Observations snow shedding from single-axis tracking PV systems, implications for resource adequacy

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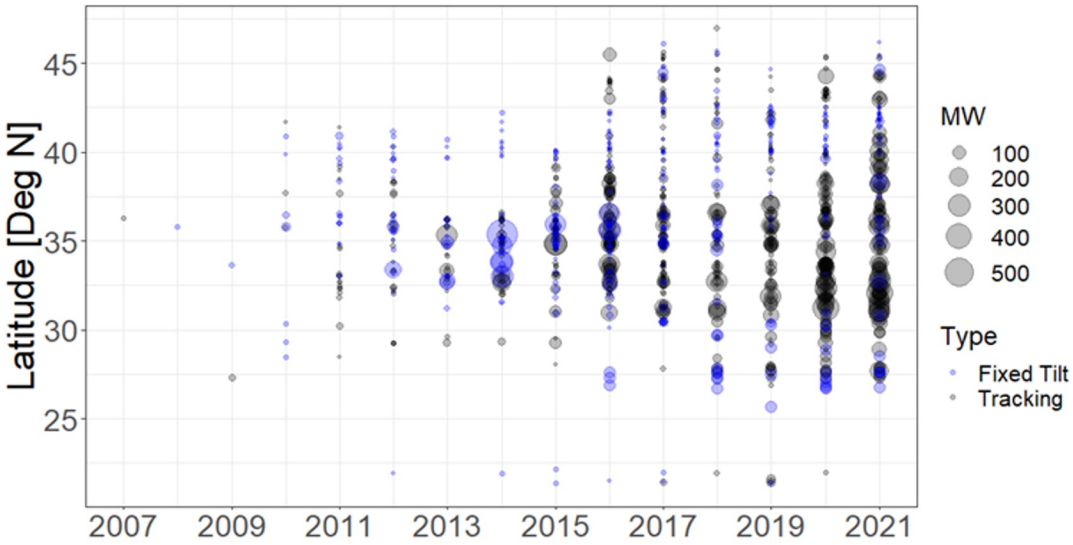
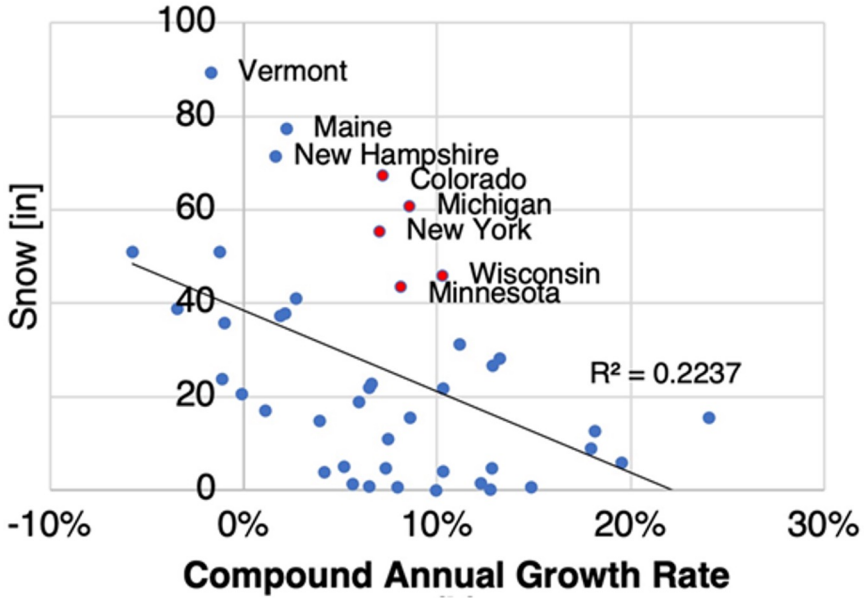
Utility-scale PV is coming north



PV installation latitude versus year. Size of bubble is proportional to the installed capacity (MW). For reference, Chicago: 41°N, Seattle: 47°N, and Phoenix: 33°N. Produced using data from[1].



Growth of state utility-scale solar versus state annual average snowfall for a high demand, high solar scenario[2]. A line of best fit is overlaid. Red = more 5% CAGR and 40" snow annual. Original citation[3]

[1]Bolinger, Seel, Warner, and Robson, *Empirical Trends in Deployment, Technology, Cost, Performance, PPA Pricing, and Value in the United States,* September 2022, Lawrence Berkeley National Laboratory, [2]P. Gagnon *et al.*, "2022 Standard Scenarios Report: A U.S. Electricity Sector Outlook," *Renewable Energy*, 2023.[3]S. Wickett and A. Dyreson, "Trends in Solar PV Growth in Snowy Climates and Impact on Resource Adequacy," in *IEEE Photovoltaics Specialist Conference*, 2023.

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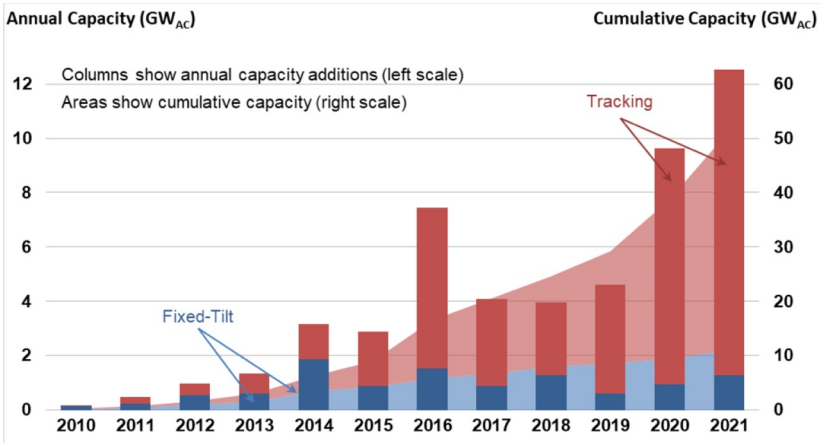
Single-axis tracking system experiments

Optimizing snow stow

- Single-axis tracking systems now dominate new installations
- The objective of this work is to develop advanced control algorithms for trackers to minimize snow retention and accelerate shedding.
  - First year: observations of baseline performance and sensor testing
  - Second year: initial tests on simple snow stow strategies
  - Third year+: test of snow stow, develop automatable control



Growth of single-axis tracking systems in US has significantly outpaced fixed-tilt systems at the utility scale in the past five years[1]

[1]Bolinger, Seel, Warner, and Robson, *Empirical Trends in Deployment, Technology, Cost, Performance, PPA Pricing, and Value in the United States,* September 2022, Lawrence Berkeley National Laboratory

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MI Solar Regional Test Center (MI RTC)

Highlights

1. Met station
2. Solar roofing
3. Snow load stations
4. Fixed tilt experiments
5. Single-axis tracking experiment

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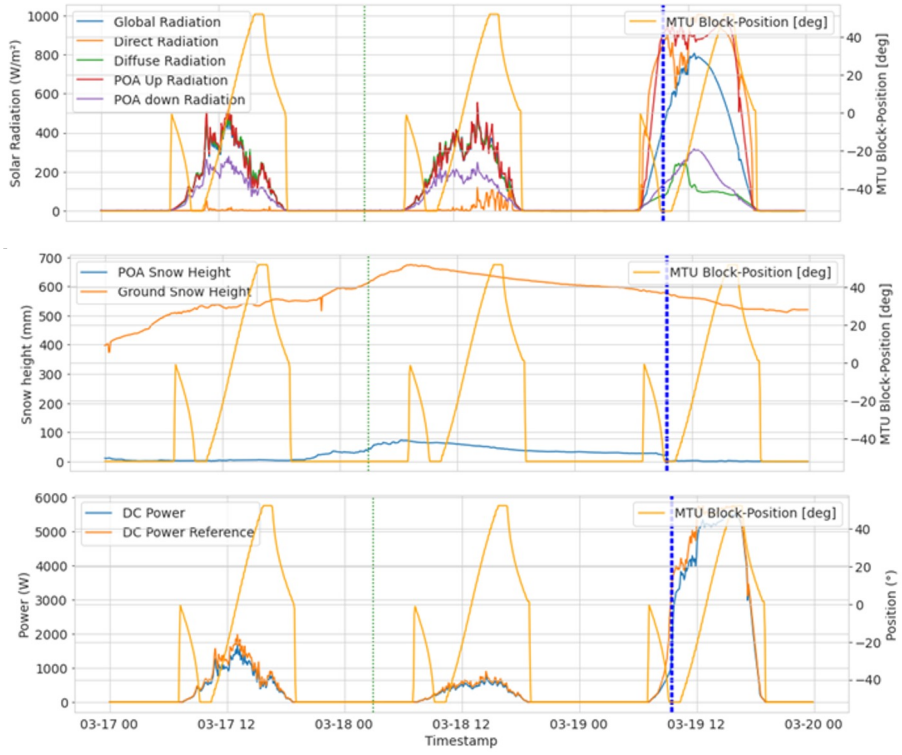
Single-axis tracking system at MI RTC

- Experiments are conducted on 4 rows of 18 Trina Solar bifacial modules = “MTU Block”
- The control is 3 rows with conventional controls = “Reference”
- Single axis tracking system provided by Array Technologies

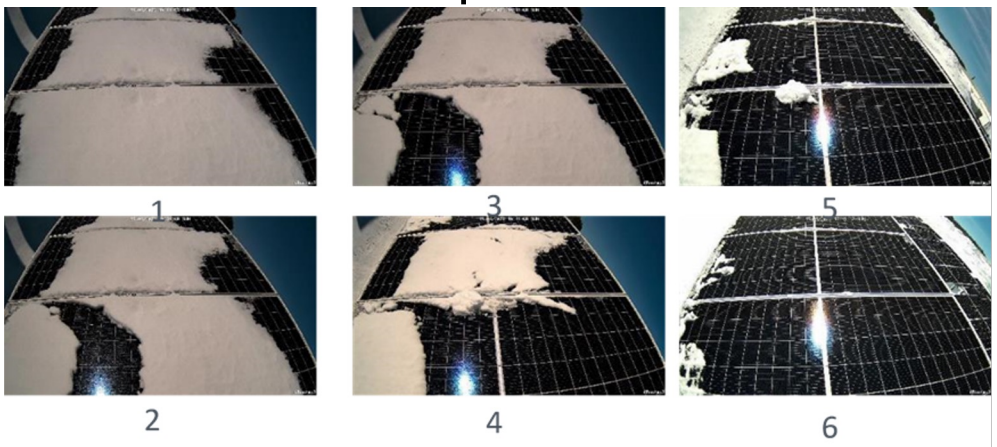
Snow sensing for tracker system

- POA laser for snow depth on tracker
- Upward and downward POA
- Ground snow depth (ultrasonic)

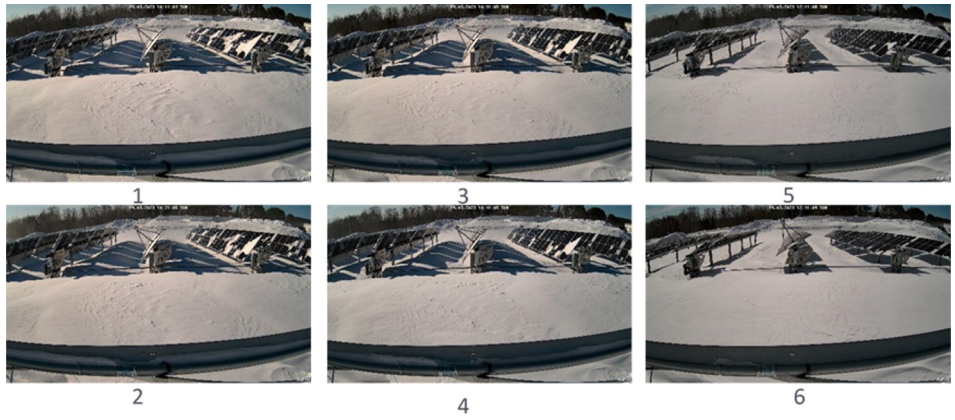


Imaging for tracker system (3 cameras)

In-plane



Side view of 4-row block



Side view - panel

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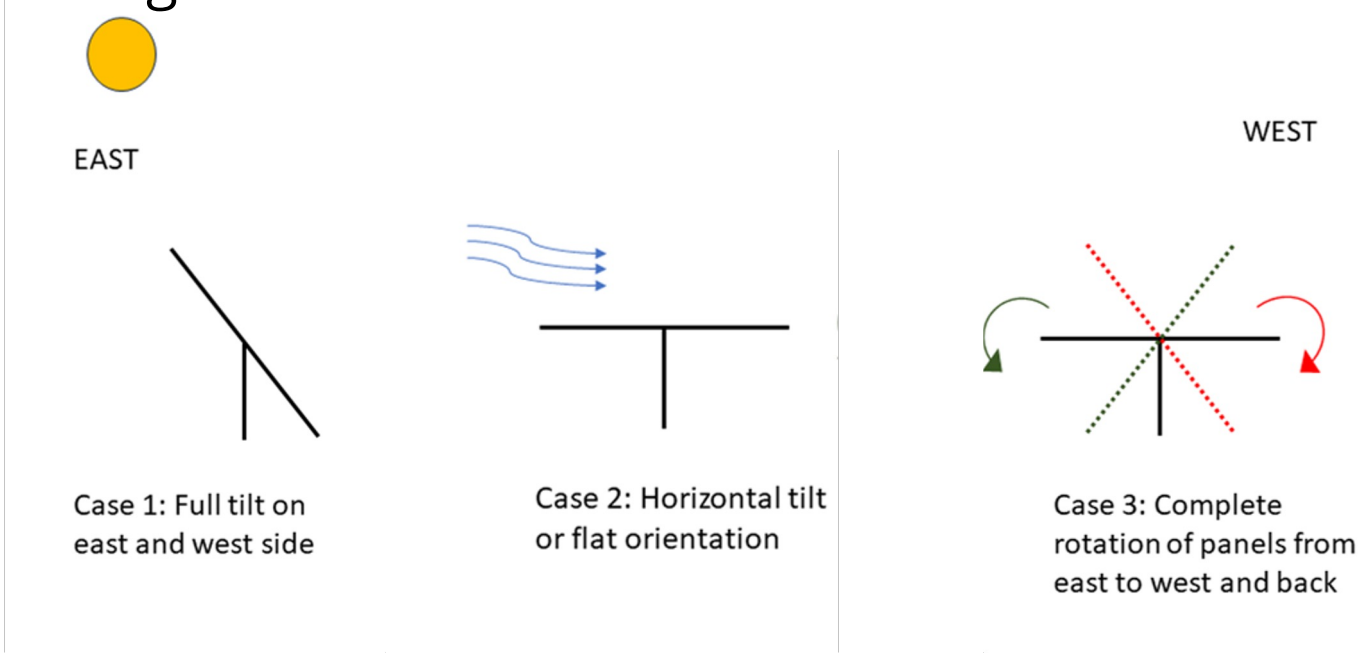
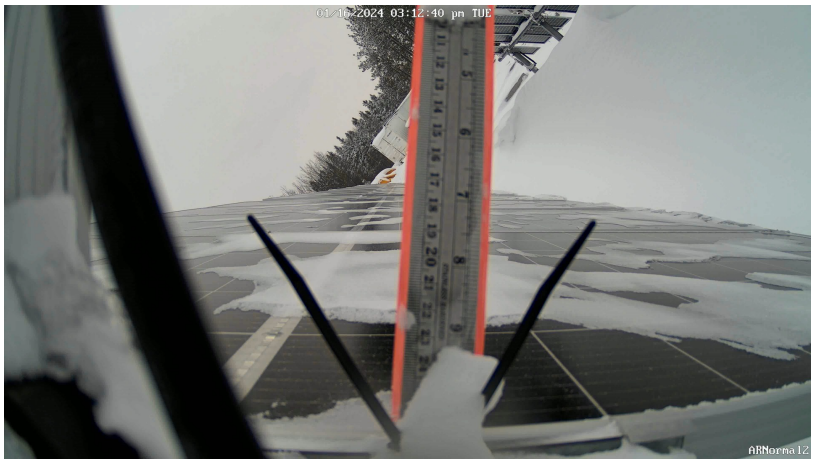
Snow stow experiments

In winter 23-24, our goal was to manually test several snow stow strategies relative to a control.



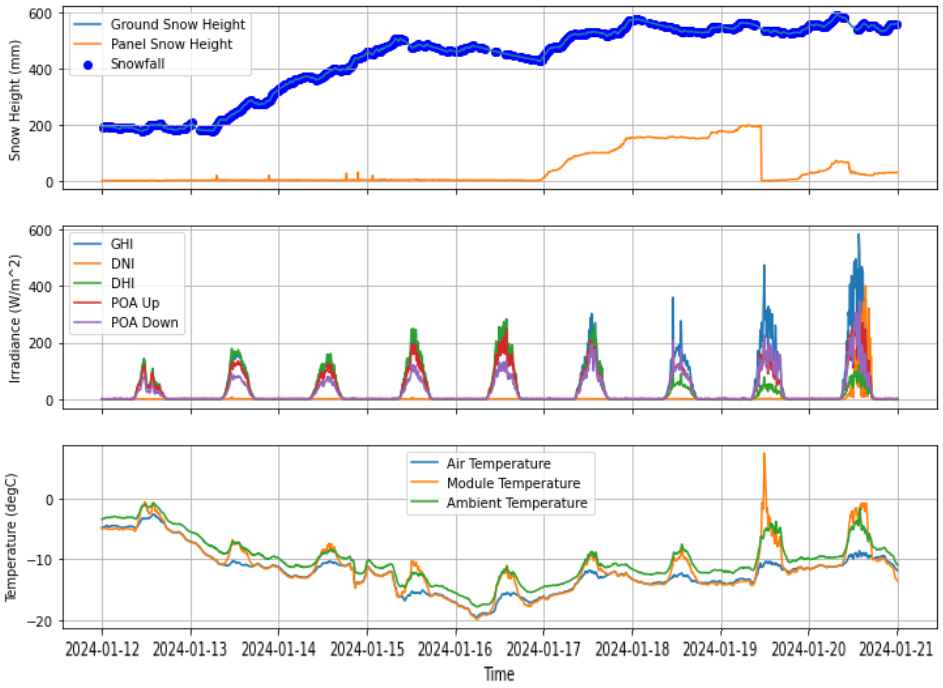
East and west stow experiments Jan 2024

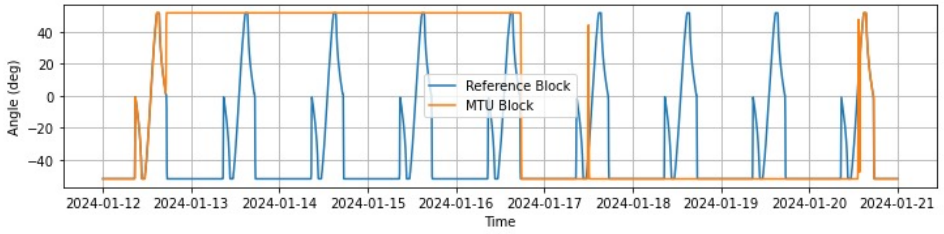
Snow shedding even observed on 19th January when the panels were at maximum tilt

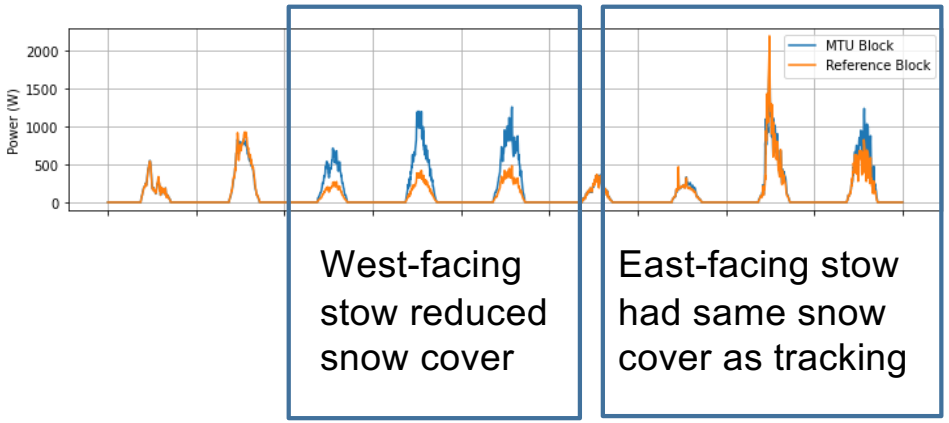


Snow accumulation observed when the panels were moved facing the wind direction

East- and west-facing stow experiments

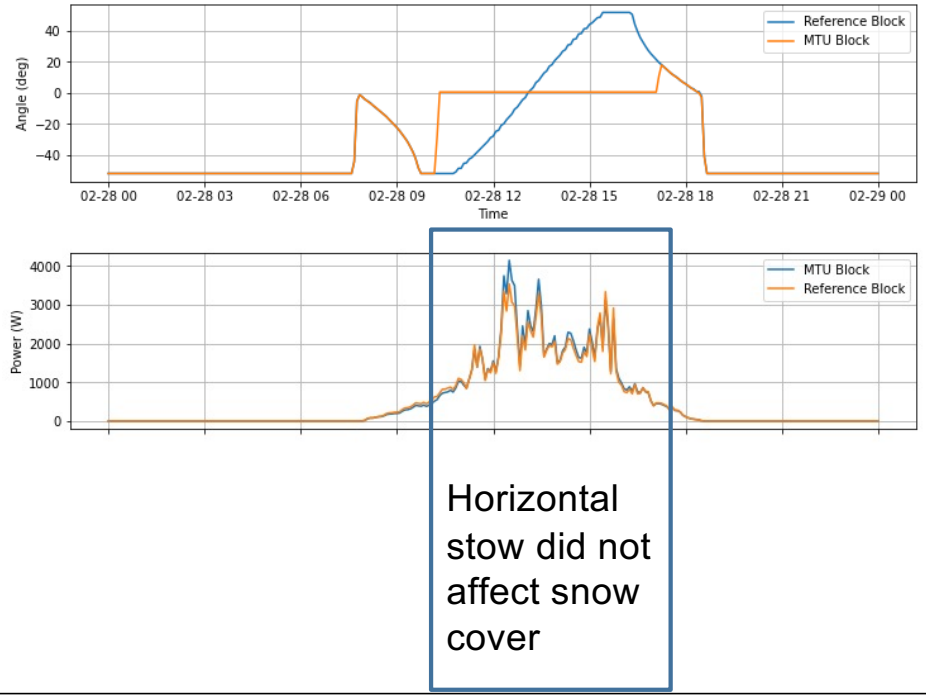






Preliminary results

Horizontal snow stow experiment



Horizontal stow did not affect snow cover

Preliminary results

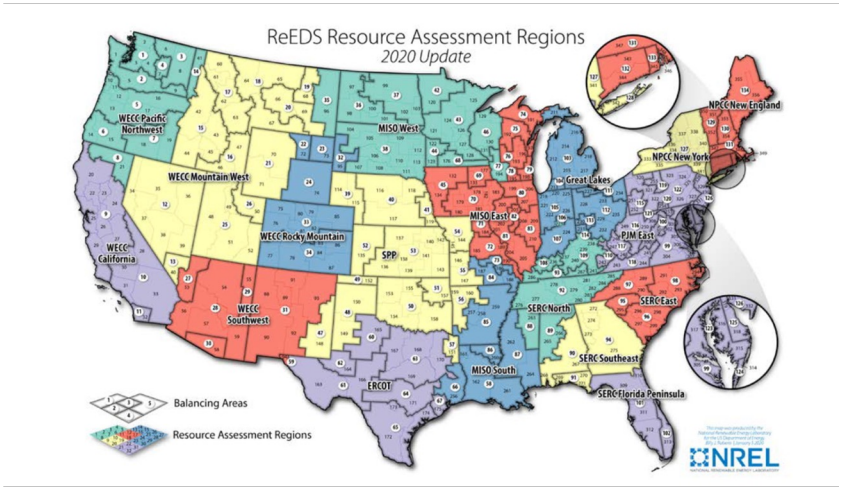
Snow stow next steps

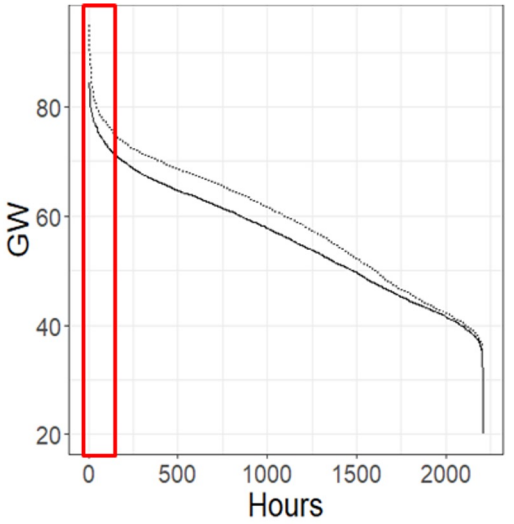
- Current goals of this work are to describe the impacts of other site weather relative to snow shedding, continue experiments with snow stow, and create an optimized, automated snow stow strategy.
- Future work may include:
  - Tests on utility-scale systems
  - Automated image analysis using POA cameras
  - Changes in tracker design for optimal snow shed

Future resource adequacy impacts

Future resource adequacy impacts?

Preliminary data were used to estimate the capacity credit (CC) of solar in potential future high-solar share systems in the midwest U.S.





The net load duration curve[1] is one way to quantify CC. In this example (right) for the utility-scale solar in the western and north central Iowa sub-region during the spring (February, March, and April). The load duration curve is dotted gray and net load is black.

[1]Ho, J., Becker, J., Brown, M., Brown, P., Chernyakhovskiy, I., Cohen, S., Cole, W., Corcoran, S., Eurek, K., Frazier, W., Gagnon, P., Gates, N., Greer, D., Jadun, P., Khanal, S., Machen, S., Macmillan, M., Mai, T., Mowers, M., … Zhou, E. (2021). Regional Energy Deployment System (ReEDS) Model Documentation: Version 2020 (NREL/TP-6A20-78195)

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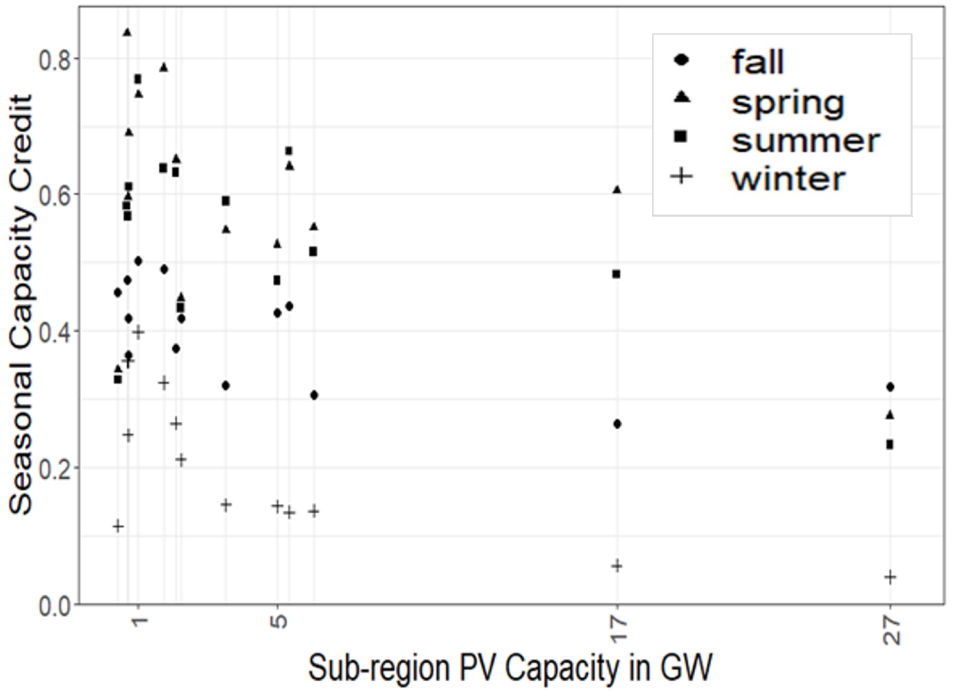
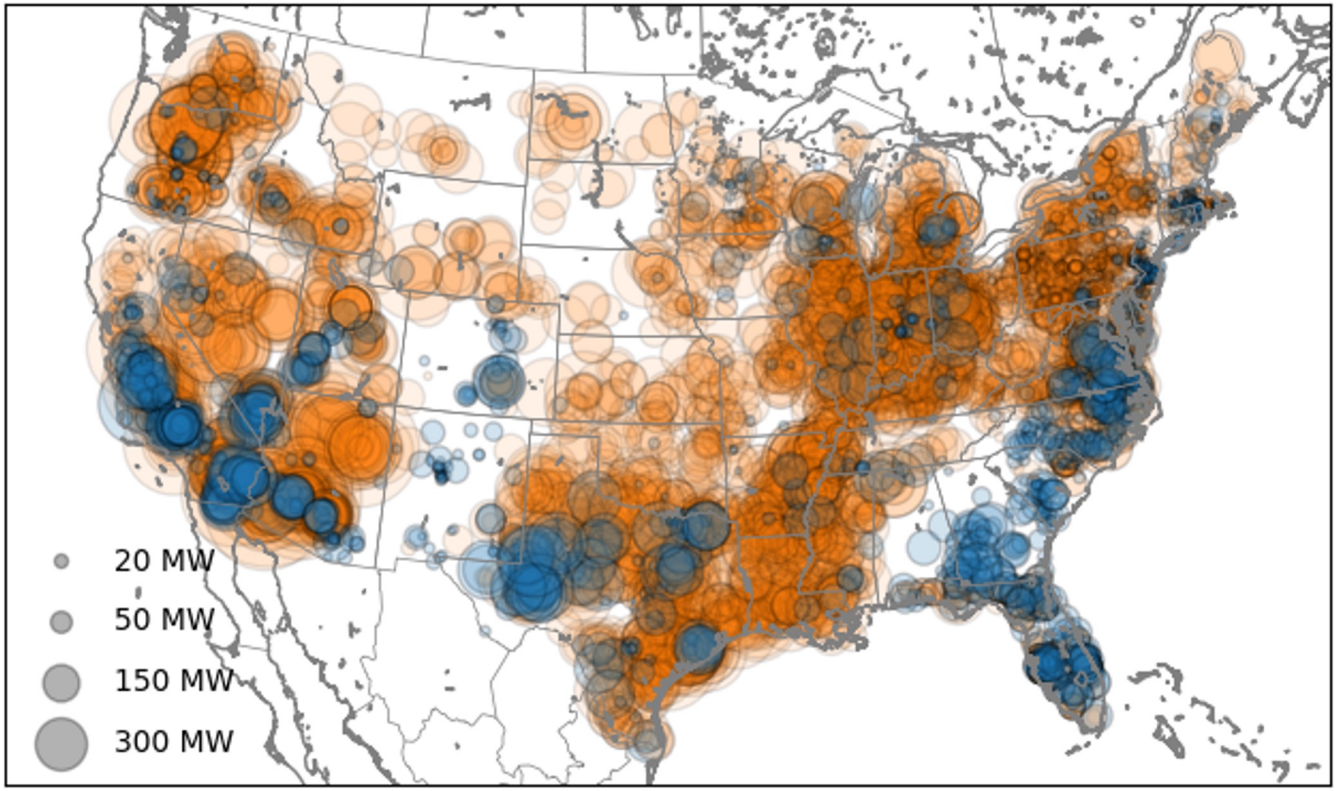
Future resource adequacy impacts?

- Capacity credit estimates for a future system without considering snow
- Spring is when snow shedding may matter most



Capacity credit for each of 14 sub-regions in MISO East for each season versus sub-region's solar capacity.

Modeling widescale impacts of snow



Blue = existing utility-scale PV sites

Orange = Queued PV

Approximate locations by county

M. Bolinger, J. Seel, J. M. Kemp, C. Warner, A. Katta, and D. Robson, "Utility-Scale Solar, 2023 Edition." Accessed: November 12, 2023. [Online]. Available: https://emp.lbl.gov/publications/utility-scale-solar-2023-edition

J. Rand *et al.*, "Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2022." Accessed: January 10, 2024. [Online]. Available: https://emp.lbl.gov/publications/queued-characteristics-power-plants-1

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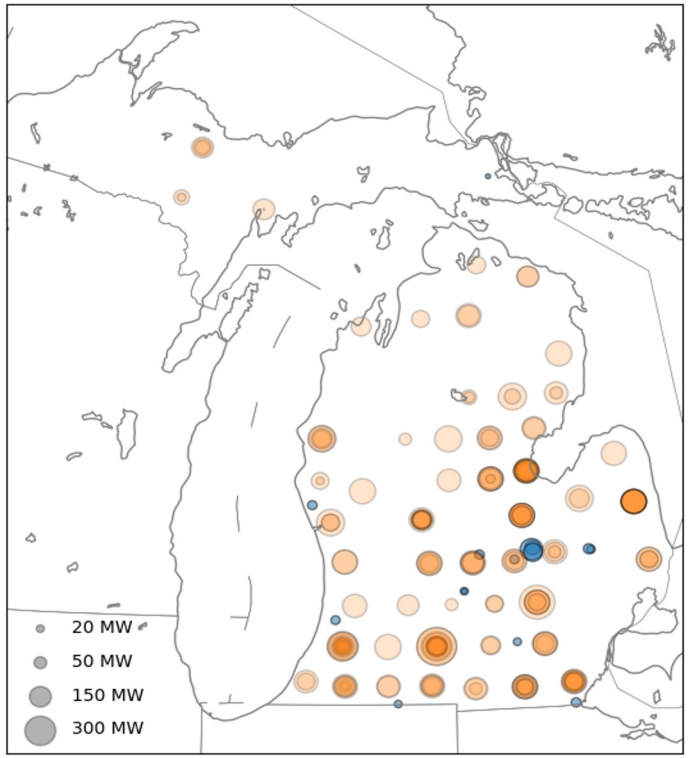
Modeling widescale impacts of snow

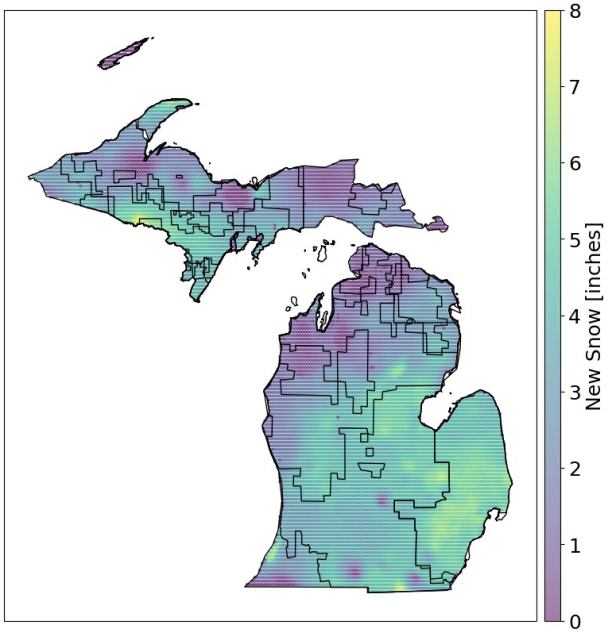


Blue = existing utility PV sites
Orange = queued PV

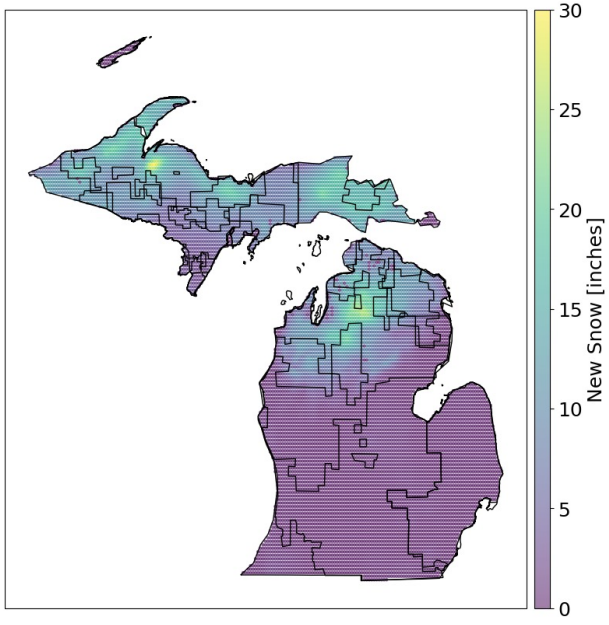
- First focusing on Michigan, we use PySAM to estimate the grid-scale impacts of PV over a wide area

Historical snow fall data

- We use a daily dataset of snow cover to determine new daily snowfall at PV sites
- Examples of recent historical events ->



December 11th-12th, 2016
Detroit Snowstorm
(widespread snow event)



March 15th-16th, 2017
Winter Storm Stella
(focused snow event)

"Daily 4 km Gridded SWE and Snow Depth from Assimilated In-Situ and Modeled Data over the Conterminous US, Version 1," National Snow and Ice Data Center. Accessed: May 30, 2023.

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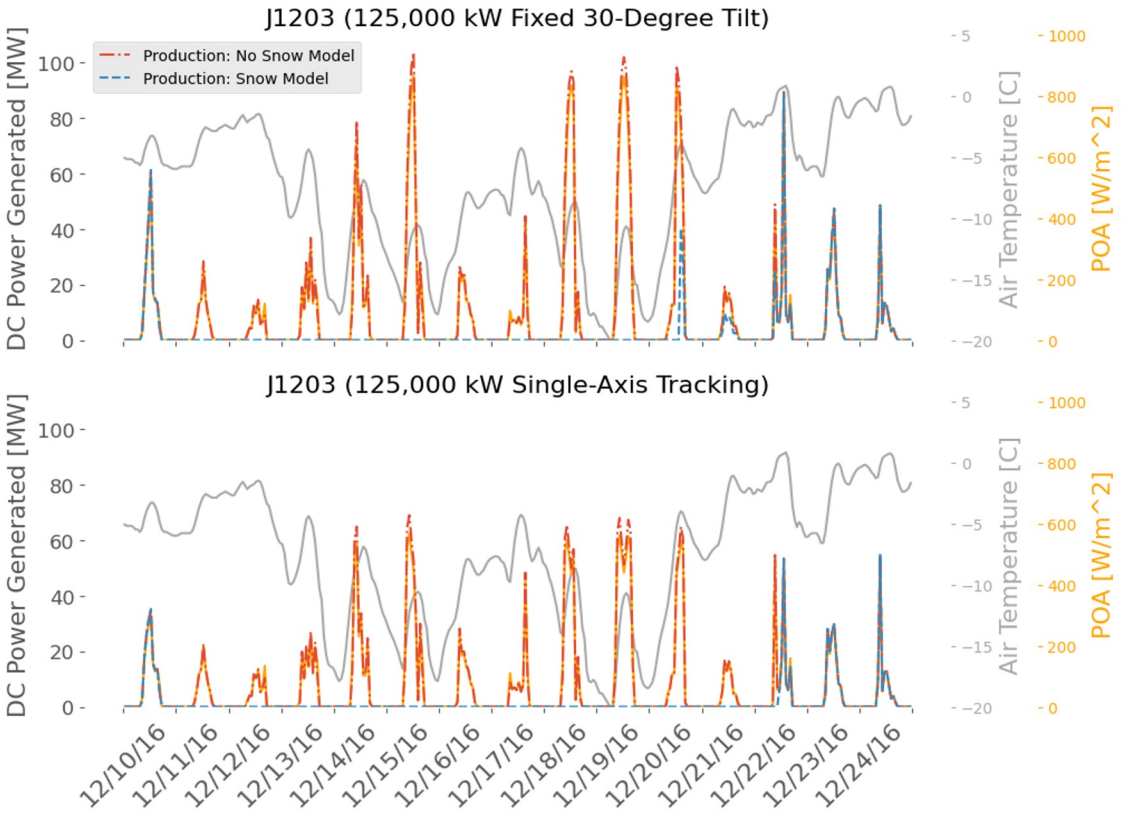
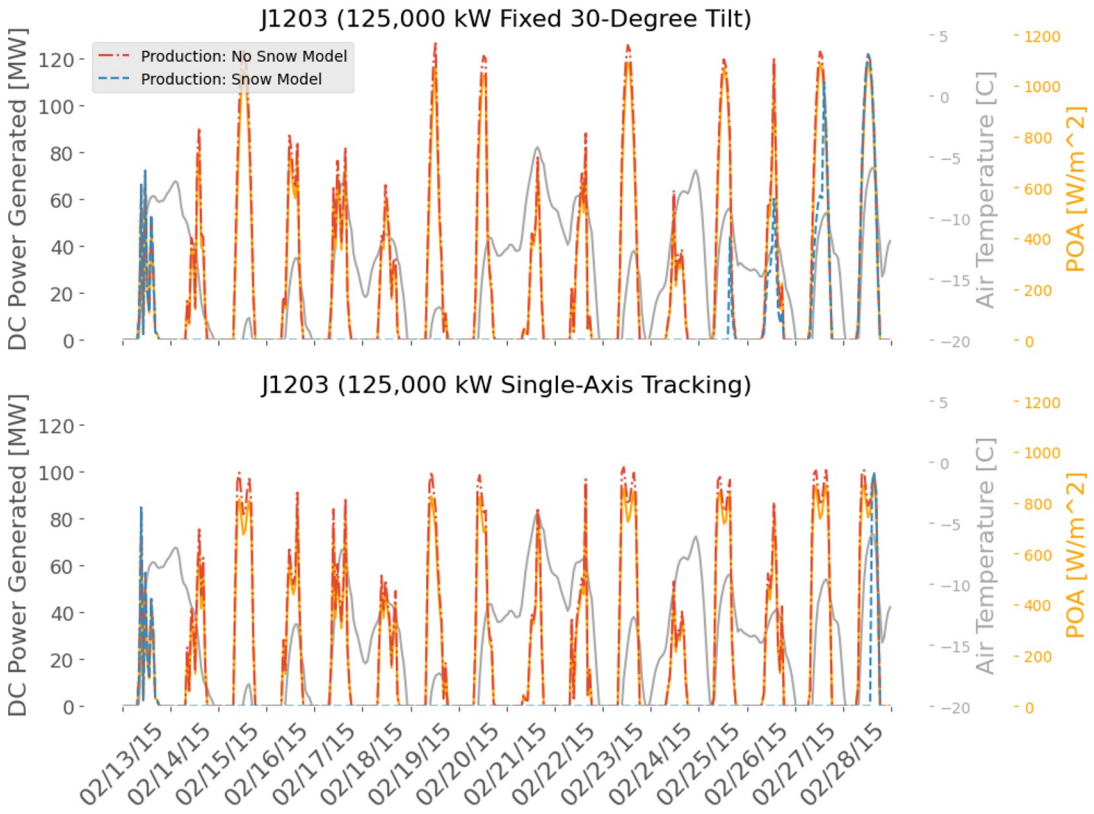
Modeling widescale impacts of snow



- 2016 Flint Storm
- Queued site theoretically under snow for over a week
- Model estimates tracker holds snow longer (related to ratio of ambient temperature and POA irradiance)

Preliminary results

Modeling widescale impacts of snow



- 2015 North American cold wave
- Queued site theoretically under snow for two weeks
- Model estimates tracker holds snow longer

Preliminary results

Next steps

- Current goal is to summarize annual losses over ten years from current and queued sites in Michigan. We are exploring the impacts of different snow sliding coefficients and fixed versus single-axis tracking system configurations.
- Future directions may include:
  - Expanding this dataset to cover the Eastern U.S.
  - Modeling hourly operations of systems in the Eastern Interconnect
  - Using resource adequacy models to estimate the impact of snow on PV relative to system adequacy and other extreme weather events
  - Incorporating the impact of climate change on future snowfall: while in the future more precipitation may fall as rain in general, infrequent heavy snow events such as lake effect snow remain important to planning power systems

Thank you! adyreson@mtu.edu

Graduate Students: Ayush Chutani, Jonathan Aurand, Shelbie Wickett, Adnan Hilal, Jacob Chizek, David Wallis, Keith Holliday

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