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Wind Loading on Parabolic Trough Collectors: Wind and Structural Loads Measurements at an Operational Powerplant

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Photo by Ulrike Egerer, NREL

1. Motivation:
Wind Loading on Parabolic Troughs

Background

- Wind loading is one of **the primary drivers of structural design costs** of concentrated solar power (CSP) collector structures.
- To date, the design of these structures **has relied on data from wind tunnels** that do not adequately capture the **dynamic effects** observed at scale.
- **Field measurements at a full-scale operational power plant** will help to better understand wind loading on collector structures.

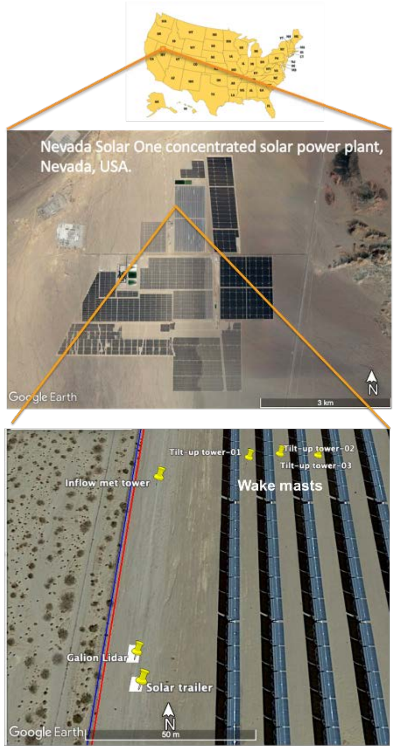
Parabolic Trough Measurement Campaign

The NREL team collects a detailed characterization of prevailing wind and turbulence conditions and resulting operational loads on parabolic troughs in a full-scale CSP plant.

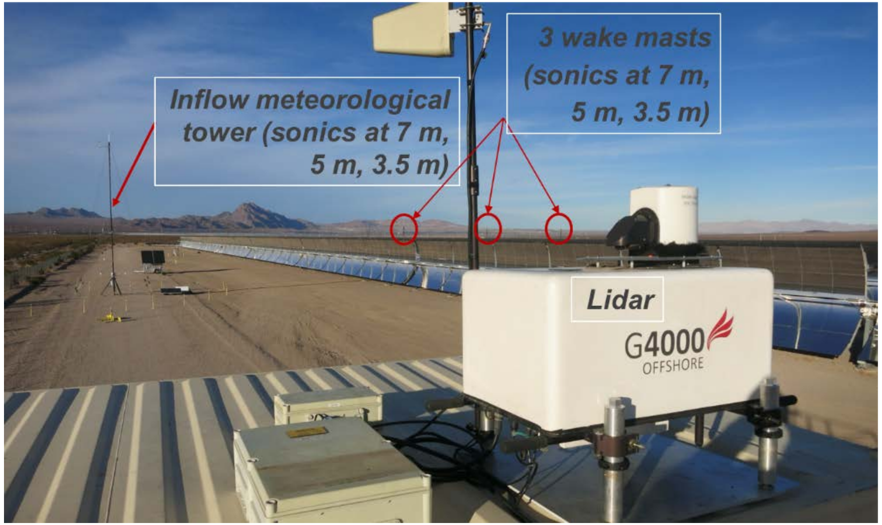
Parabolic trough rows at the **Nevada Solar One (NSO)** solar power plant with damaged mirrors on the outer edge of the field. *Photos by Ulrike Egerer, NREL*

Methods: Wind and Turbulence Measurements

Wind and turbulence measurements at the Nevada Solar One (NSO) power plant
November 2021–June 2023

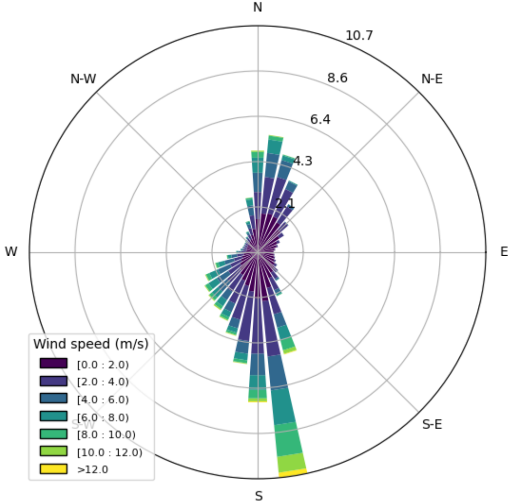


Images from Google Earth



Sonic anemometers within and above the trough field at the inflow mast and wake masts. *Photo by Dave Jager, NREL*

Inflow wind characterization



Methods: Structural Loads Measurements

Additional structural loads measurements at NSO: November 2022–June 2023

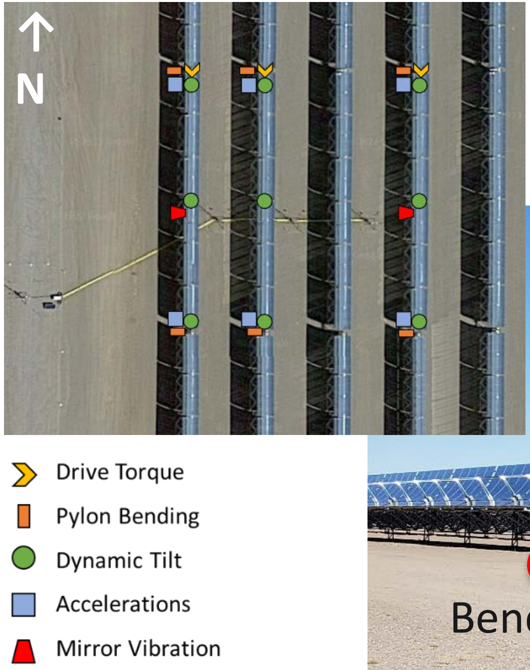
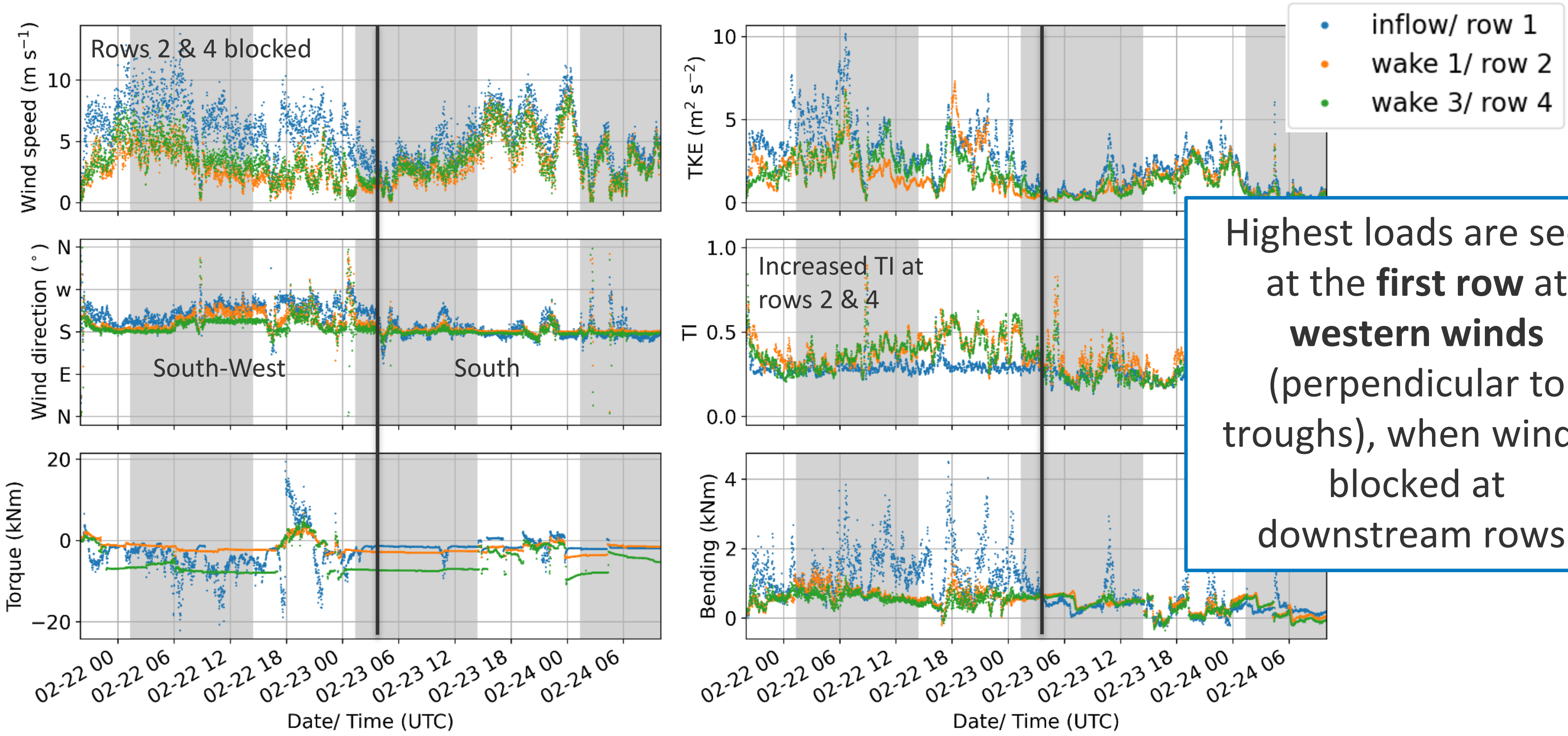


Photo by Ulrike Egerer, NREL

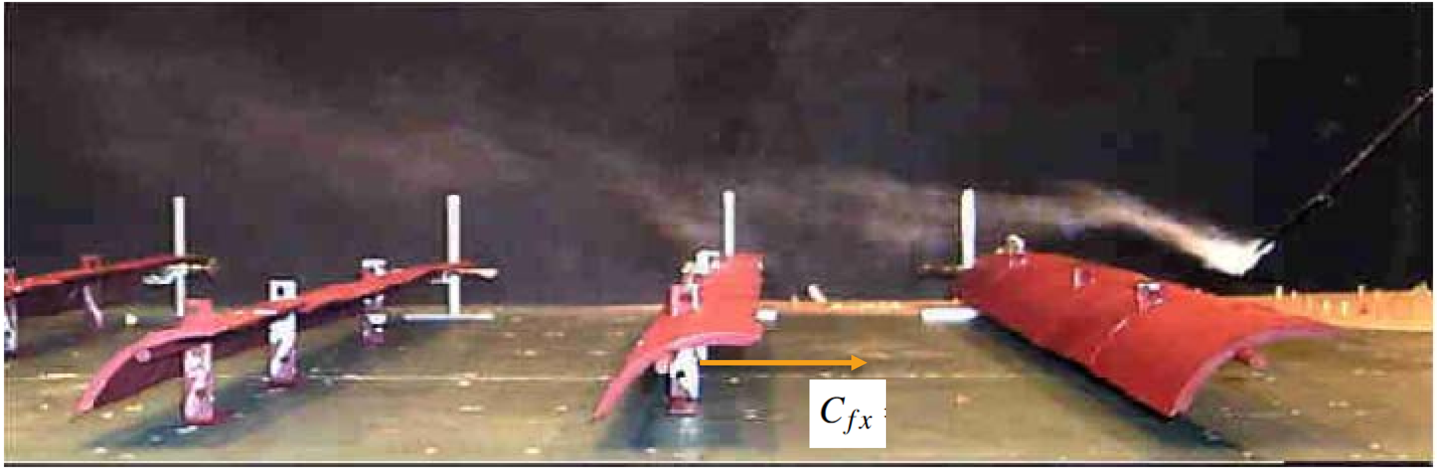
2. Case Study: Support Structure Loads Are Driven by Wind Speed, Direction, and Row Position



Highest loads are seen at the **first row** at **western winds** (perpendicular to troughs), when wind is blocked at downstream rows.

3. Support Structure Loads: Comparison to Wind Tunnel

Hosoya et al. (2008): Comprehensive wind tunnel tests



Drag force coefficient:

$$C_{fx} = \frac{F_x}{\frac{\rho}{2} U^2 \cdot L_{\text{segment}} \cdot W}$$

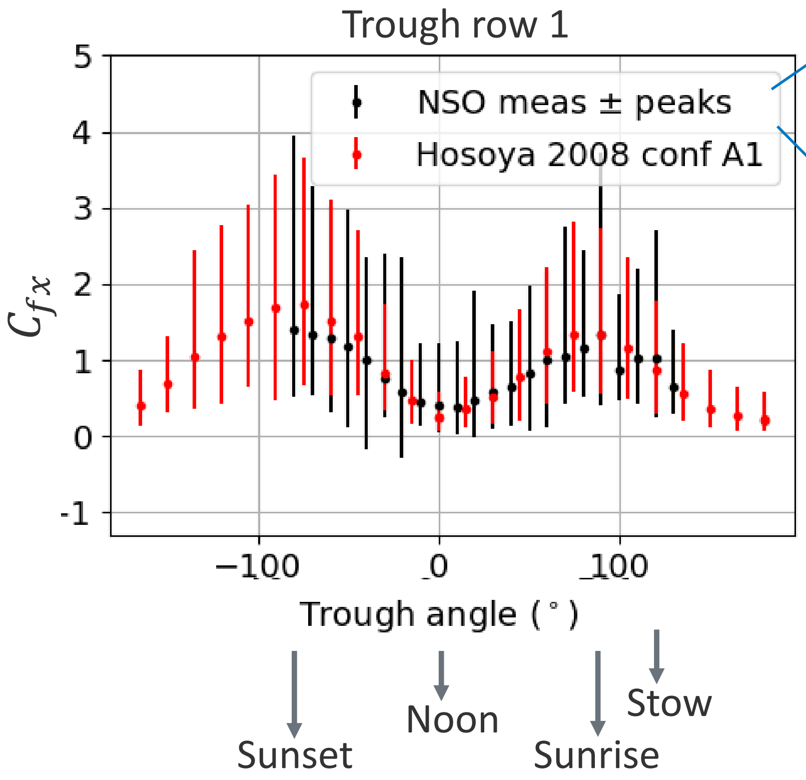
F_x	Drag force
U	Mean wind speed
$L_{segment}$	Length of trough segment
W	Aperture width

Hosoya, N, Peterka, J A, Gee, R C, and Kearney, D. 2008. *Wind Tunnel Tests of Parabolic Trough Solar Collectors: March 2001--August 2003*. Golden, CO: National Renewable Energy Laboratory. NREL/SR-550-32282. doi:10.2172/929597.

Support Structure Loads: Comparison of NSO Dataset to Wind Tunnel Tests

Drag force coefficient:

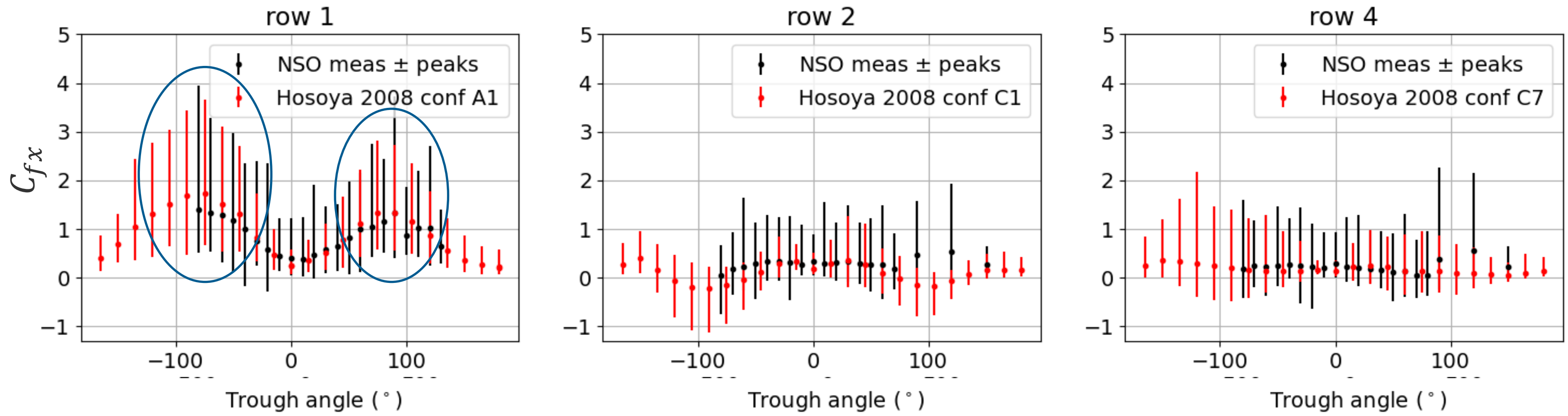
$$C_{fx} = \frac{F_x}{\frac{\rho}{2} U^2 \cdot L_{\text{segment}} \cdot W}$$



NSO: mean **± peak loads** (wind direction: 260°–280°)

Hosoya et al. (2008): mean **± peak loads** (0º yaw)

Support Structure Loads: Comparison to Wind Tunnel



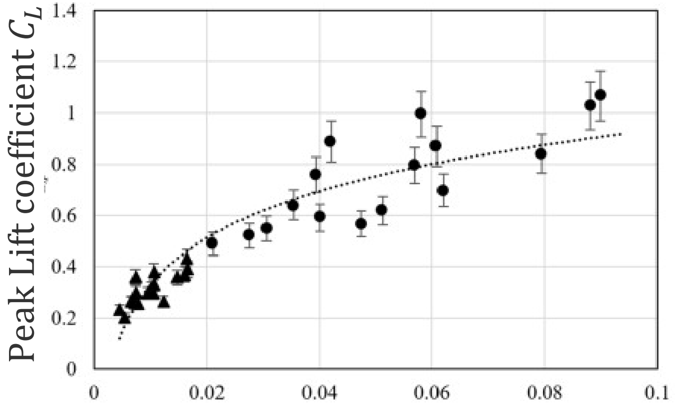
- Basic patterns for static loads agree well with wind tunnel results.
- NSO measurements show **higher peak loads** than wind tunnel tests.
- The first row experiences the highest static and **dynamic loads,** despite the higher TI at downstream rows.

4. Impact Factors on Dynamic Loads

What causes high dynamic loads on full-scale CSP structures?

Probable impact factors are trough angle, high winds, high TKE or TI, specific length scales L_w.

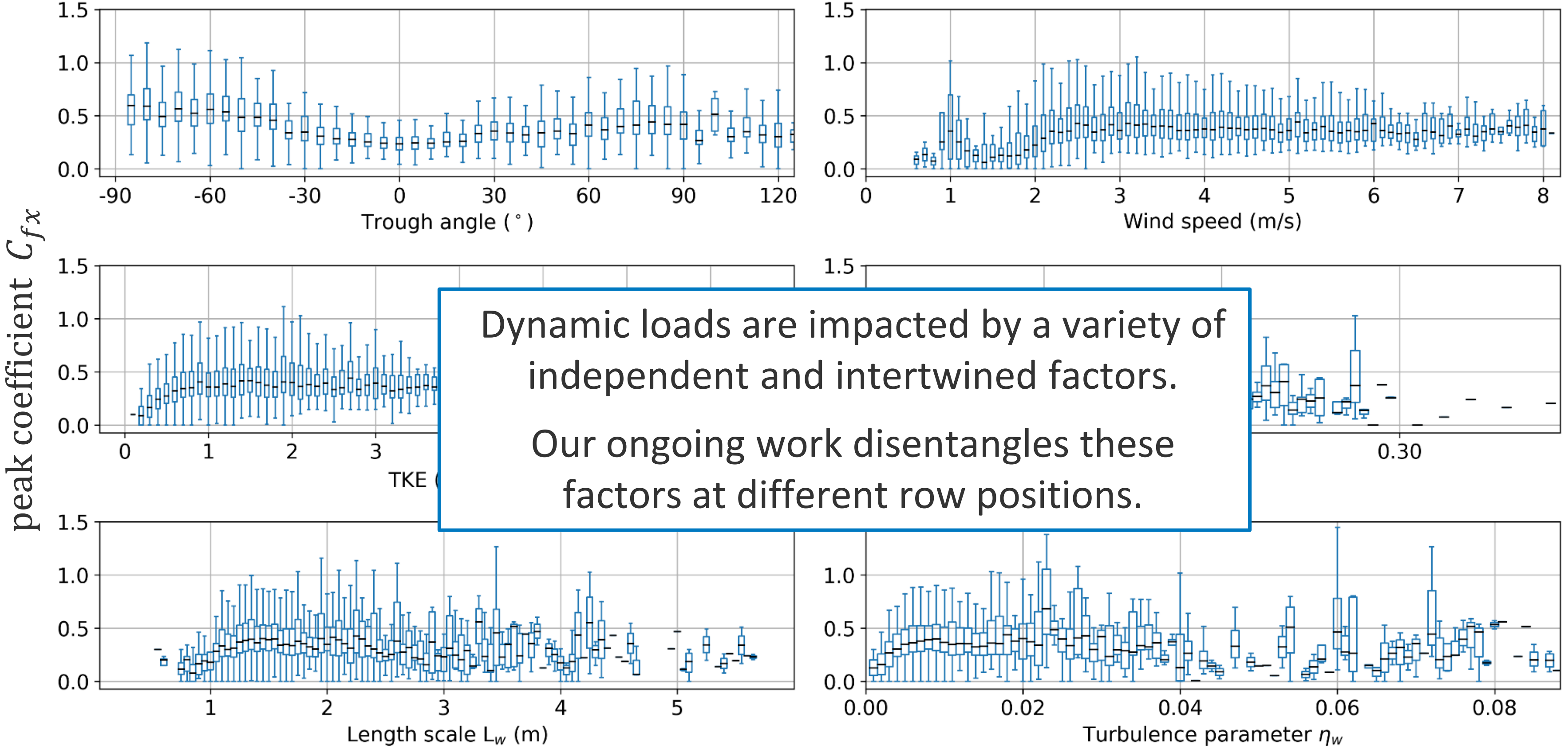
Jafari et al. (2019) introduced a **turbulence parameter η** (for heliostats) to describe peak lift coefficients.



$$\eta = \mathrm{TI_w} \cdot (L_w/W)^{2.4}$$

Jafari Azadeh, Farzin Ghanadi, Maziar Arjomandi, Matthew J. Emes, and Benjamin S. Cazzolato. 2019. Correlating Turbulence Intensity and Length Scale With the Unsteady Lift Force on Flat Plates in an Atmospheric Boundary Layer Flow. *Journal of Wind Engineering and Industrial Aerodynamics* 189 (June 2019): 218–230. https://doi.org/10.1016/j.jweia.2019.03.029.

Impact Factors on Dynamic Loads (first row)



Dynamic loads are impacted by a variety of independent and intertwined factors.

Our ongoing work disentangles these factors at different row positions.

Summary

Key Messages

- **First-of-its-kind, long-term data set from an operational parabolic trough plant** sheds light on wind-structural load interactions.
- Static load observations **align with previous wind tunnel tests**, while dynamic loads show differences.
- Our ongoing research aims to identify **key factors contributing to high dynamic loads** on collector structures.

Thank you!

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