Modeling wind in agrivoltaics and its impact on eddy covariance flux measurements

National Laboratory of the Rockies + CattleTracker SILICON RANCH

How PVade was used to quantify wind impacts on ecosystem services measurements in an agrivoltaic project

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Overview

- A collaborative study between NLR and Silicon Ranch investigates whether a solar array alters the wind flow and thus interferes with wind measurements used for ecosystem services calculations at an agrivoltaics site.
- Using simulations, this work predicts the wind flow under various environmental conditions, including different wind speeds, wind directions, and panel tilt angles.
- The study concludes that at the tower's 6-meter sensor height, the impact of the panels is not significant, with a wind speed difference of less than 4%.
- This result validates the use of such towers for reliable ecosystem exchange measurements within solar fields.

Figure 1: Quanterra Systems eddy covariance flux tower at the Bancroft Station agrivoltaic array.

Motivation

- Silicon Ranch is conducting a research study at their Bancroft Station agrivoltaics site in which they are using eddy covariance flux towers to measure the ecosystem exchange.
- The flux towers were not originally designed for use in PV arrays, so the research team is interested in finding out if the presence of the PV panels changes the effectiveness of these measurements.

Figure 2: Aerial map view of Bancroft Solar Farm, an agrivoltaic installation near Blakely, GA.

Research Question: Under what environmental conditions (wind speed, wind direction, air temperature) and panel tilt angles are the mean wind speeds at the measurement heights significantly altered (>3%) by the presence of the PV panels?

Experimental Measurement Set-Up

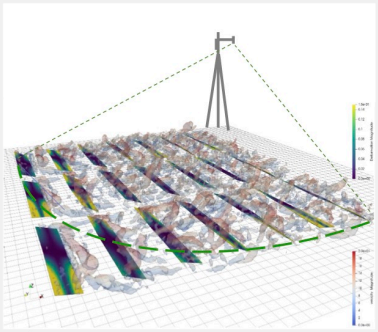

Figure 3: PVade flow simulation of wind in a PV array, showing vortices formed by the panels and deformation of the panels. Flux tower and fetch footprint diagram added for context. Figure not to scale.

- Eddy Covariance Flux towers measure ecosystem exchange in and out of the environment within their fetch footprint.
- Ecosystem exchange (measured by carbon uptake), wind speed, and wind direction are measured at the millisecond rate, and aggregated into 30min values.

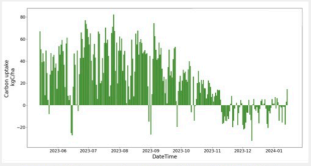

Figure 4: Daily ecosystem CO_2 uptake at Bancroft Station

Methods

- Used NLR's PVade to model the wind in the agrivoltaic array using Silicon Ranch's PV array dimensions and site conditions
- Four regimes were determined to represent characteristic wind conditions, temperature conditions, and tilt angles.

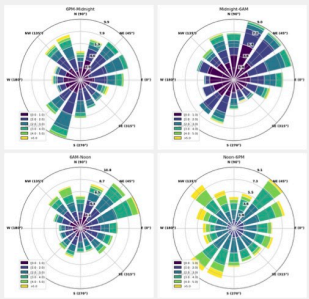

Figure 5: Wind roses for four time periods of the day. Highest wind speeds seen during the Noon-6pm regime.

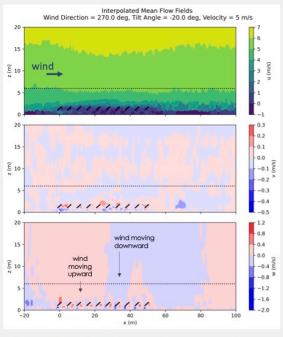

Figure 6: Mean flow fields showing the streamwise (u), spanwise (v), and vertical (w) components. The black dotted line denotes the flux tower measurement height.

Results

In the fully-developed region of the array, the mean velocity profiles were compared to those over open pasture (without PV panels)

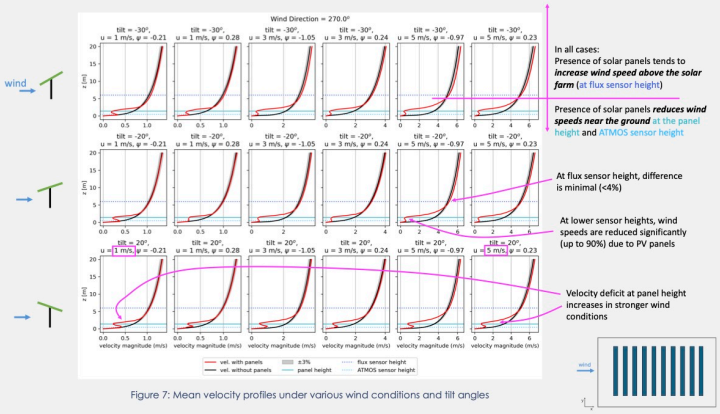

Figure 7: Mean velocity profiles under various wind conditions and tilt angles

Findings & Conclusions

- At the **height of the flux tower (6m), the wind speed measured is not significantly altered by the presence of solar panels.** The percent difference is less than 4% and is generally greatest during daytime conditions at higher wind speeds (of 3 m/s or greater when measured at 6m height) and perpendicular wind direction (from the East).
- **At lower heights, the flow is significantly altered** (wind speeds are reduced) by the presence of solar panels. The percent difference increases with wind speed.
- **Steeper tilt angles when front-winded and higher freestream wind speeds lead to greater impact** of the presence of the panels.
- While **PVade** was designed to study wind-driven loads of PV trackers, it can be used to **predict wind in a given agrivoltaic array.**

Scan to learn more and get started with PVade!

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