What to consider for improved accuracy and reduced uncertainty in resource measurement campaigns

Annalise Miller & Nate Croft

PVPMC 2024

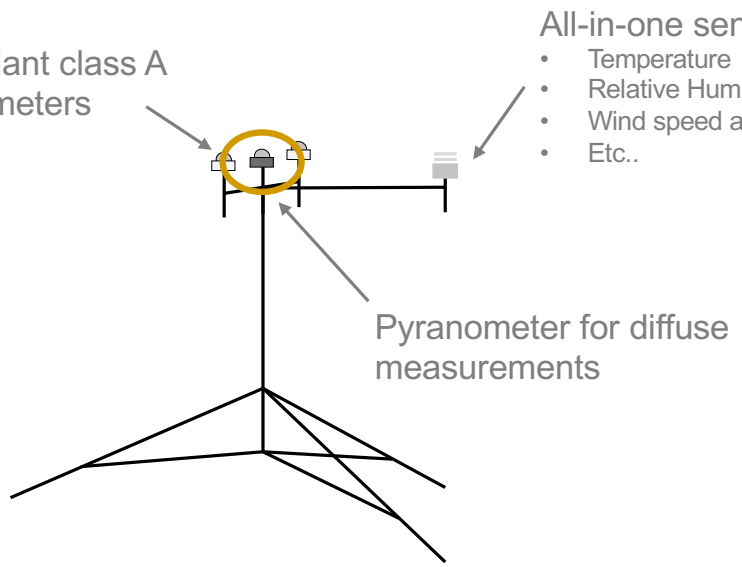
LUMINATE

Background

- **Why:** we are seeing more clients approach project development *with* measurement campaigns.
  - Clients and banks both want to reduce uncertainty in an energy estimate.
  - Satellite data are good, but it can be biased. Particularly in specific regions.

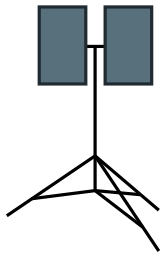
- **The problem:** the industry has not converged on exactly what a measurement campaign should look like or how to conduct and interpret the results of an MCP analysis

Typical Features of Measurement Stations

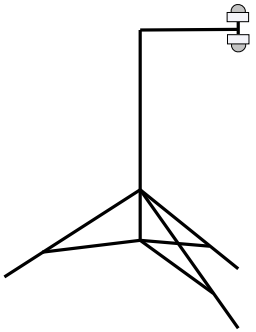


- Maintenance Frequency: Weekly
- Include Photos: yes
- Campaign Duration: 1 year

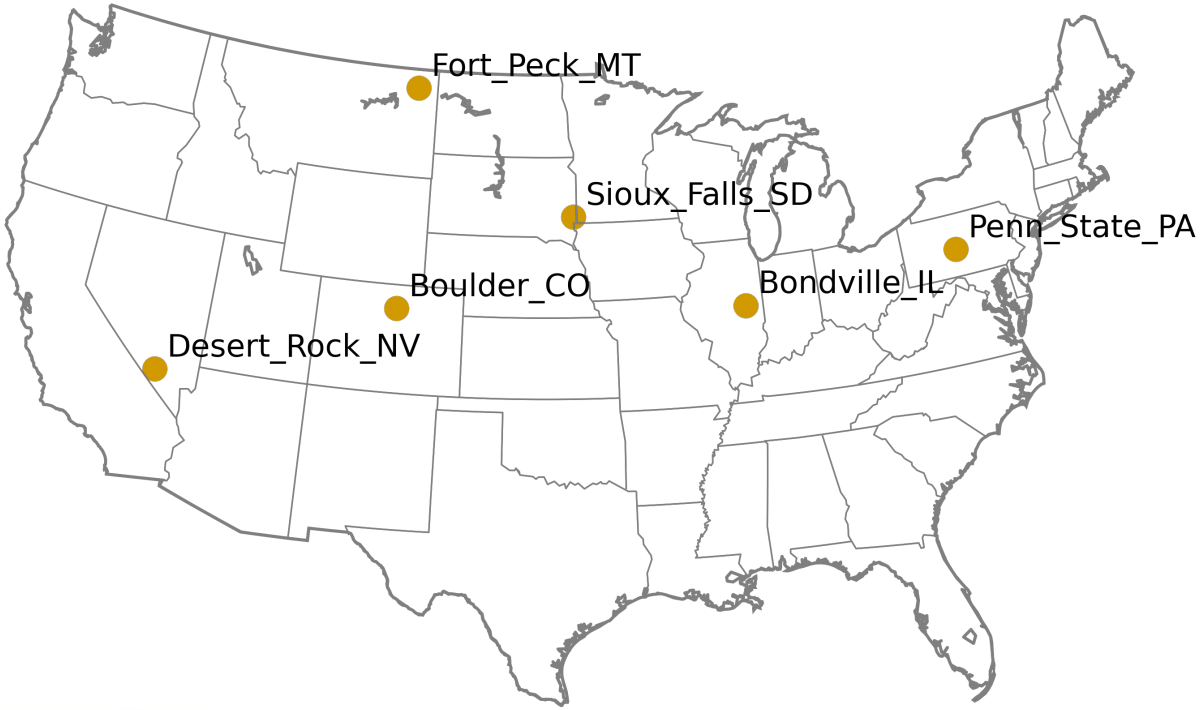
Reference module soiling station



Albedometer



SURFRAD Stations

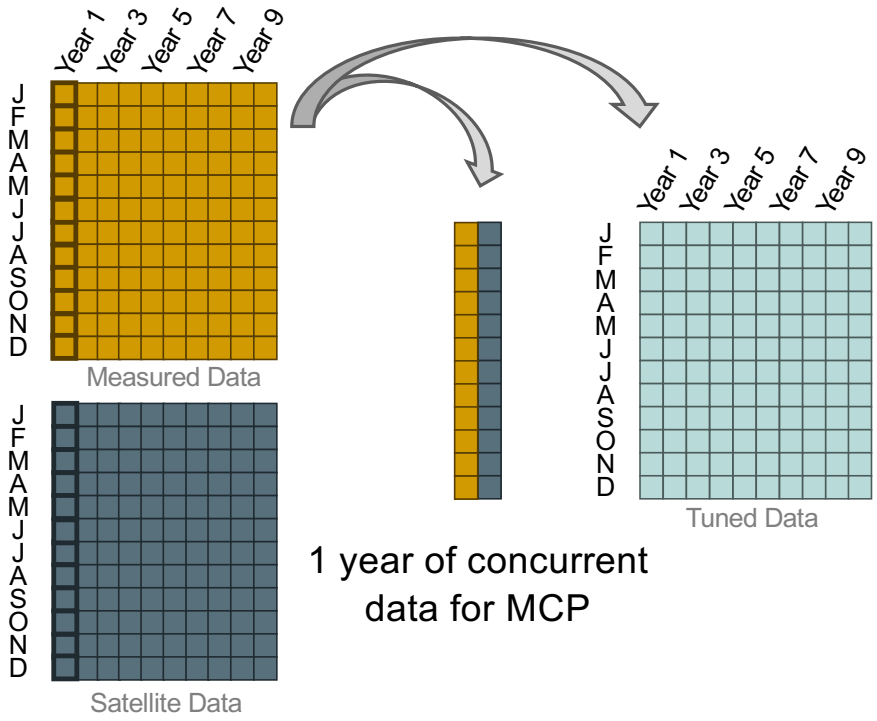


Why SURFRAD?

- Long-term measurements
  - GHI and DHI values
  - 15-24 years
- High Quality with QC markers
- Geographically Varied

LUMINATE

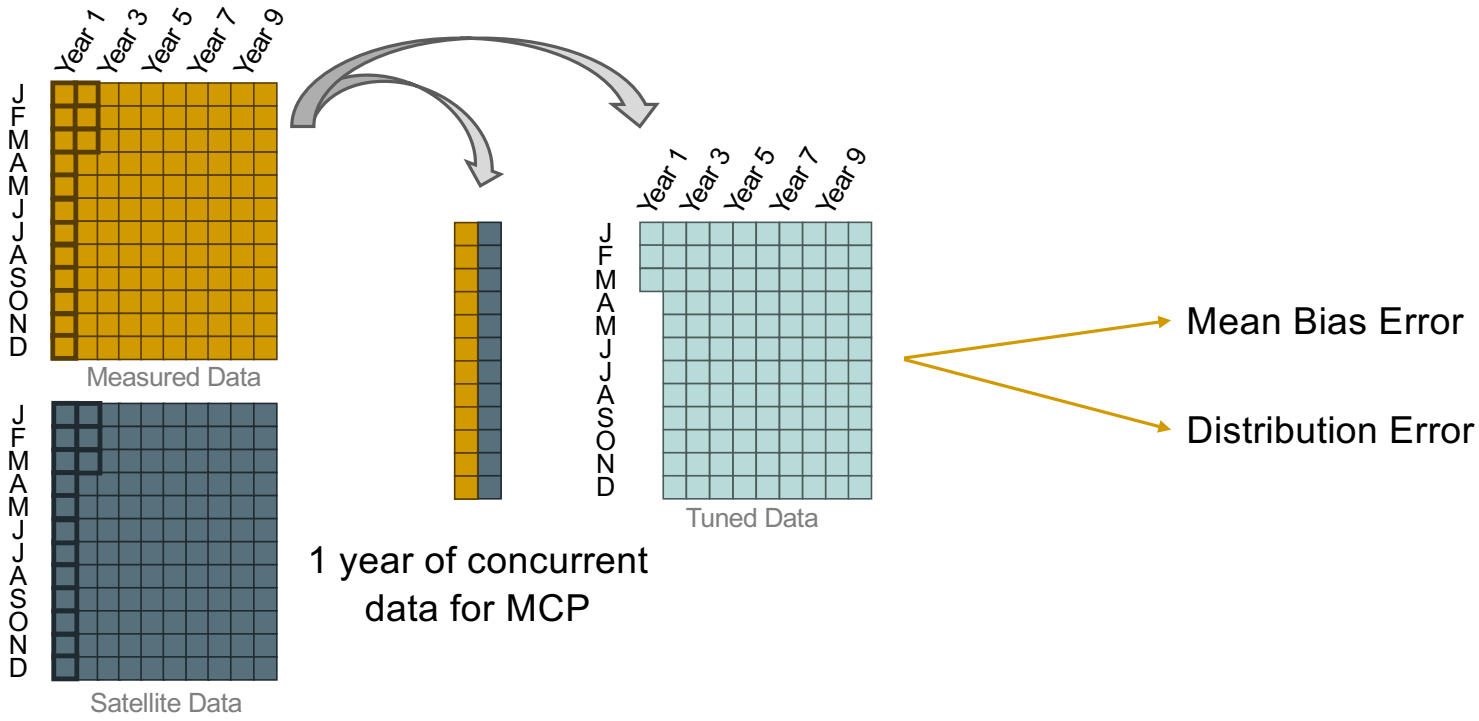
Do Measurements Improve Irradiance Data?



[X] years of concurrent Satellite and Measured data

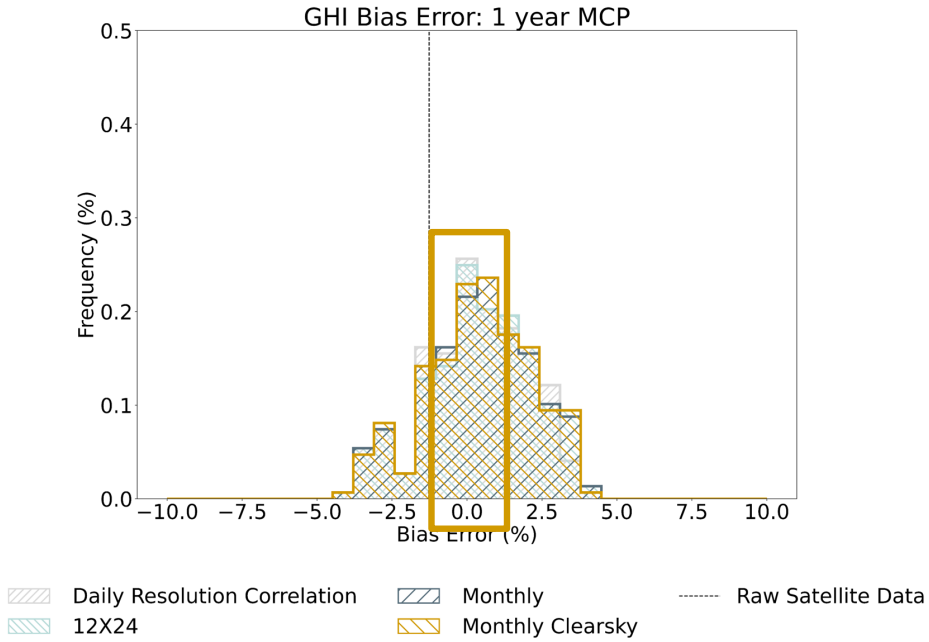
LUMINATE

Do Measurements Improve Irradiance Data?



[X] years of concurrent Satellite and Measured data

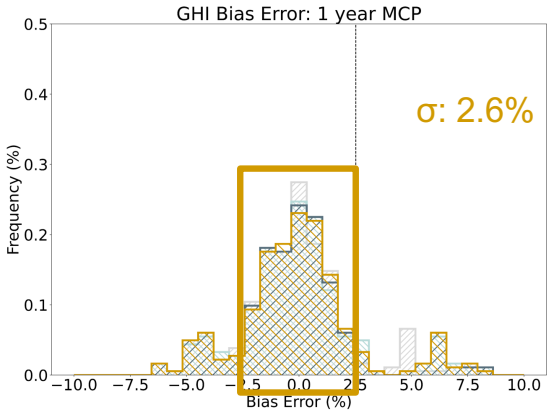
Do Measurements Improve Irradiance Data?



Mean Bias Error

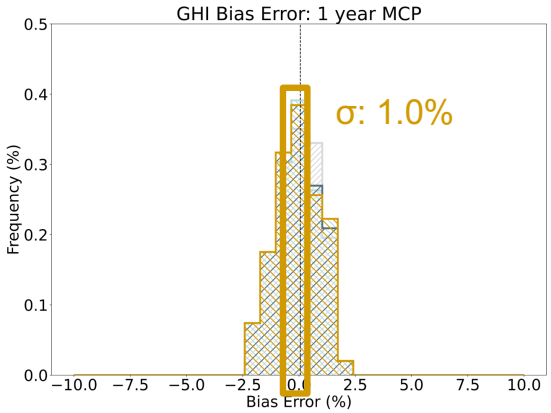
Do Measurements Improve Irradiance Data?

Fort Peck, MT



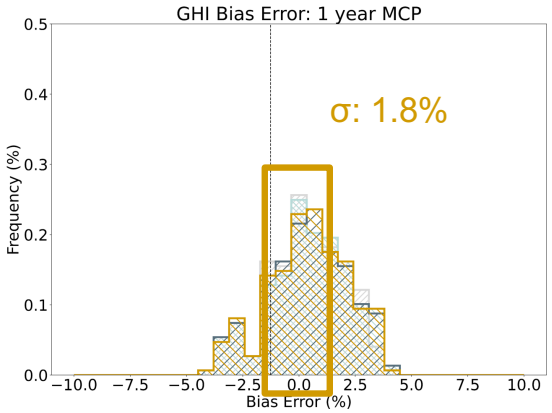
Frequency of Improvement: 77-78%

Desert Rock, NV

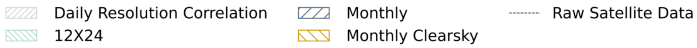


Frequency of Improvement: 4%

Boulder, CO



Frequency of Improvement: 53-55%

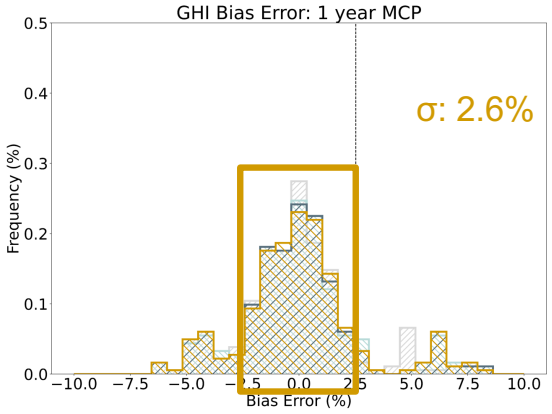


LUMINATE

[1] J. Alfi, A. Kubiniec, G. Mani, J. Christopherson, Y. He and J. Bosch

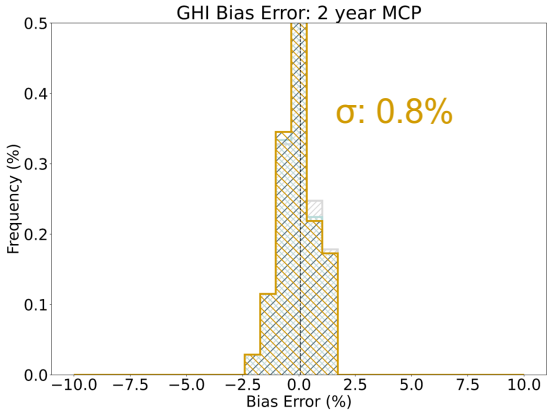
Do Measurements Improve Irradiance Data?

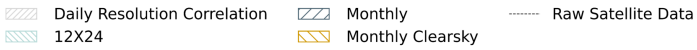
Fort Peck, MT



Frequency of Improvement: 77-78%

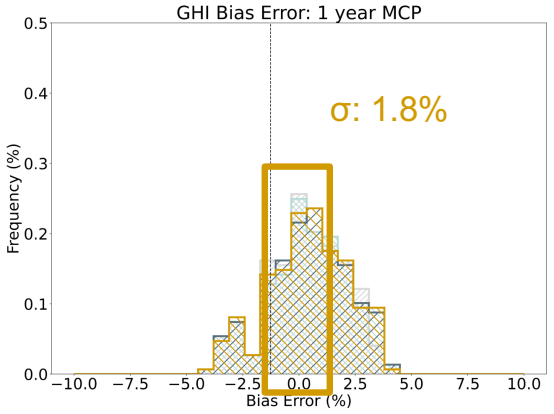
Desert Rock, NV





Frequency of Improvement: 5%

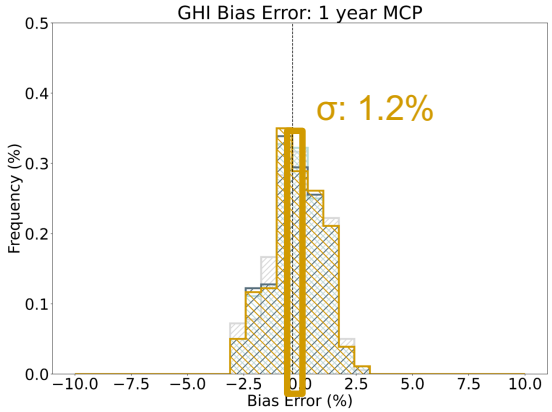
Boulder, CO



Frequency of Improvement: 53-55%

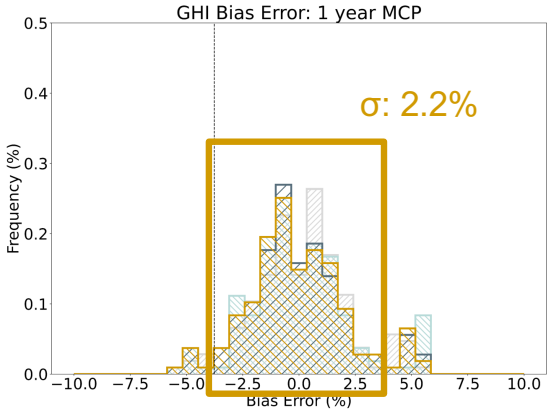
Do Measurements Improve Irradiance Data?

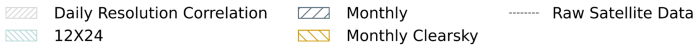
Penn State, PA



Frequency of Improvement: 19-22%

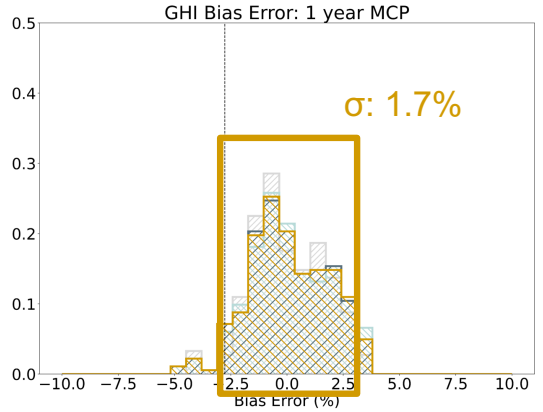
Sioux Falls, SD





Frequency of Improvement: 87-89%

Bondville, IL



Frequency of Improvement: 88-94%

Do Measurements Improve Irradiance Data?

Usually!

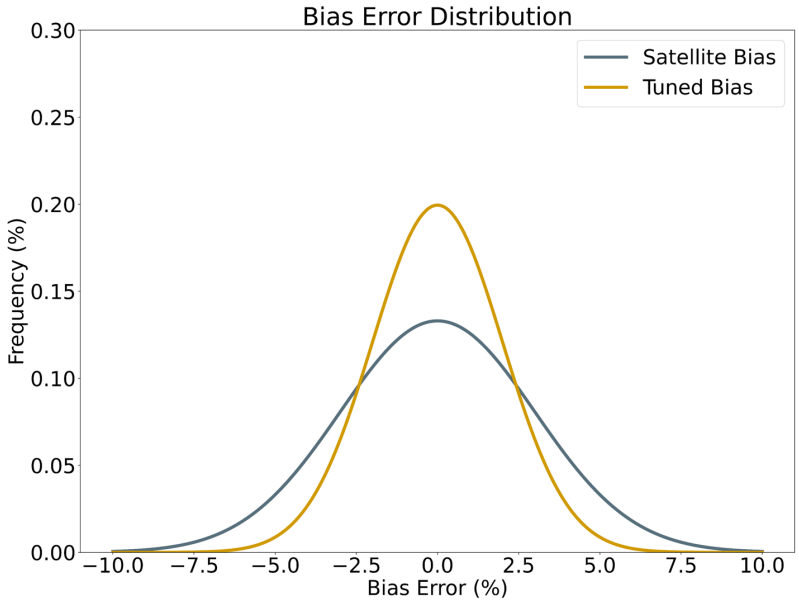
Example:

Results of Tuning

- Mean bias: 0%
- Uncertainty (Standard Deviation): 2%
  - Variation due to time period of tuning data

Raw Satellite Data

- Mean Bias: 0%
- Uncertainty (Standard Deviation): 3%
  - Variation geographically

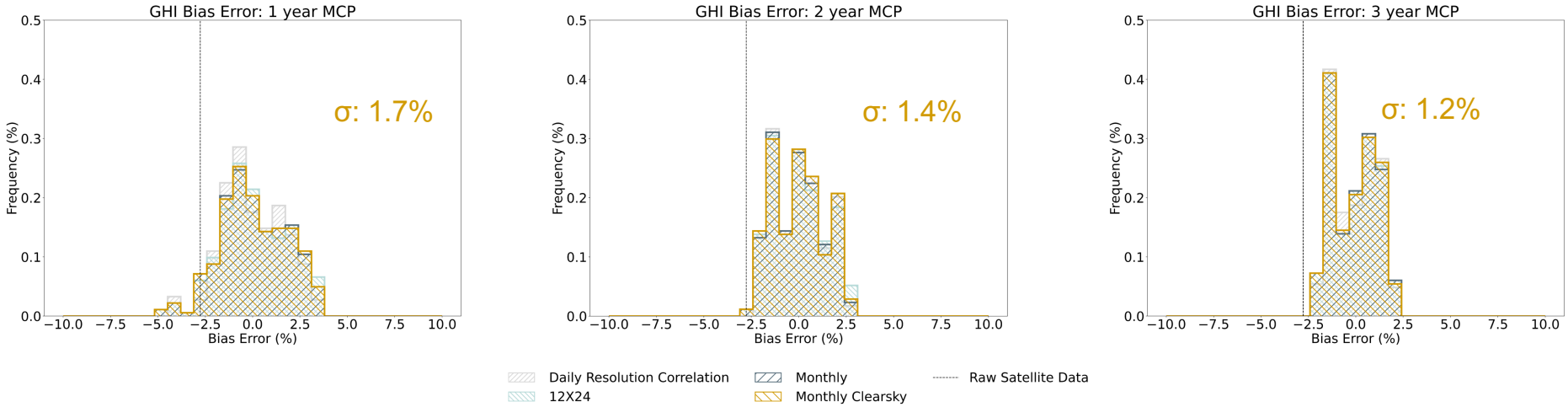


Reduced Bias Error
63% of the time

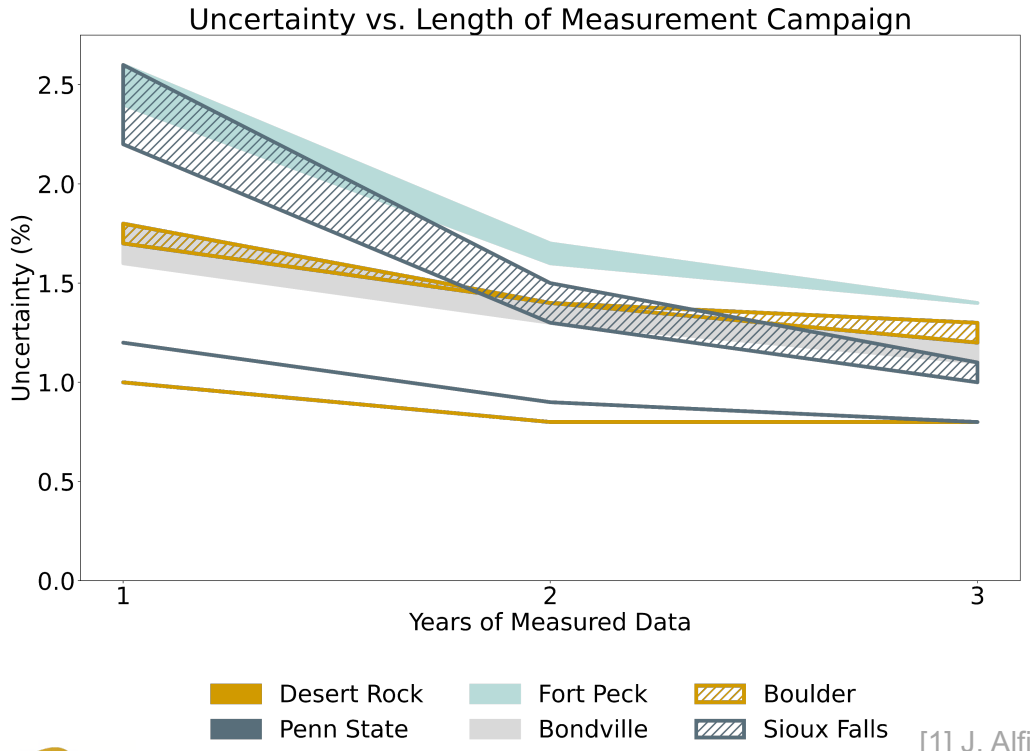
Reduced Uncertainty ≠ Reduced Bias

How does length of campaign impact MCP results?

Bondville, IL



How does length of campaign impact MCP results?



Increasing IAV*

Proposed threshold for second year of measurements: 2%

* In reality the benefit you get from additional measurements is going to depend on how consistent the satellite data errors were and will change with your satellite source selection. IAV is only a proxy.

[1] J. Alfi, A. Kubiniec, G. Mani, J. Christopherson, Y. He and J. Bosch
[2] L. Tafur, R. Darawali, and H. Darling

Do Measurements Improve Irradiance Data?

Usually!

Example:

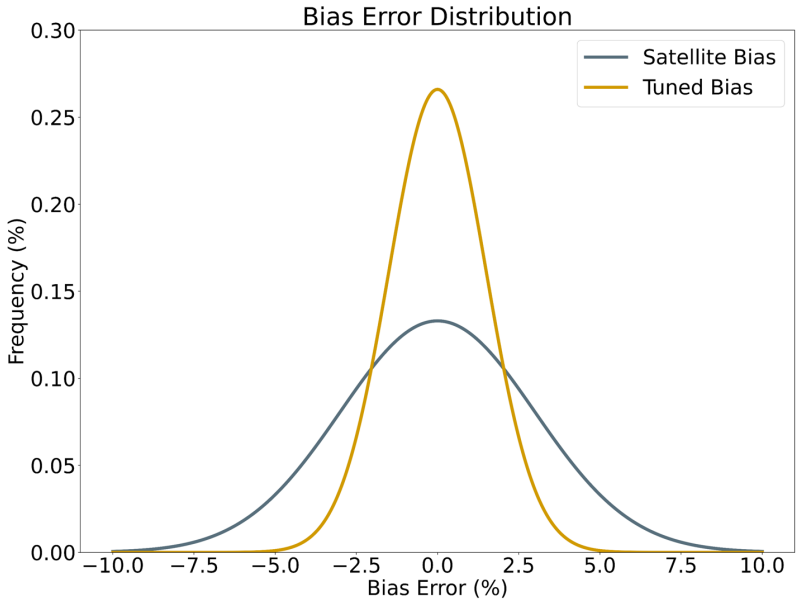
Results of Tuning

- Mean bias: 0%
- Uncertainty (Standard Deviation): 1.5%
  - Variation due to time period of tuning data

Raw Dataset

- Mean Bias: 0%
- Uncertainty (Standard Deviation): 3%
  - Variation geographically

Reduced Bias Error
70% of the time



Do Measurements Improve Irradiance Data?

Usually!

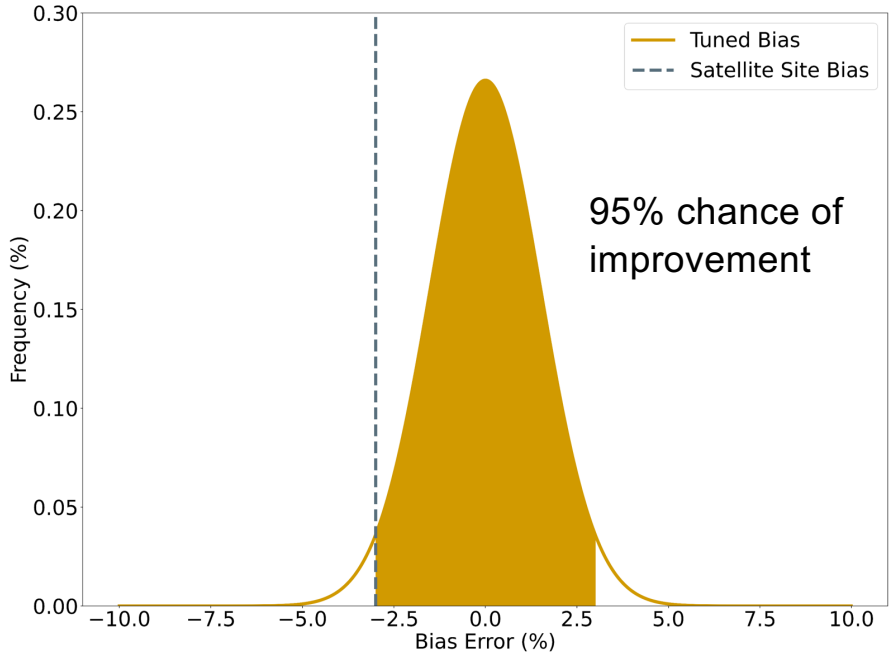
Example:

Results of Tuning

- Mean bias: 0%
- Uncertainty (Standard Deviation): 1.5%
  - Variation due to time period of tuning data

Raw Dataset

- Select site with -3.0% bias



Do Measurements Improve Irradiance Data?

Usually!

Example:

Results of Tuning

- Mean bias: 0%
- Uncertainty (Standard Deviation): 1.5%
  - Variation due to time period of tuning data

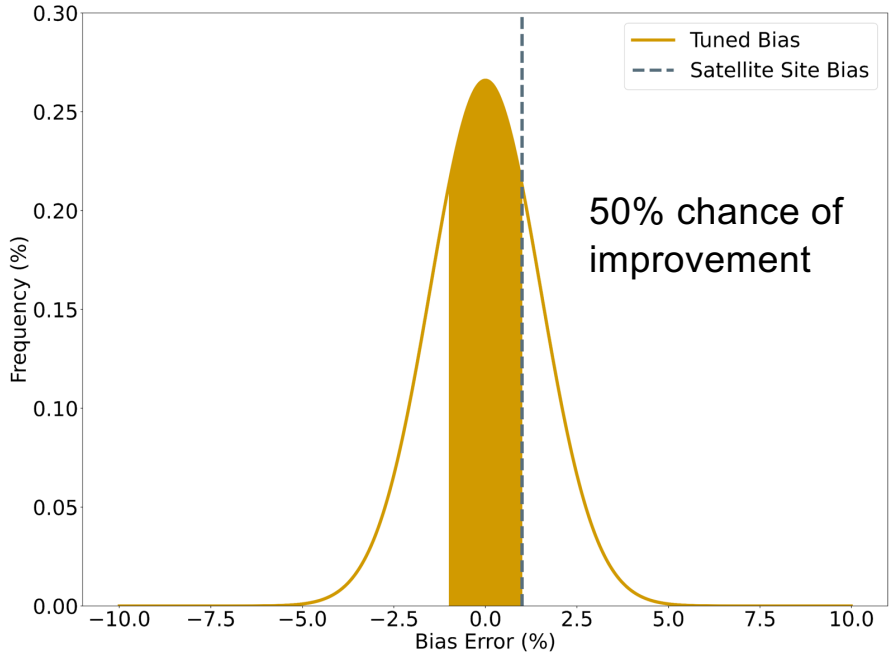
Raw Dataset

- Select site with +1.0% bias

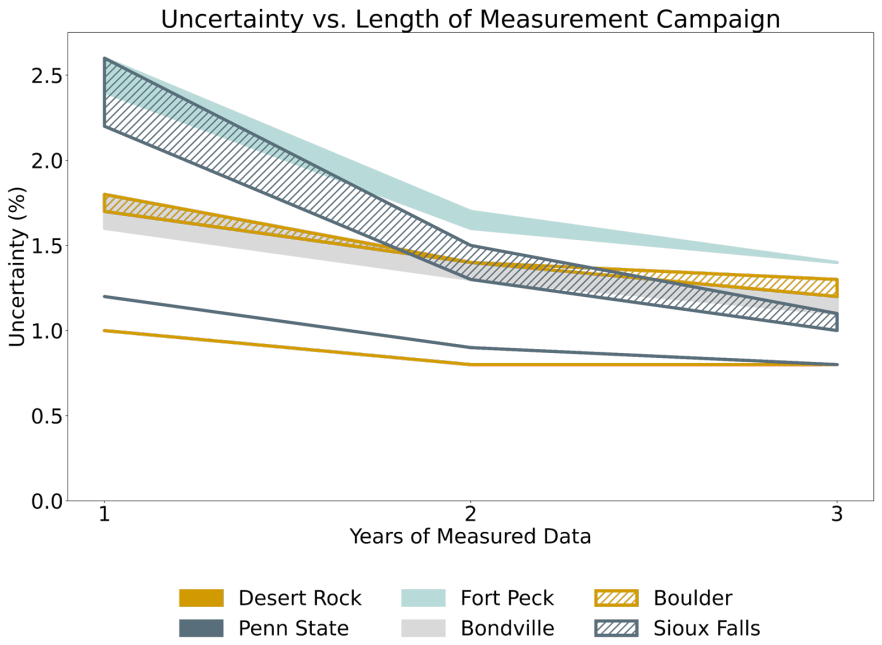
-1.0% on GHI

-0.9% on Energy

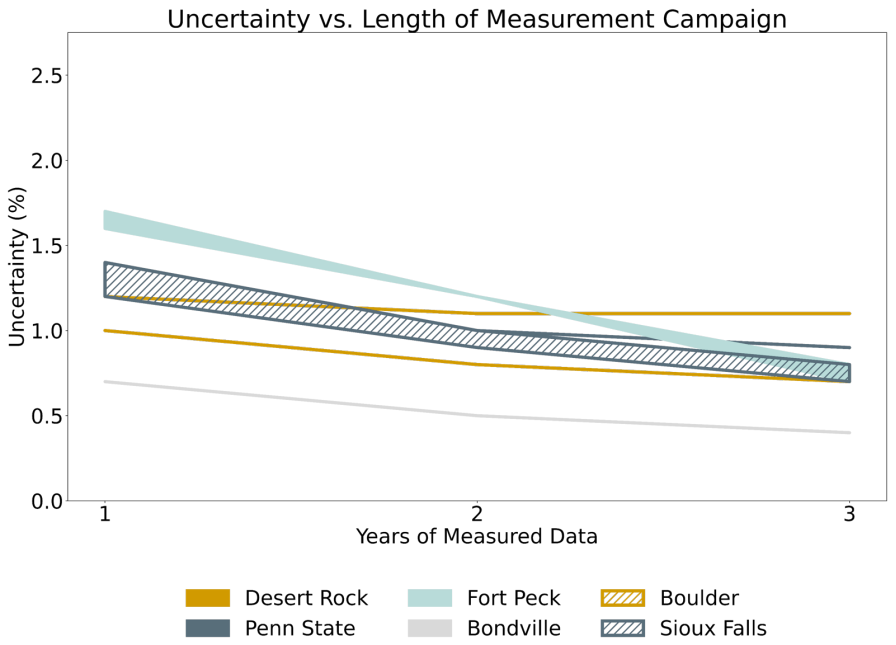
+0.1% on P90



How does satellite data source impact MCP results?

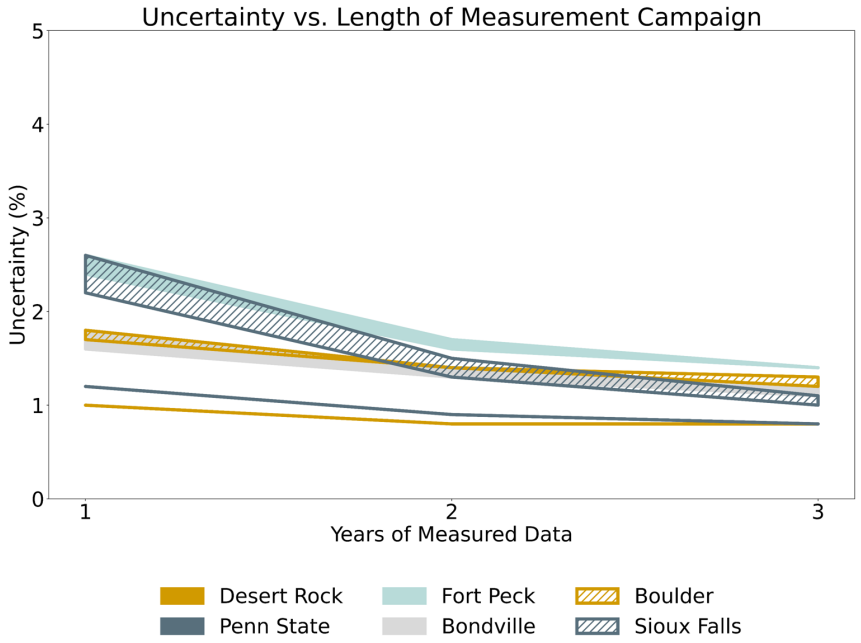


Satellite source “A”

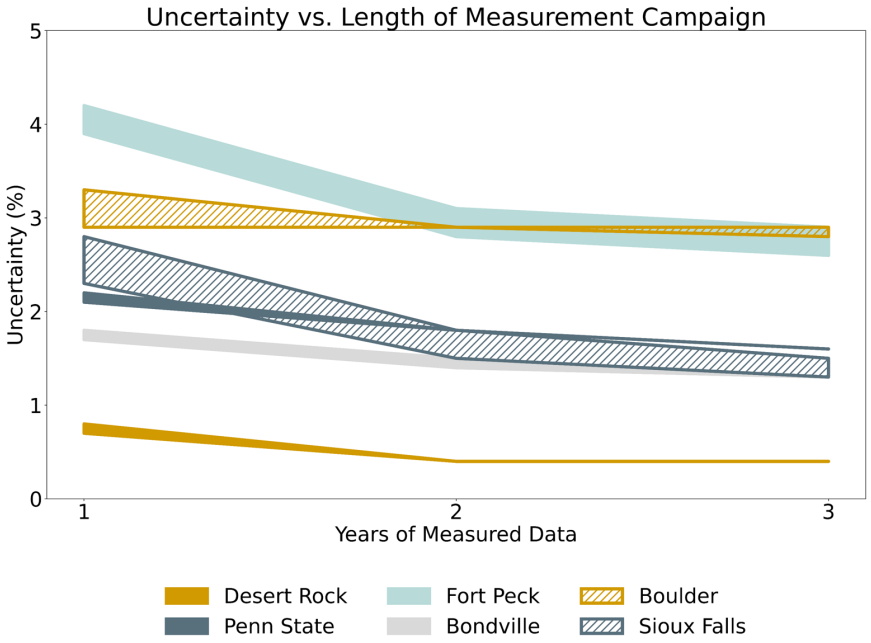


Satellite source “B”

How does satellite data source impact MCP results?



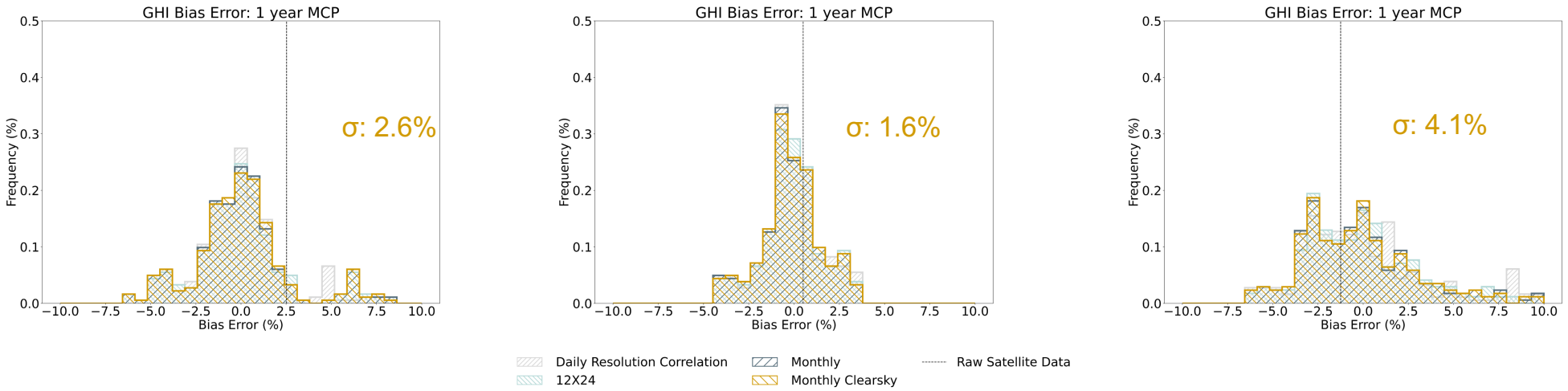
Satellite source “A”



Satellite source “C”

How does satellite data source impact MCP results?

Fort Peck, MT



Satellite source “A”

Satellite source “B”

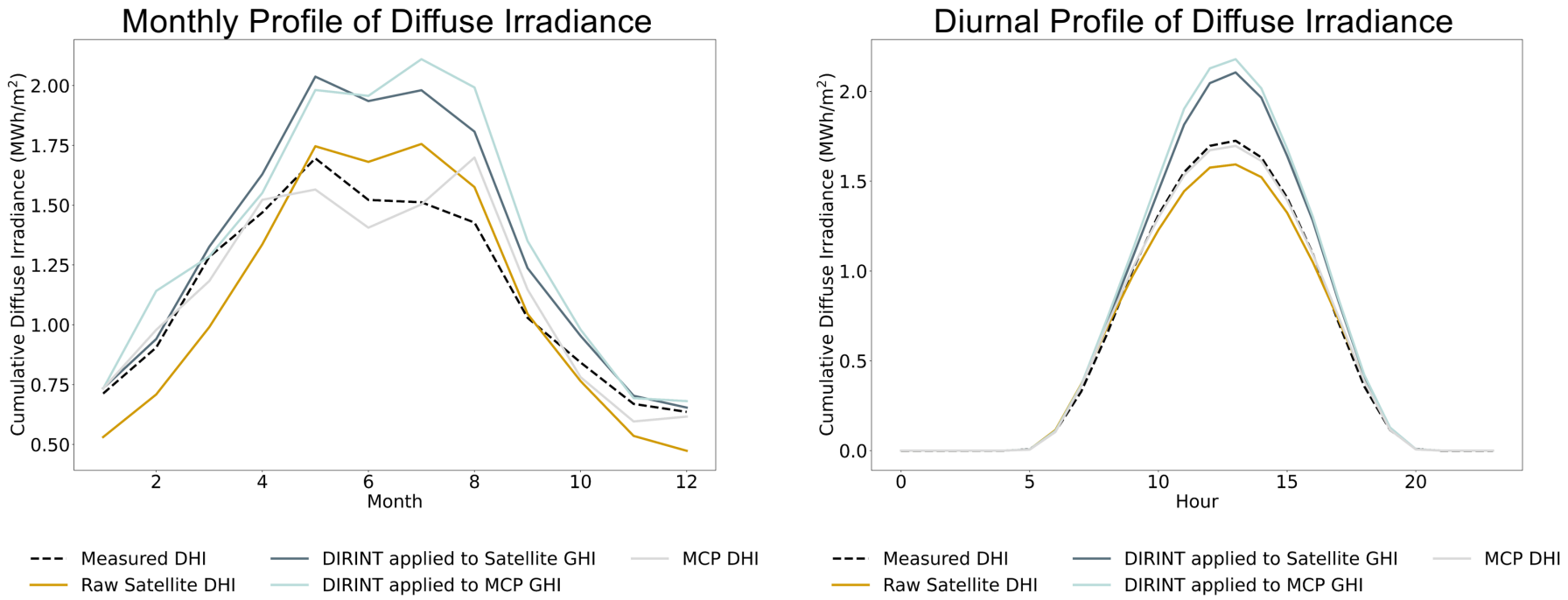
Satellite source “C”

Are Diffuse Measurements Important?

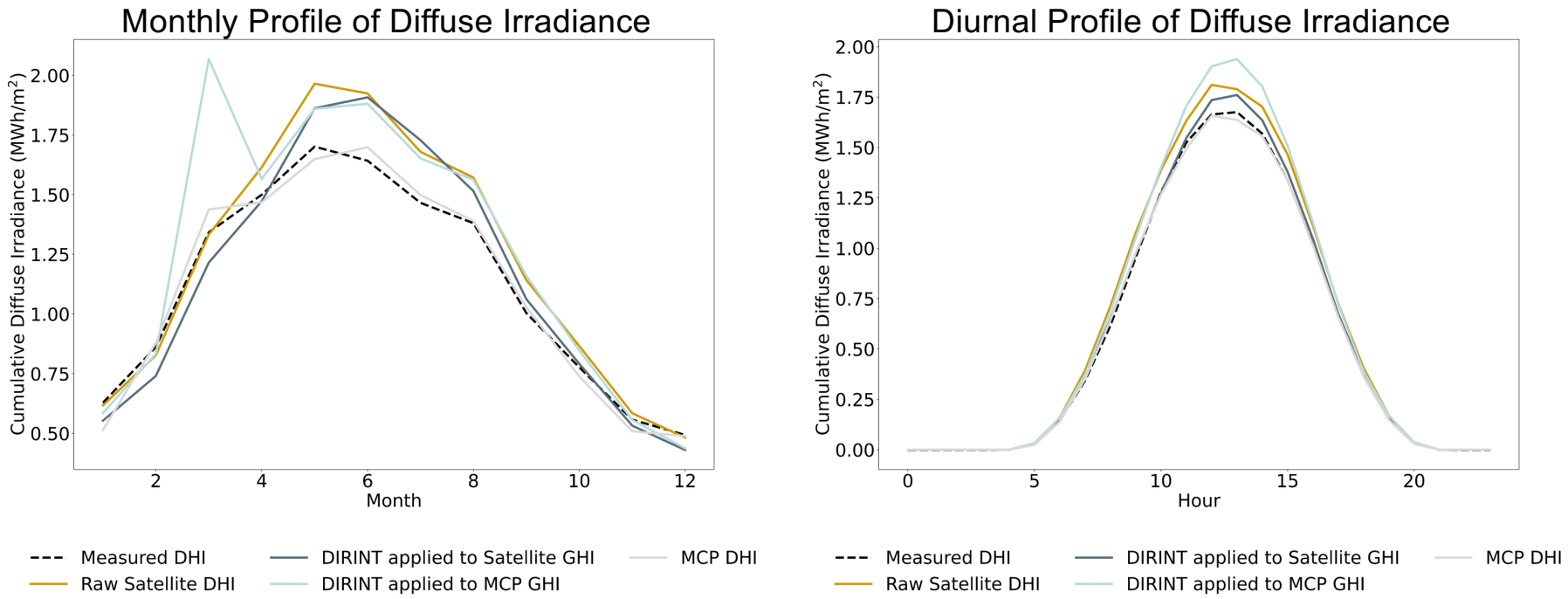
- Recap:
  - GHI measurements can help us reduce resource uncertainty
  - Longer measurement periods can help us reduce resource uncertainty
  - Sometimes the MCP process with increase the overall bias error
  - Your satellite data source does matter

- But what do we do once we have tuned the GHI?
  - Use a decomposition model to determine DNI and DHI based on tuned GHI
    - DIRINT (Modified DISC), with and without the dew point modifier
  - Measure DHI and correct satellite data through MCP processing

Are Diffuse Measurements Important?



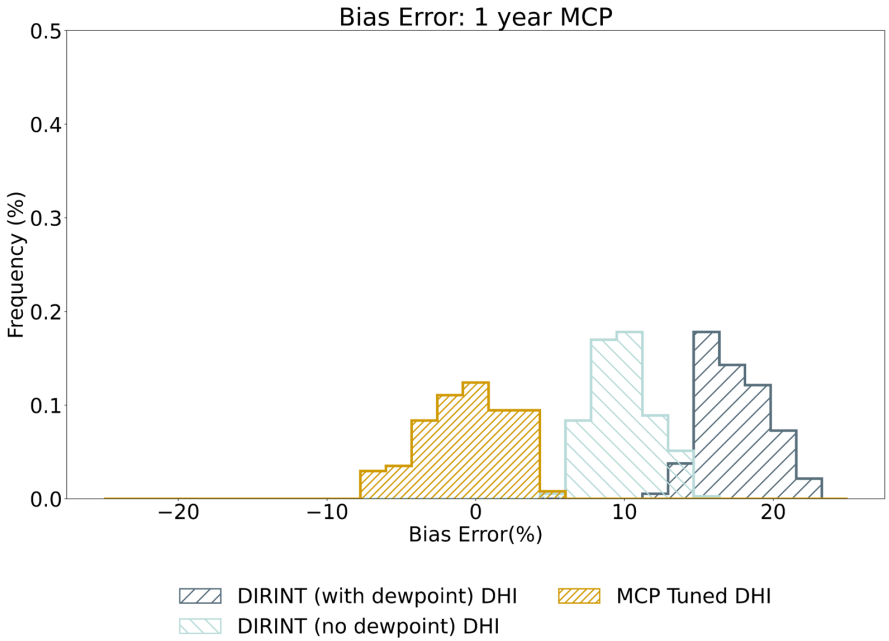
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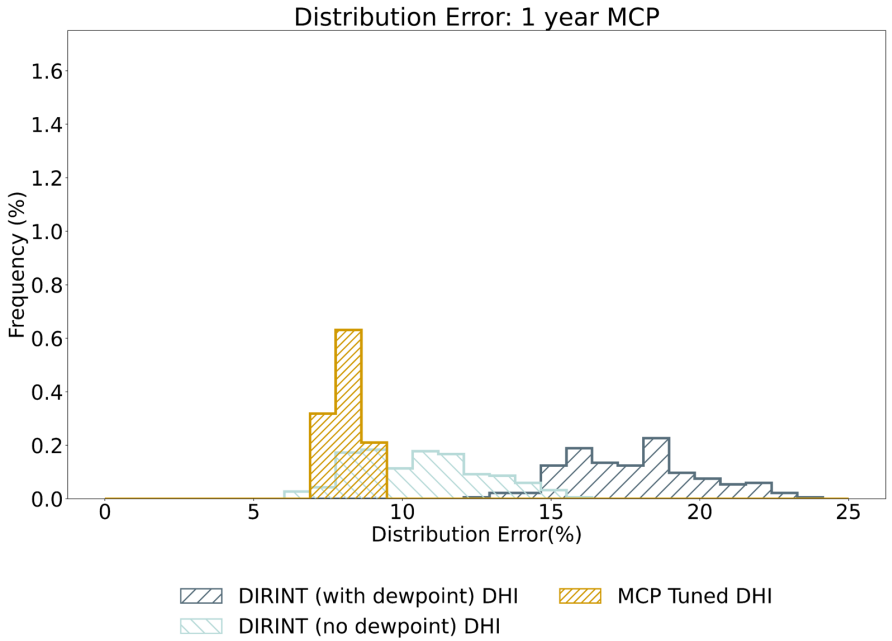


LUMINATE

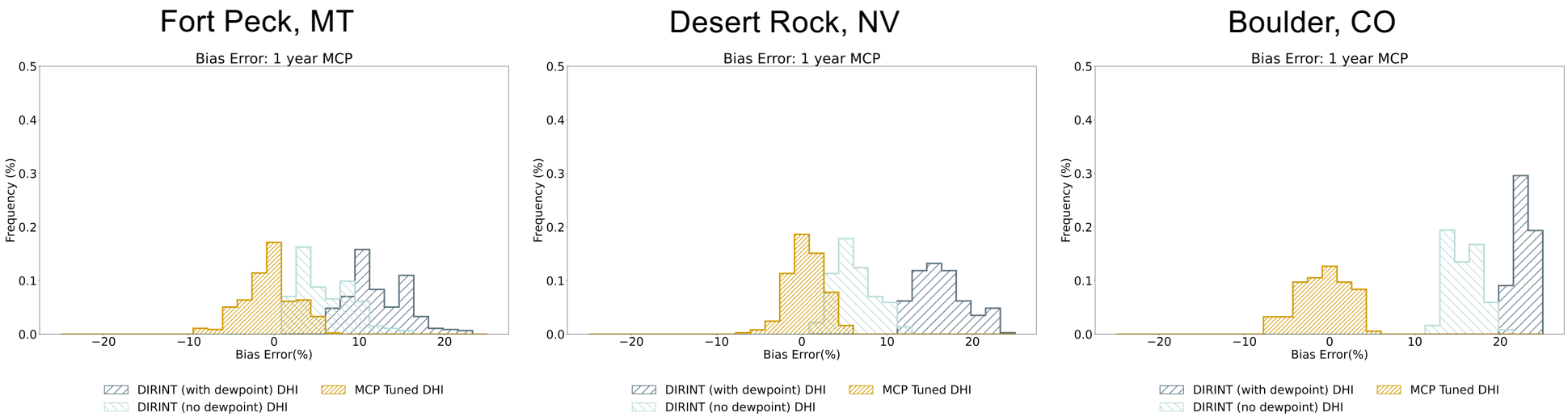
* It is common to use lower class diffuse sensors with higher uncertainty

Are Diffuse Measurements Important?



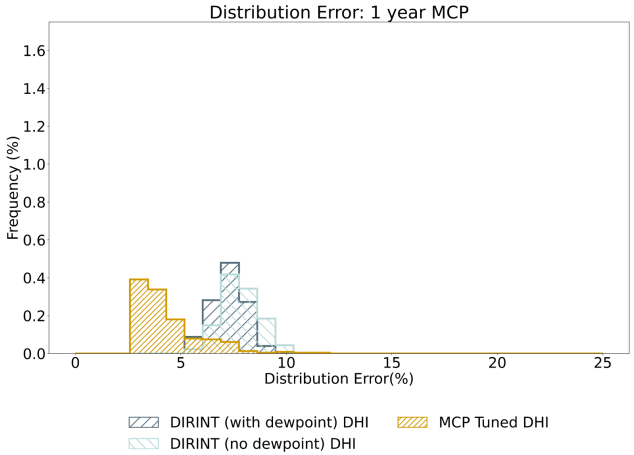


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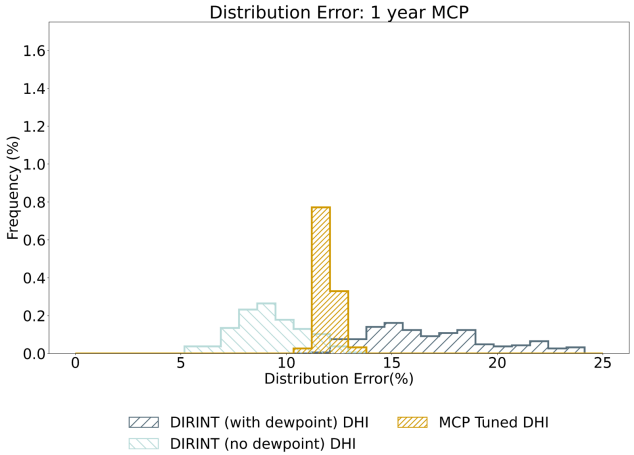


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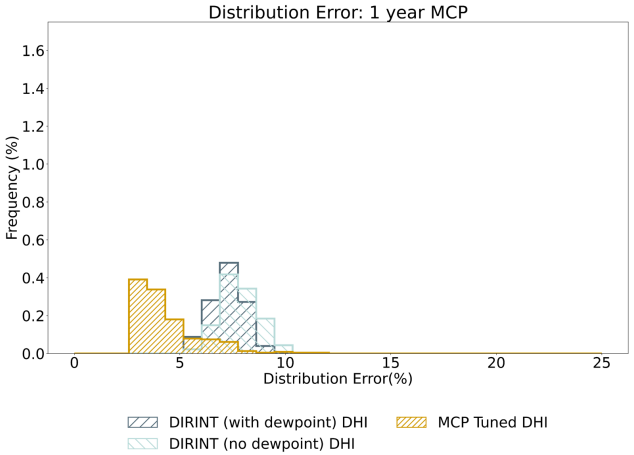
Fort Peck, MT



Desert Rock, NV

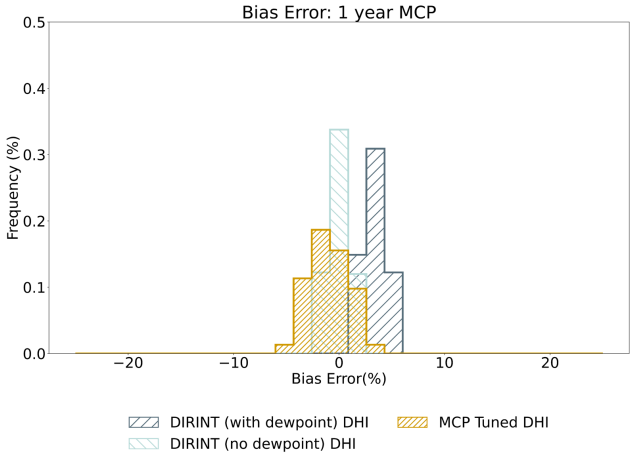


Boulder, CO

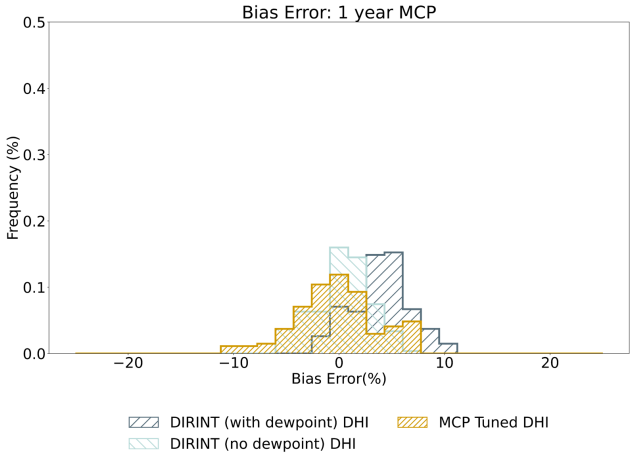


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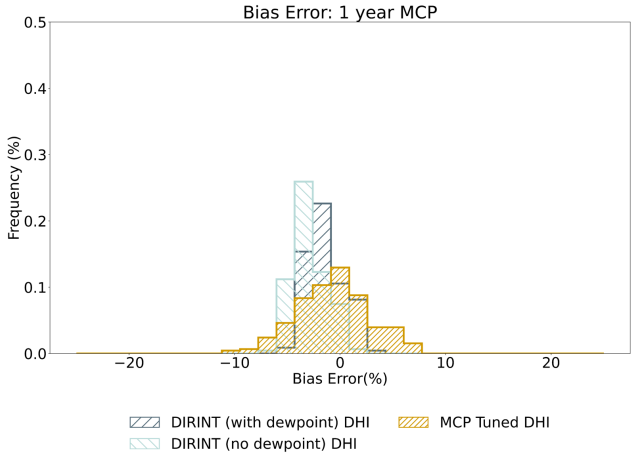
Penn State, PA



Sioux Falls, SD

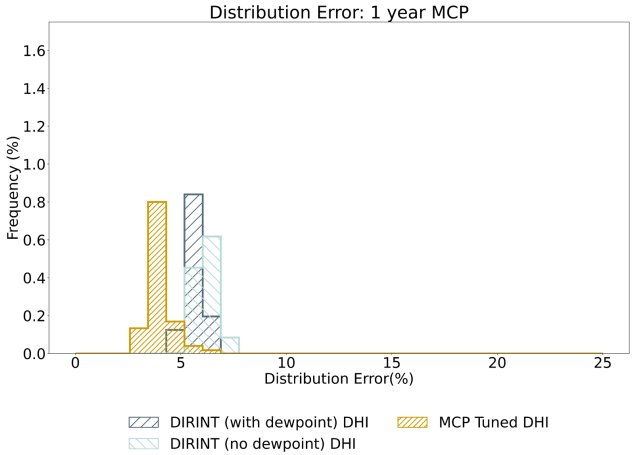


Bondville, IL

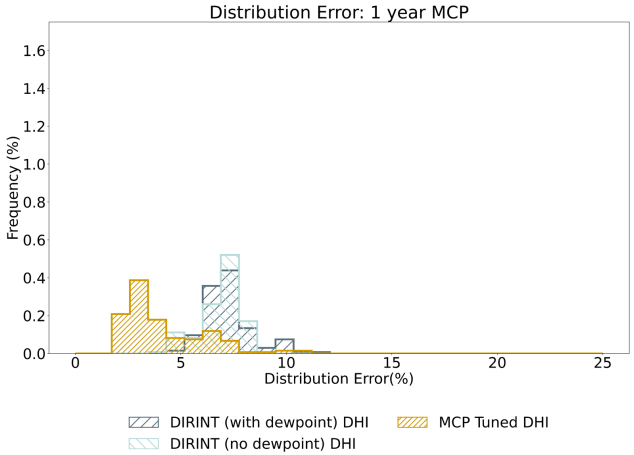


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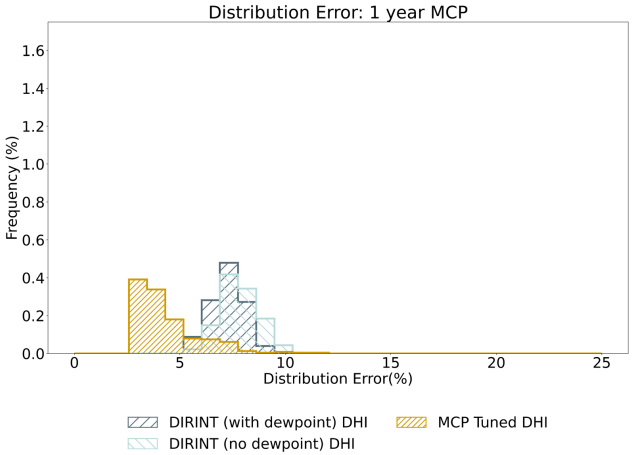
Penn State, PA



Sioux Falls, SD



Bondville, IL



But at what cost?

Annalise's unsolicited, handwavey cost model*

*Cost model developed through communication with P. Hall and C. Grover

- Commissioning + Decommissioning: $15,000 - $20,000
- Baseline Station: $20,000
- Weekly Maintenance: $200/week
- Added Diffuse Sensor: $8,000
- Lifetime Cost of Solar Farm: $1,500,000/$MW_{AC}$

	1 Year	2 Years	3 Years
Without Diffuse	$45.4k	$55.8k (+$10.4k)	$66.2k (+$10.4k)
With Diffuse	$53.4k	$63.8k (+$10.4k)	$74.2k (+$10.4k)

~0.1% of the total levelized cost of 50 MW_{AC} solar farm

Conclusions

- High quality irradiance measurements can reduce uncertainty in a resource assessment
  - This does not mean that a tuned dataset will have lower bias than a satellite data set for every site.
  - It's still worth it!
- Longer measurement periods can reduce uncertainty in a resource assessment
  - You may be able to get more out of longer measurement campaigns at sites with higher IAV
- Diffuse measurements can reduce uncertainty in a resource assessment

Thank you!

- Nate Croft
- Peter Hall
- Cathy Grover
- Mark Mikofski (Open-source code is great)

References

[1] J. Alfi, A. Kubiniec, G. Mani, J. Christopherson, Y. He and J. Bosch, "Importance of input data and uncertainty associated with tuning satellite to ground solar irradiation," 2016 IEEE 43rd Photovoltaic Specialists Conference (PVSC), Portland, OR, USA, 2016, pp. 0301-0305.

[2] L. Tafur, R. Darawali, and H. Darling, “Expansion of Common Measure-Correlate-Predict Analysis Considerations,” 2023 Resource & Technology Conference, Austin, TX, USA, 2023.