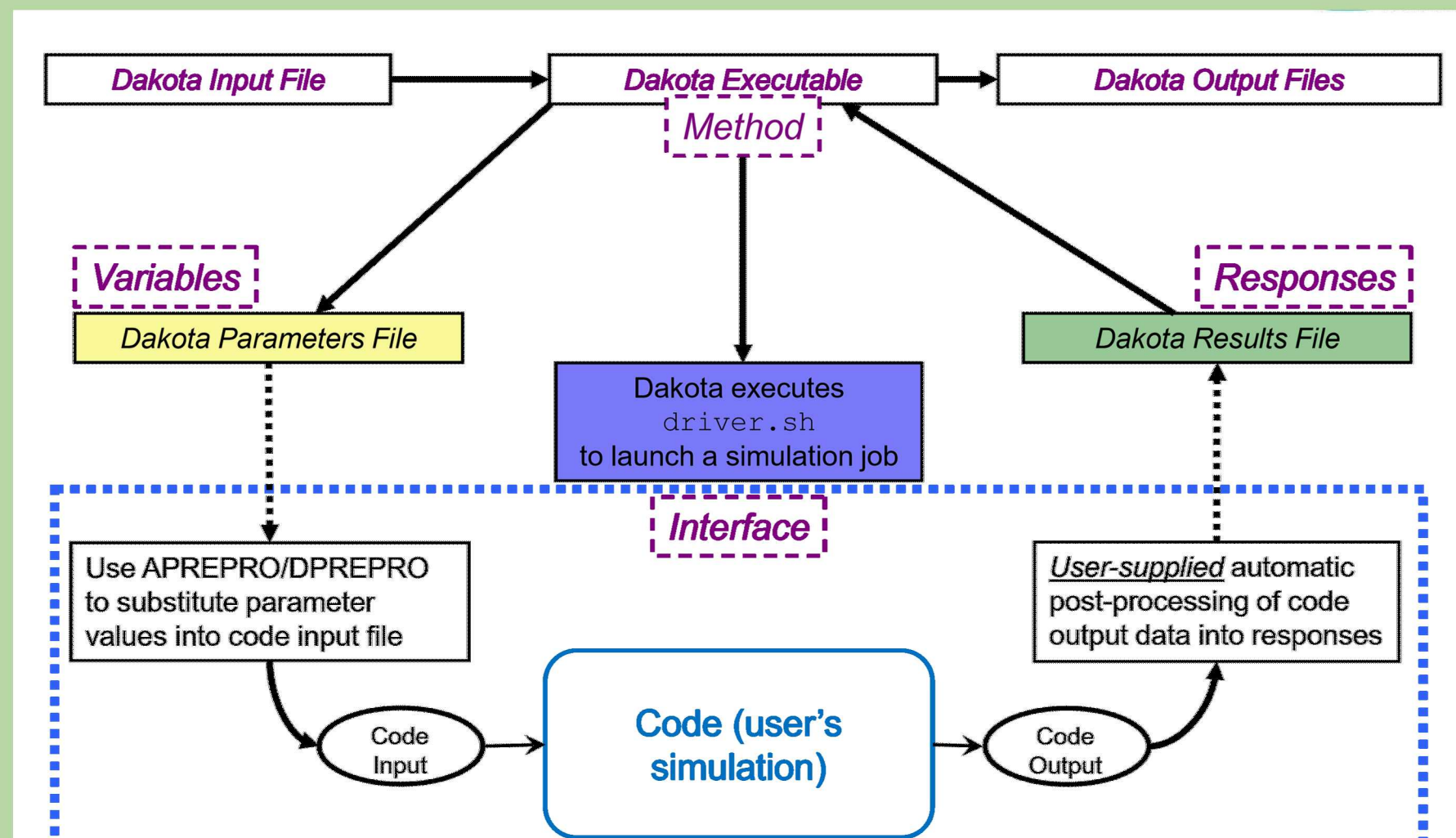
- What is the best system design for bifacial PV on Single axis trackers?
- Bifacial performance is more sensitive to certain parameters not considered that important for monofacial PV performance:
 - Albedo
 - Hub height
 - Tube gap, etc...

Models

- BIFACIAL RADIANCE**: NREL Python wrapper predicts incident irradiance using Radiance ray-tracing tools
 - Hourly cell-level incident irradiance calculations for bifacial arrays
 - Fixed tilt and horizontal single-axis tracker systems available
 - Solar position calculations from pvlib-python



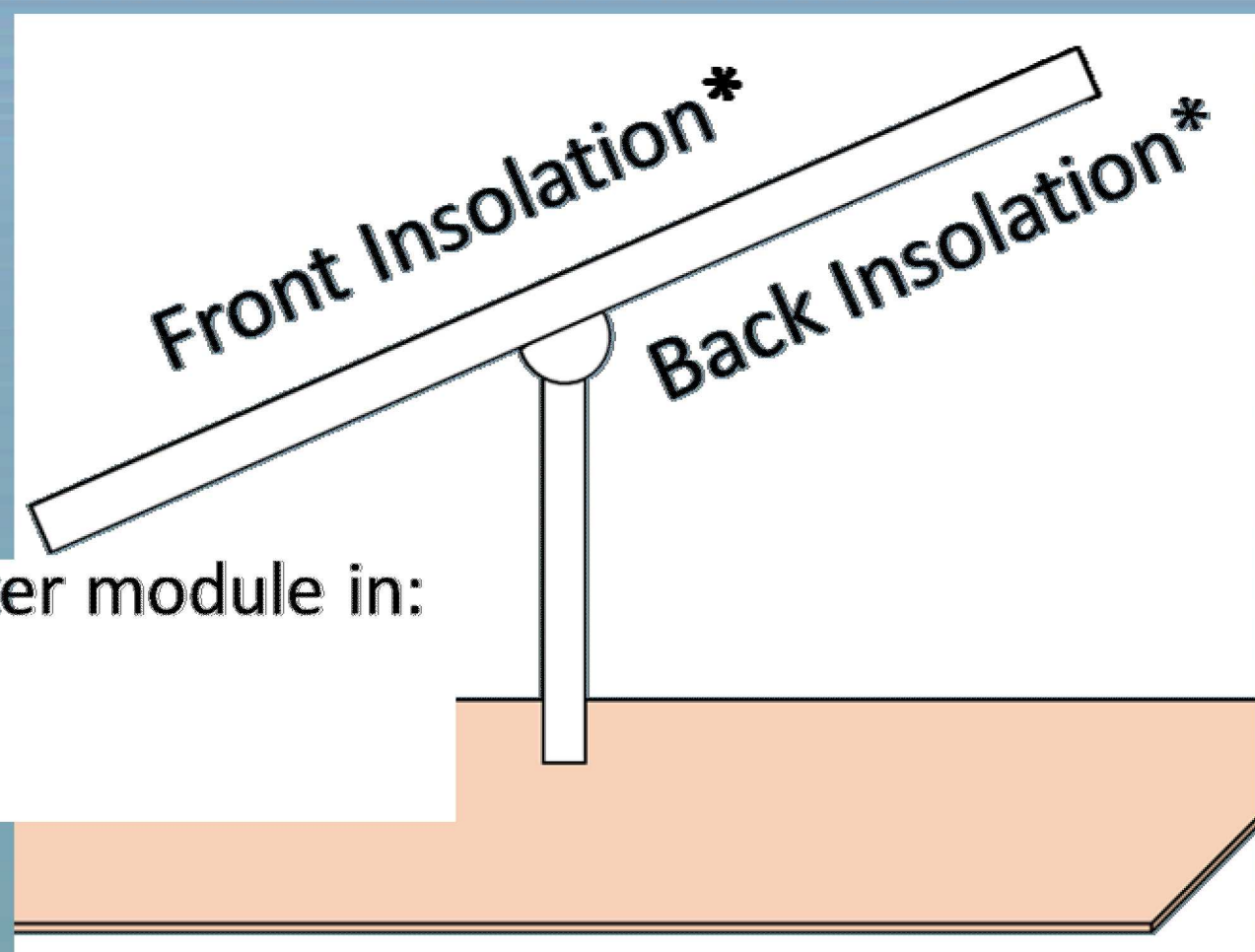
- DAKOTA**: Sandia developed optimization software
 - Automatic parameter sampling (Latin Hypercube Sampling) for robust sensitivity, optimization studies
 - Parallel processing suited for multi-core HPC environment



- HPC cluster: 71 Teraflop peak cluster with 168 dual socket, 8-core 2.7 GHz Intel Sandy Bridge processors with 64 GB of RAM per node.

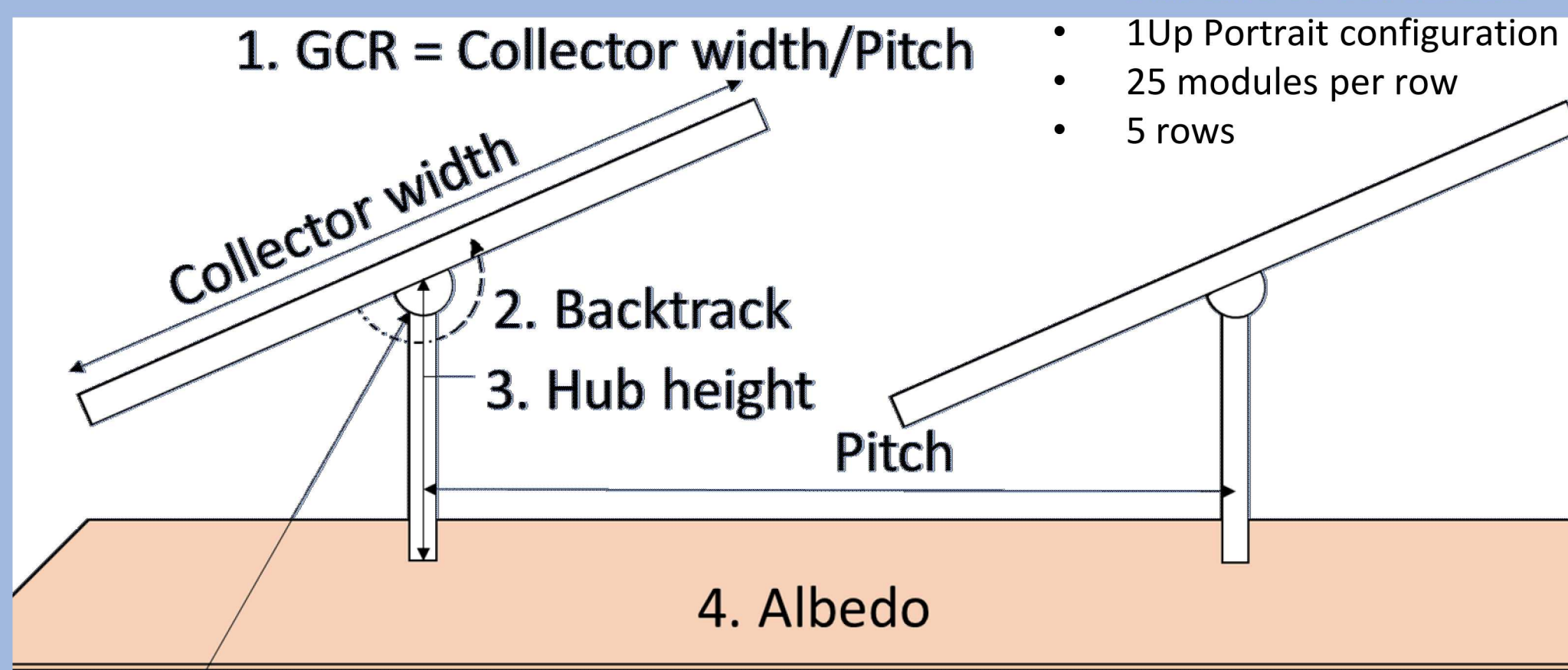
Approach

- Latin Hypercube Sampling (LHS): Random sampling from uniform probability bins with reordering to minimize cross correlation
- 100 realizations: annual simulations for 3 HSAT test cases:
 - 36-day annual sample with wide albedo range
 - 36-day annual sample with albedo range .15-.25 (typical ground conditions)
 - 365-day annual approximation with .15-.25 albedo range
 - 36-day annual sample with albedo range .75-.85 (snow conditions)
- 36 day annual samples include max, min, median daily insolation for each month
- Outputs analyzed with Stepwise Regression where variables are sequentially added to regression until ~95% of the variability is accounted for.
- Model outputs:
 - Irradiance on front and back of each cell



Approach

- Model inputs:

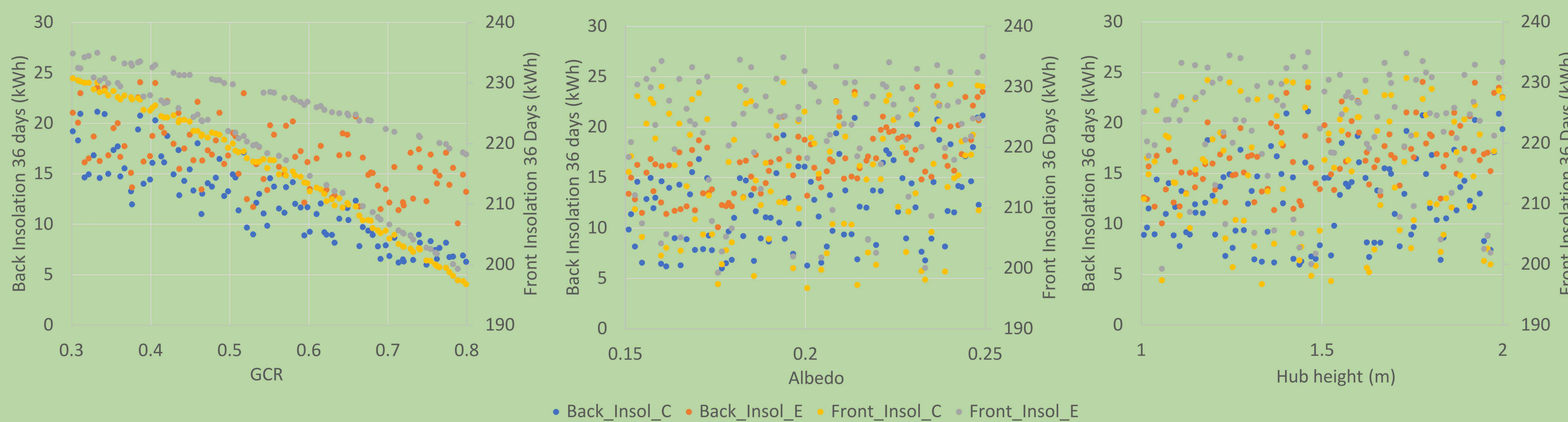


- Standard 60-cell module
- 1Up Portrait configuration
- 25 modules per row
- 5 rows

Inputs	Description	Type	Range	Units
GCR	Collector width/row-to-row distance	Float	.3-.8	meters/meters
Albedo	Ratio of light reflected by ground	Float	1. [.10-.80] 2-3. [.15-.25] 4. [.75-.85]	None
Hub height	Height of tracker from ground	Float	1-2	meters
Tube gap	distance of module from torque tube in Z	Float	1-10	centimeters
Backtrack	True= backtracking False="true" tracking	Boolean	True, False	none
Tube shape	Shape of torque tube	String	Round, Oct, Square, Hex	none

Results

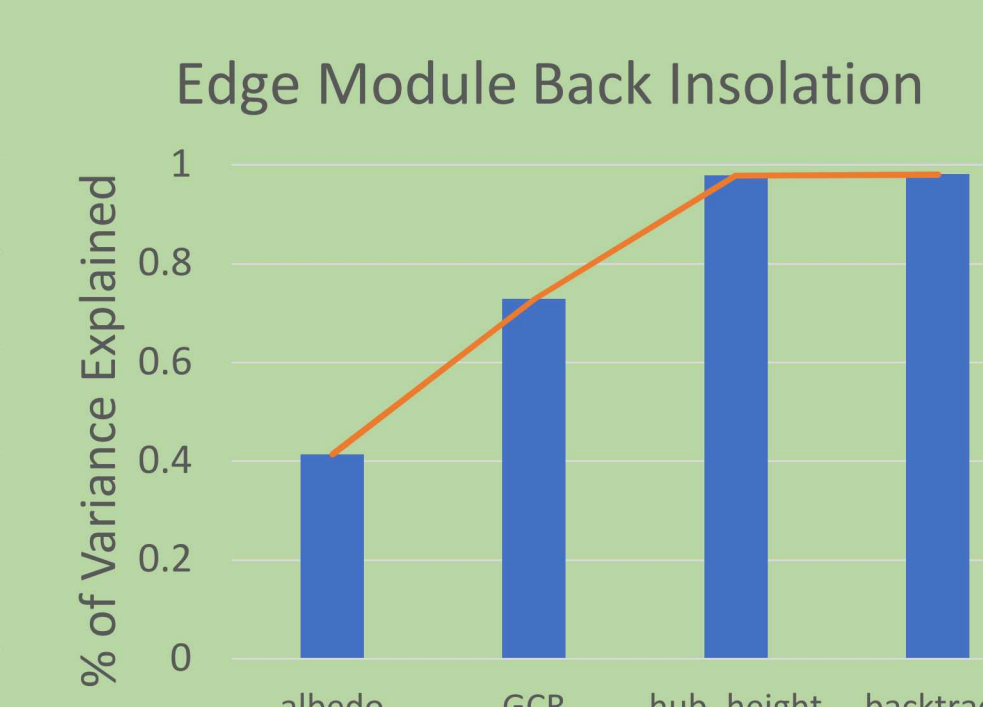
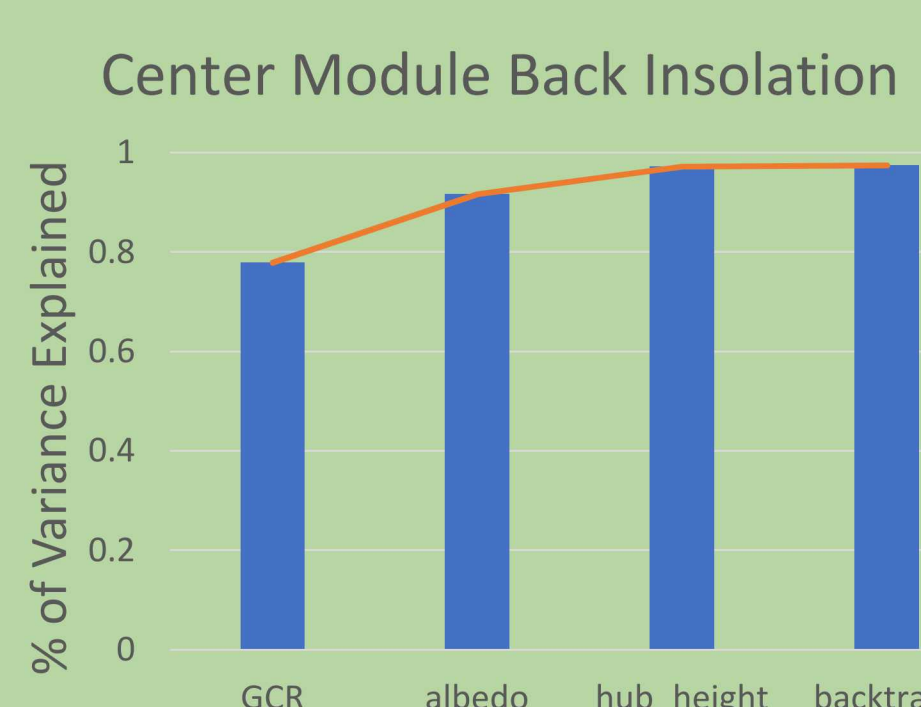
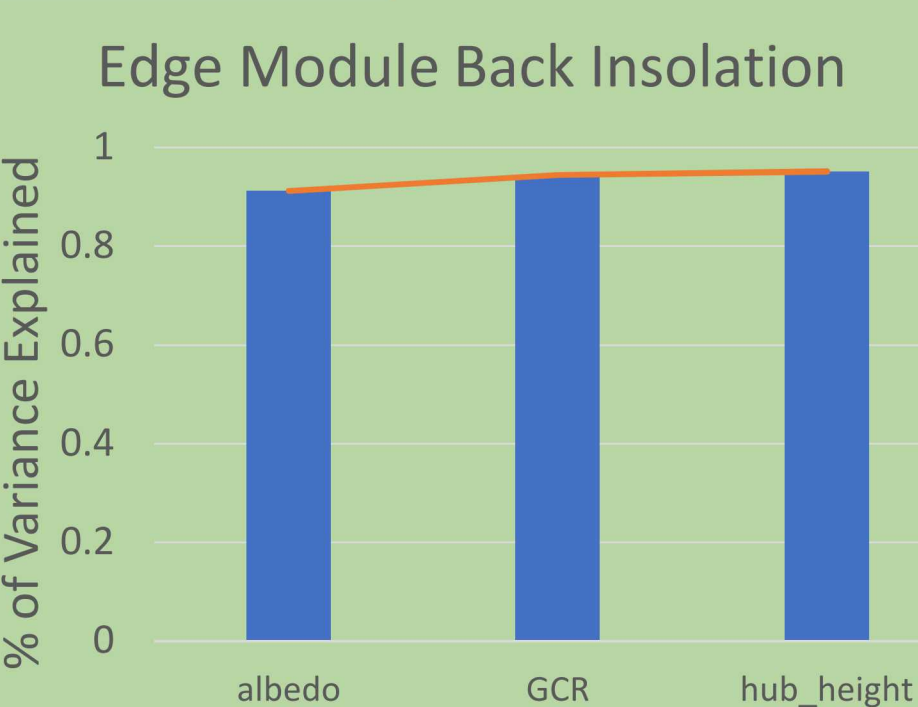
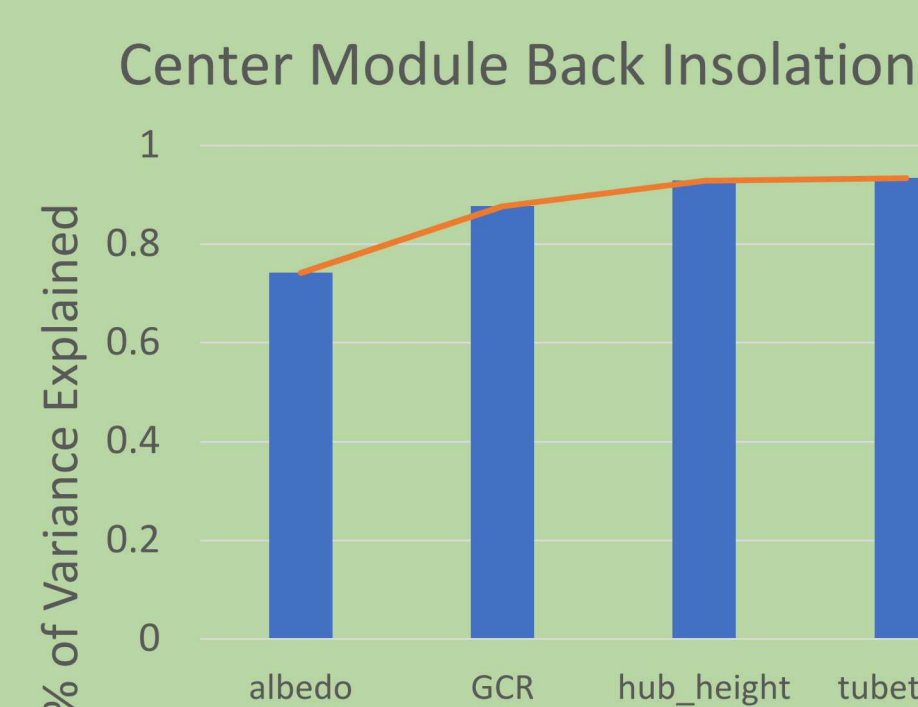
- Results of albedo range .15-.25 study show that GCR and albedo have the most influence on the variability of both the front and rear irradiance received, particularly in the center row where row-to-row shading due to GCR has greater effect.



- Stepwise Regression** results show that the insolation variability for edge modules is most explained by albedo when values are low, while the center modules behavior is dominated by changes in GCR.

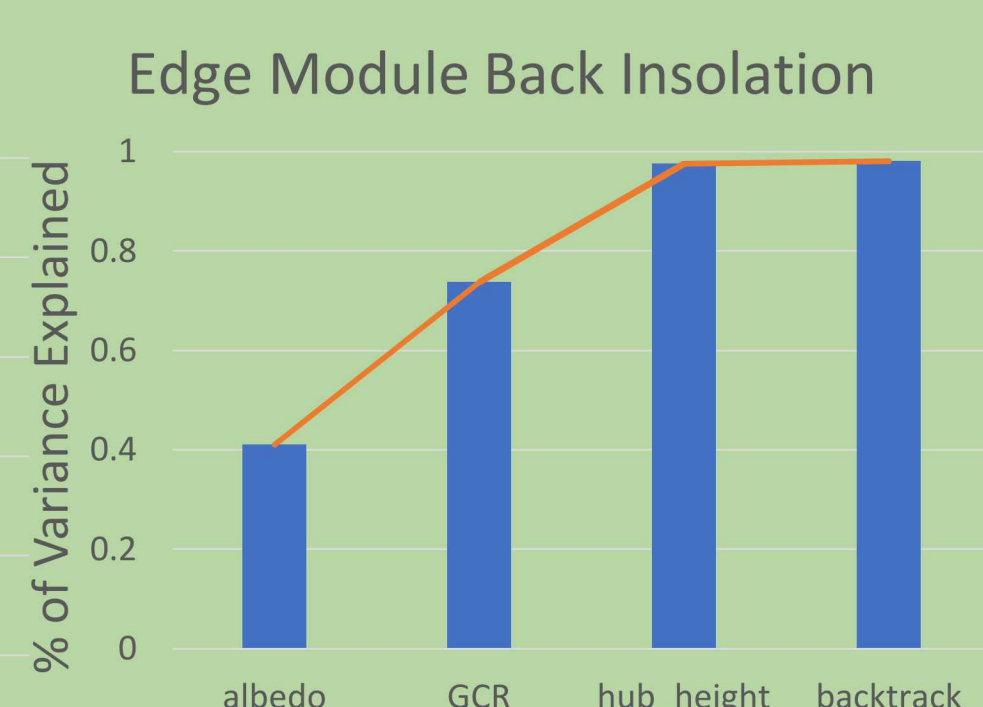
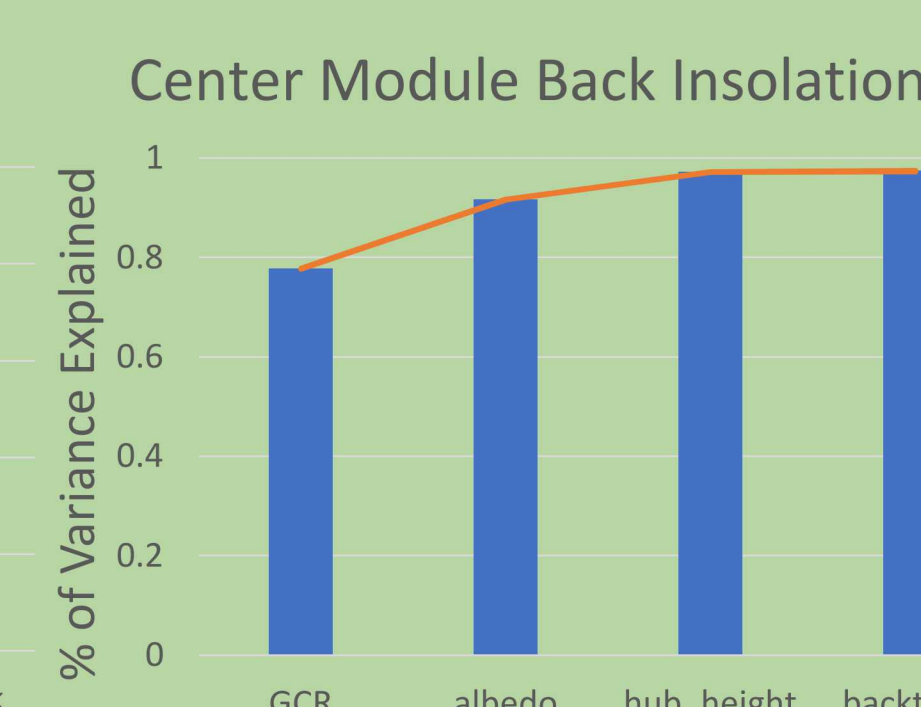
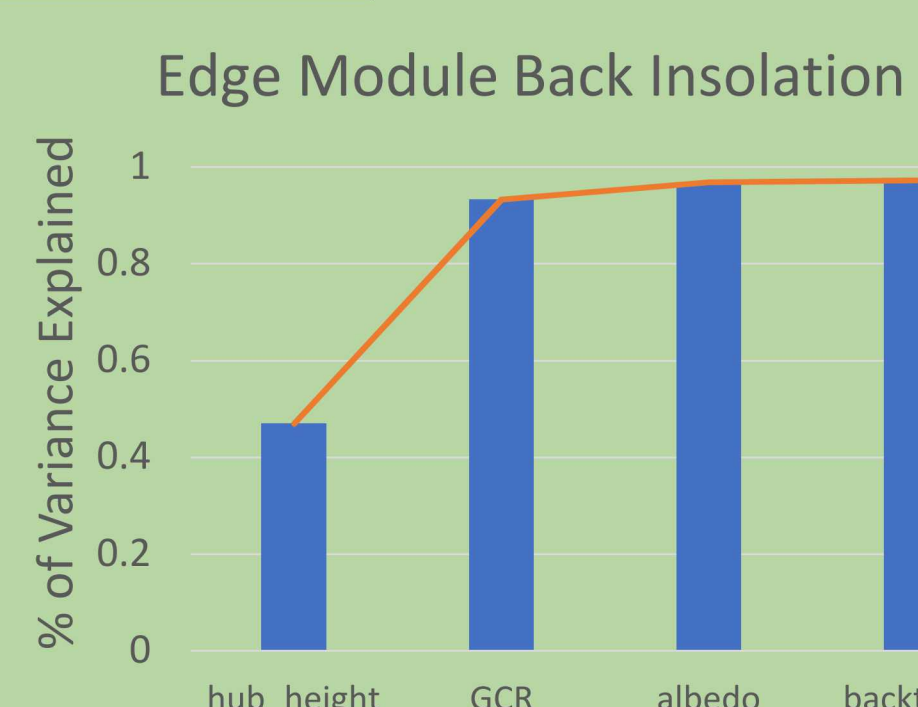
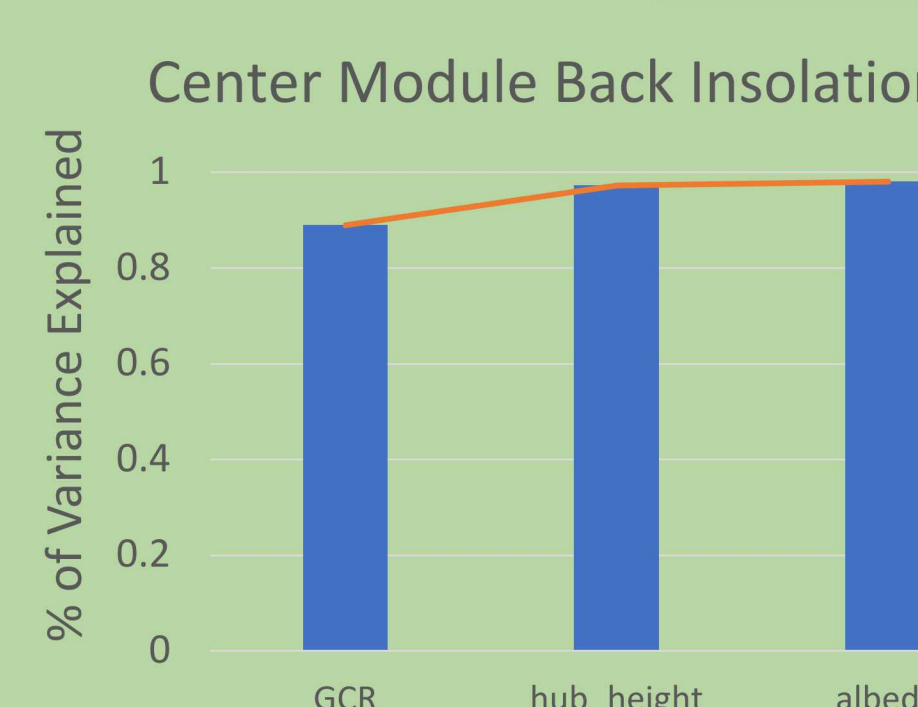
- Comparison of the Annual and 36-day results shows that nearly identical dependencies, validates the use of 36-day representative samples for future studies.

Albedo Range .10-.80



Albedo Range .15-.25 (Annual)

Albedo Range .75-.85

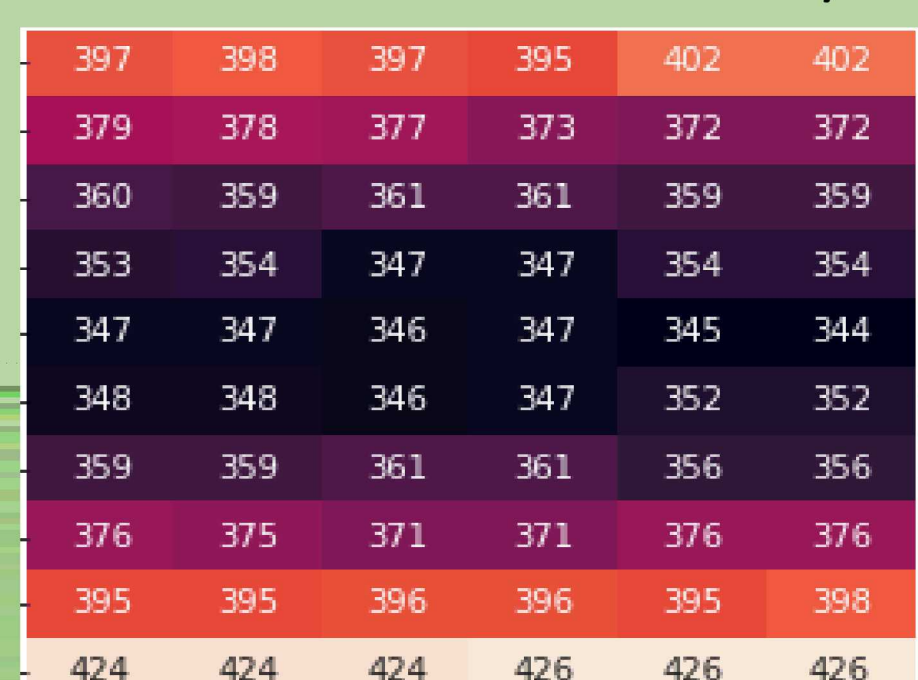


Albedo Range .15-.25 (36 days)

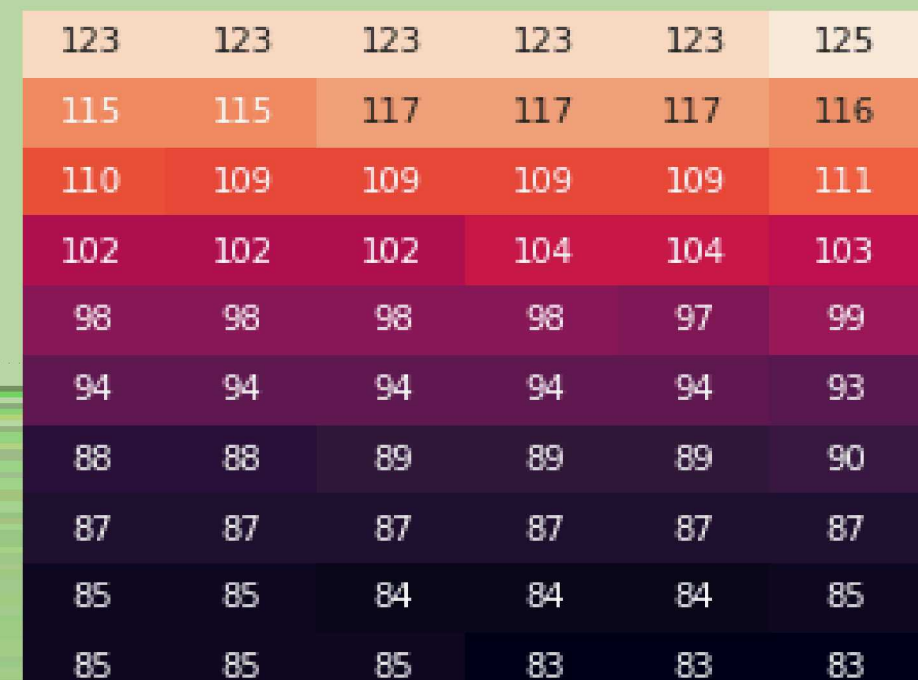
- Bifacial_radiance allows for cell-level irradiance scans; these scans show that the torque tube can limit the irradiance received in the center cells of a module

Albedo Range .75-.85

Summer: Std Dev = 24.9 W/m²

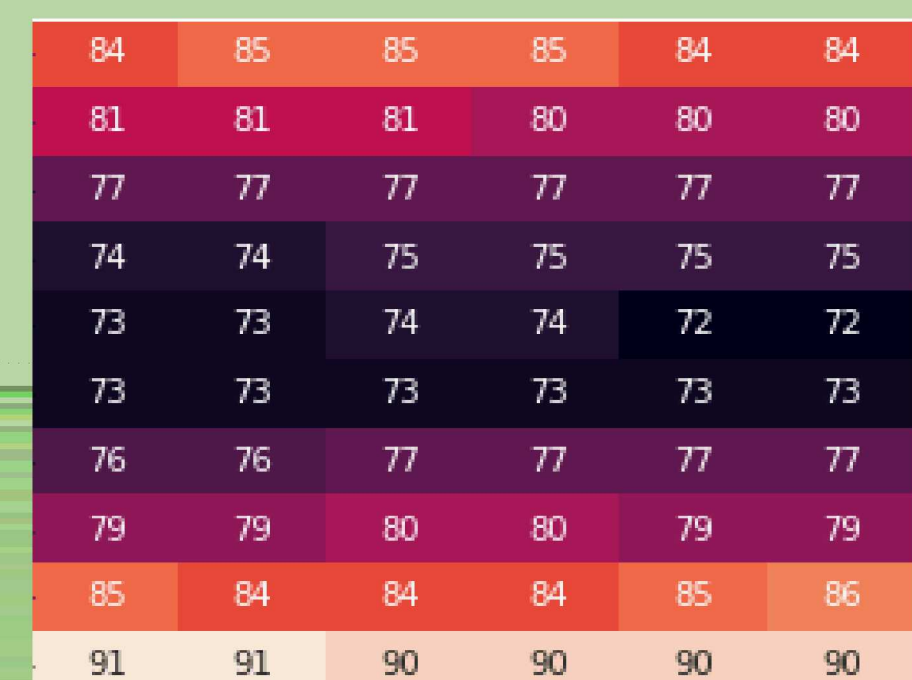


Winter: Std Dev = 13.3 W/m²

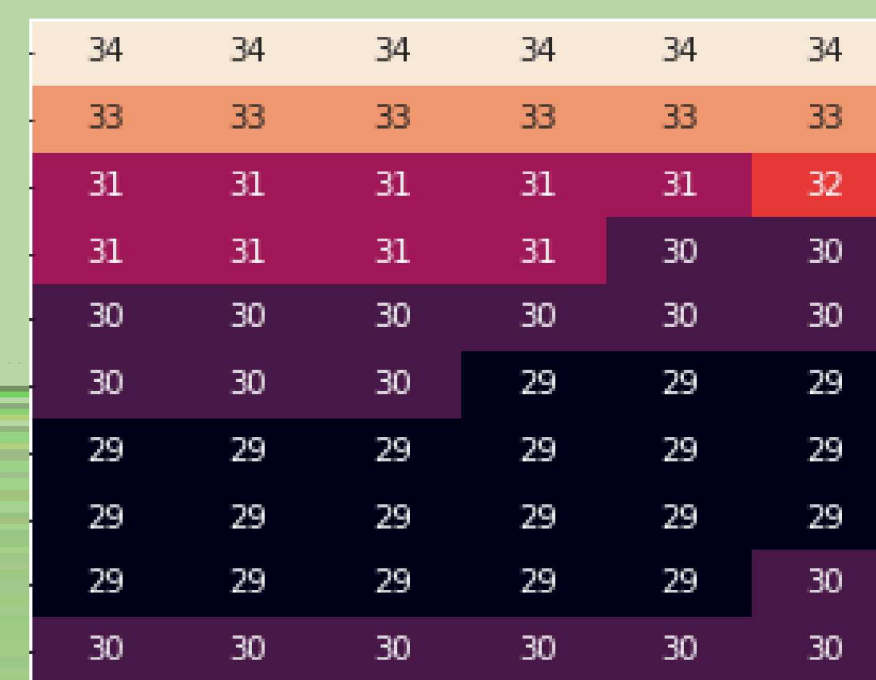


Albedo Range .15-.25

Summer: Std Dev = 5.5 W/m²



Winter: Std Dev = 1.7 W/m²



Higher albedo results in a larger Stddev, meaning that these conditions could result in more electrical mismatch.

Findings

- Albedo and GCR are the most influential parameters
 - Finding high albedo sites or enhancing albedo may be justified.
- Hub height and backtracking are of secondary importance.
- Tube gap and tube shape appear to not be very influential parameters.

Acknowledgements

- Bifacial_Radiance developed at NREL:
 - (https://github.com/NREL/bifacial_radiance)
- Dakota developed at Sandia National Laboratories:
 - (<https://dakota.sandia.gov>)