



**SOLAR ENERGY
TECHNOLOGIES OFFICE**
U.S. Department Of Energy

Tracking Error at an Operational Concentrating Solar Power Plant

B. J. Stanislawski, U. Egerer, S. Dana, and S. Yellapantula

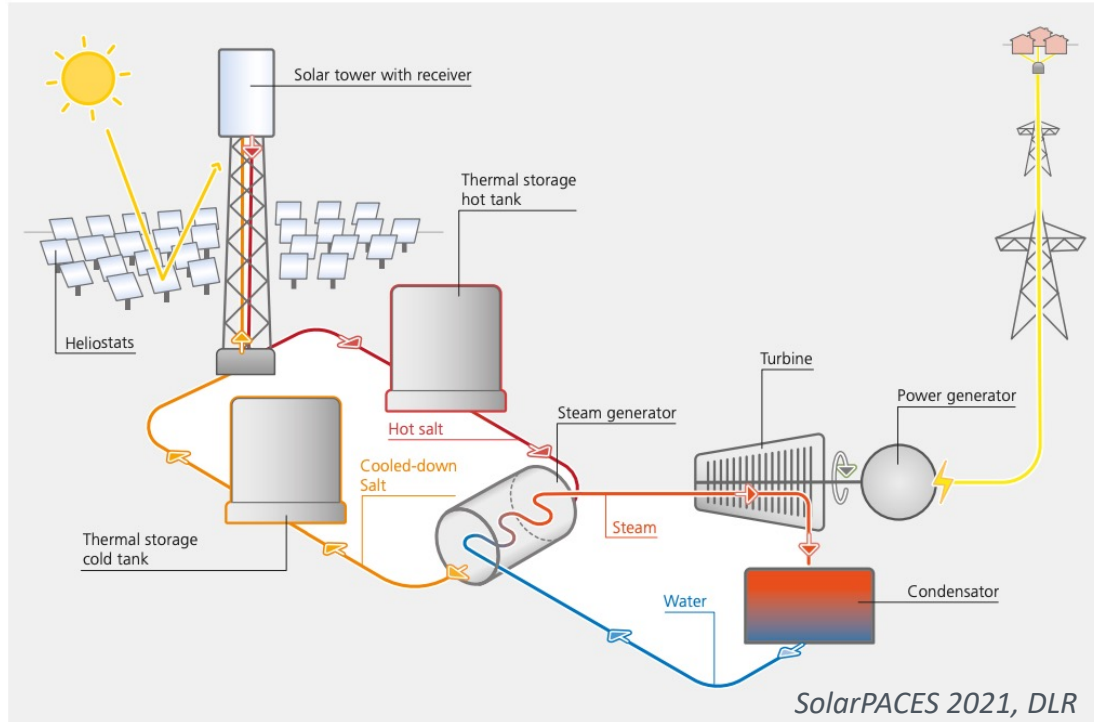
ASME Energy Sustainability 2024

July 16, 2024 | Anaheim, CA

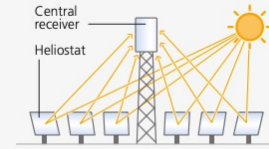


Why CSP?

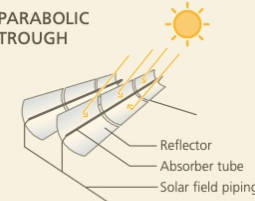
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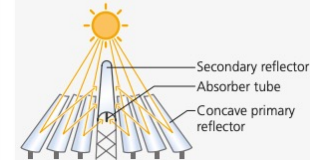
SOLAR TOWER



PARABOLIC TROUGH



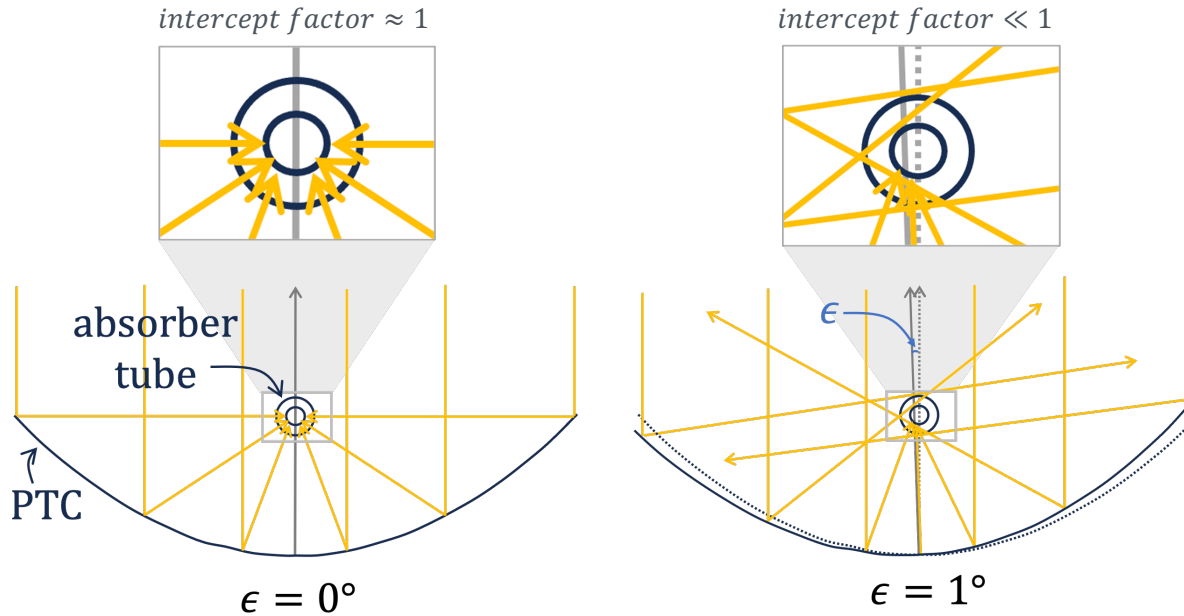
LINEAR-FRESNEL-REFLECTOR (LFR)



Unlike solar photovoltaic technologies, CSP has an **inherent capacity to store heat energy** for later conversion to electricity.

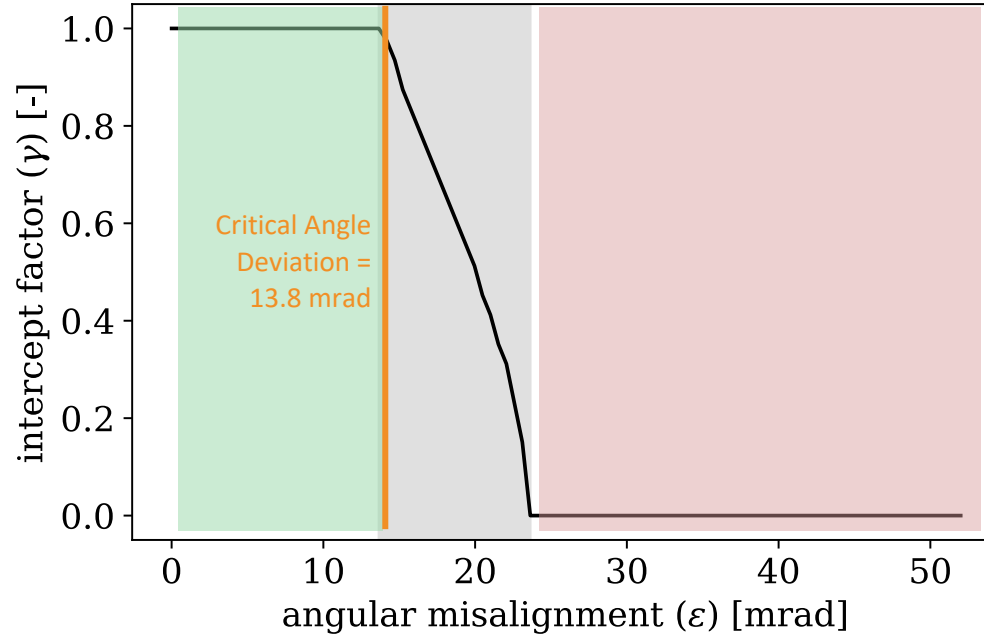
Tracking Error Reduces Optical Performance

Tracking error: the angular offset of a collector away from the sun position along the transversal plane.



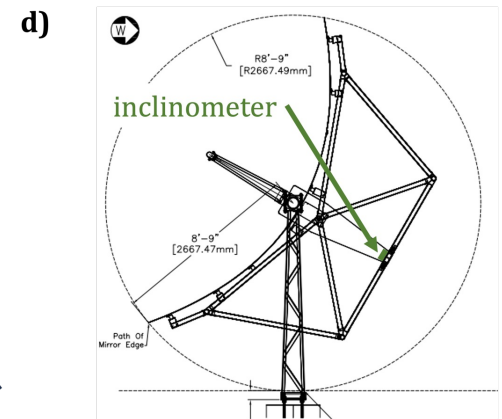
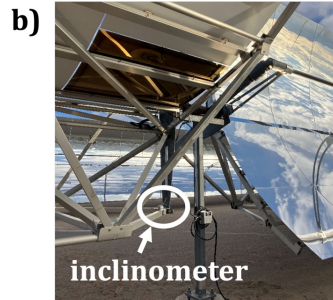
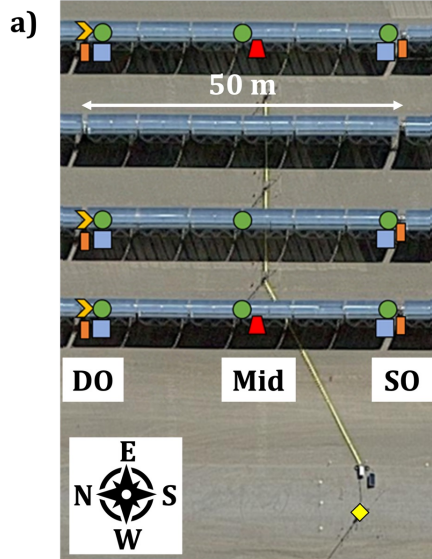
$$\text{intercept factor } (\gamma) = \frac{\text{number of rays that hit the absorber}}{\text{number of rays that hit the collector}}$$

Tracking error reduces optical performance

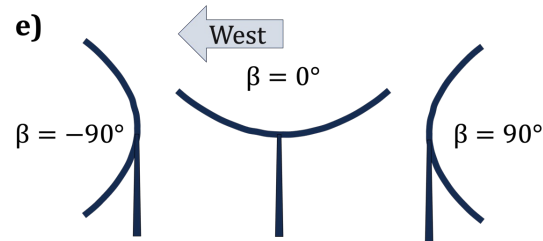


$$\text{intercept factor } (\gamma) = \frac{\text{number of rays that hit the absorber}}{\text{number of rays that hit the collector}}$$

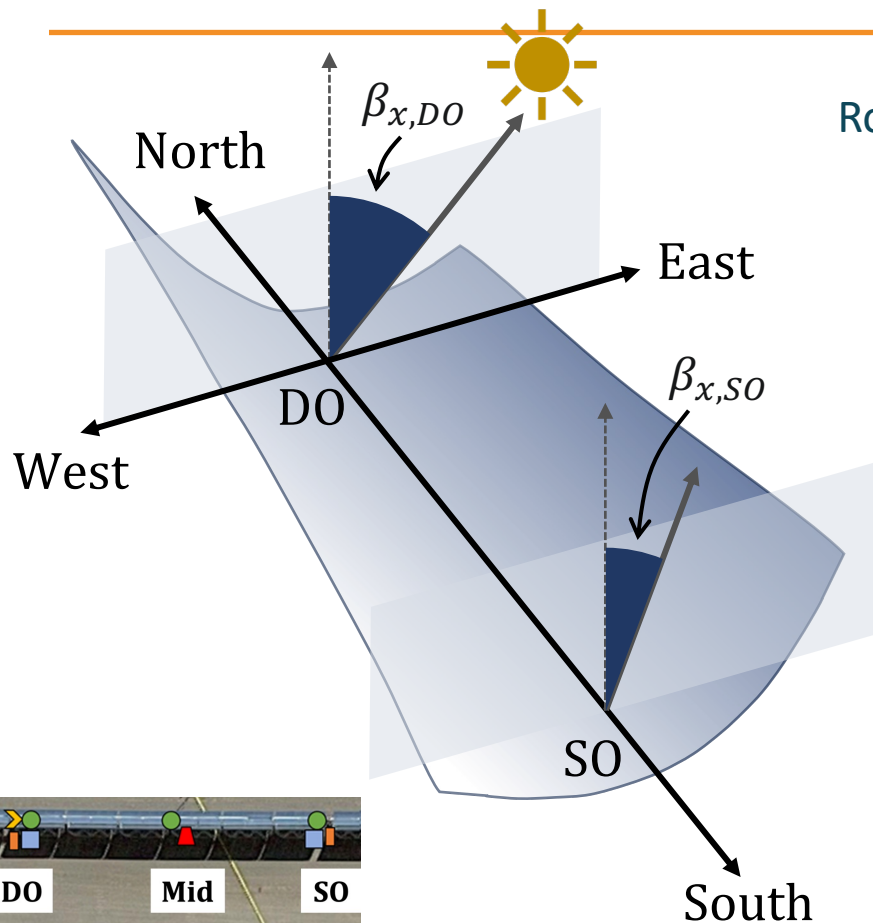
Field measurement sensor layout



- Drive Torque
- Pylon Bending
- Dynamic Tilt
- Accelerations
- ▲ Mirror Vibration
- ◆ Wind Speed



Calculation of torsional error



Row 1, 2, 4

DO, Mid, SO

$$\beta_{x,y} - \beta_{x,DO} = \epsilon_{torsion}$$

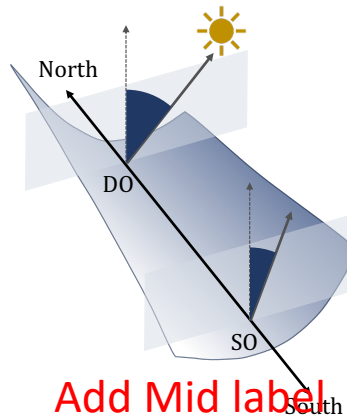


Research Questions

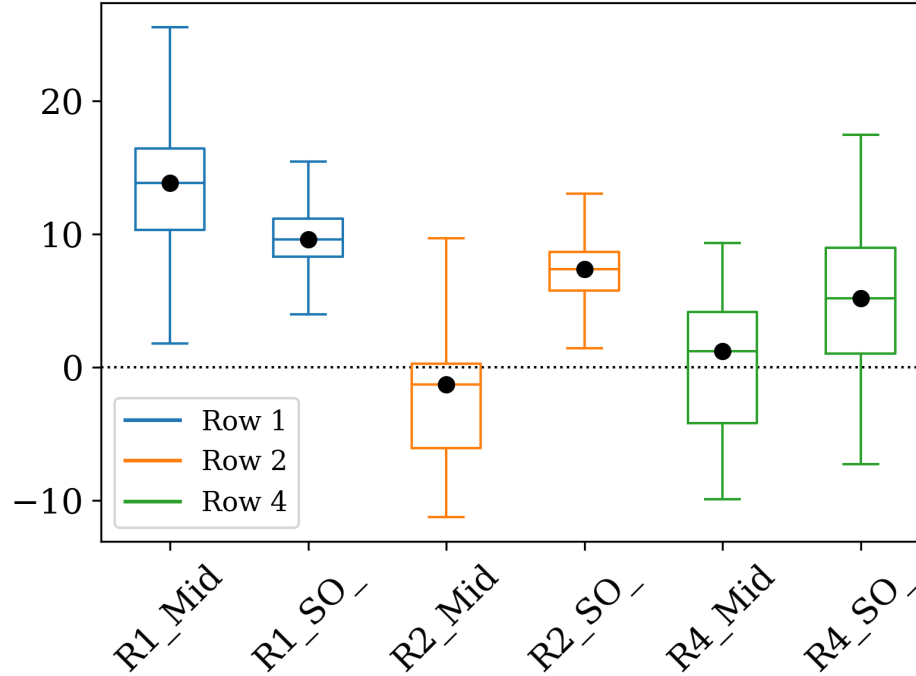
1. How does torsional misalignment of PTC support structures vary over time and by location at three rows at an operational CSP plant?
2. How does wind loading affect the torsional misalignment?

Torsional error during 7-month period

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Torsional error
 $\beta_{x,y} - \beta_{x,DO}$ [mrad]



Row 1 Mid lags behind DO by a median of 13.9 mrad.

Row 2 Mid tracks ahead of DO by a median of 13.9 mrad.

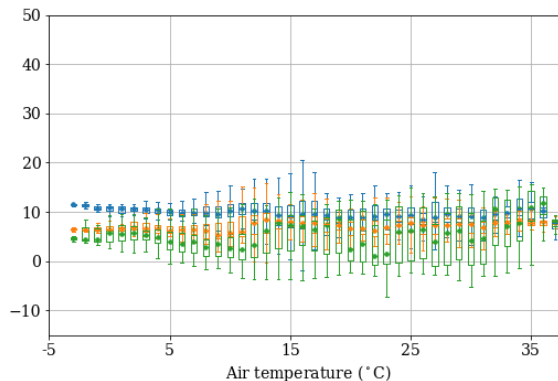
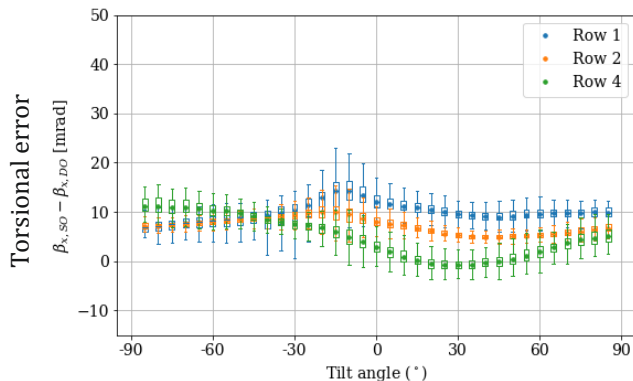
Part of the Row 1 solar collector assembly (SCA) may suffer from reduced optical performance

Potential causes for torsional error trends

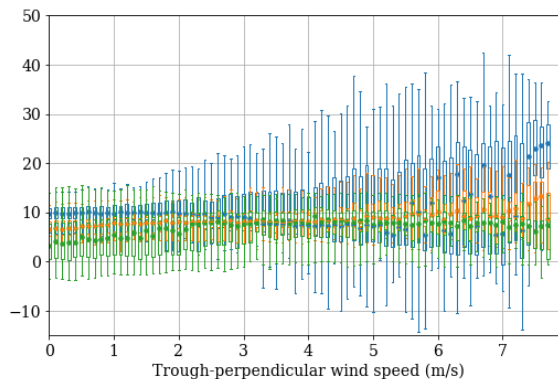
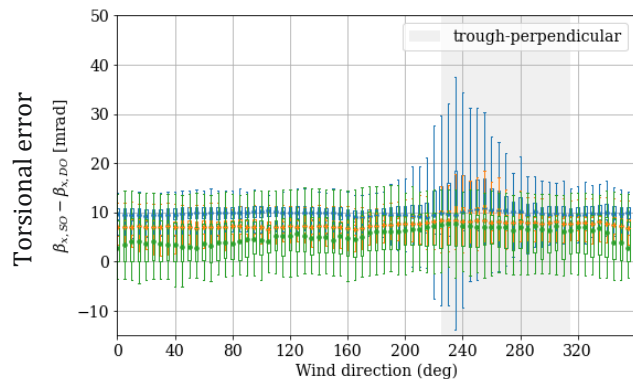
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Strong correlation between torsional error and tilt angle



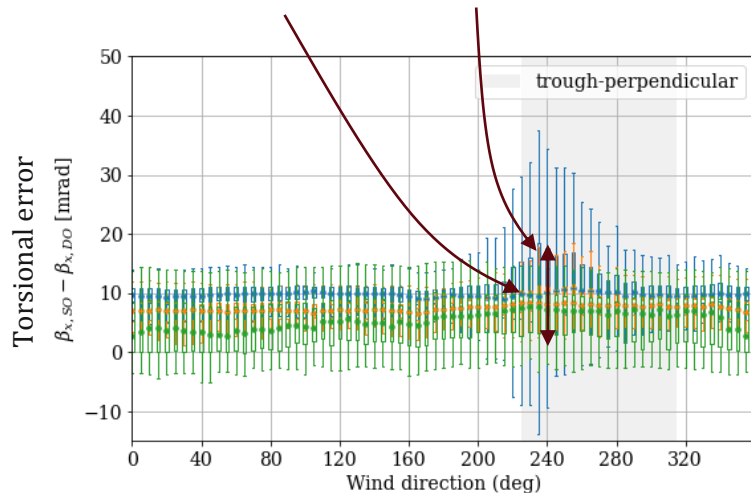
Largely insensitive to air temperature



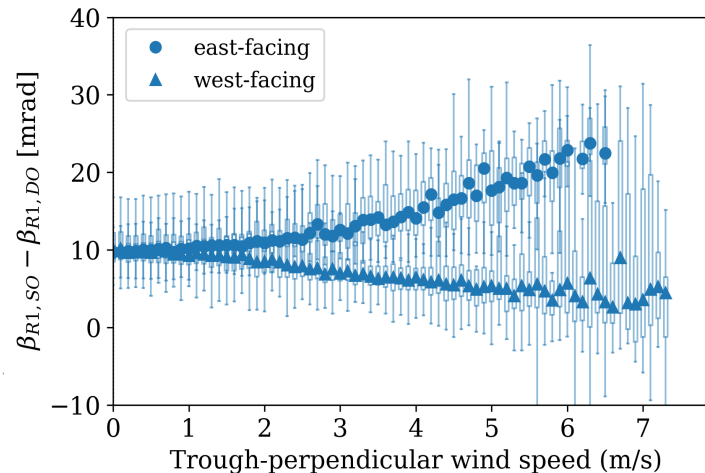
Potential causes for torsional error trends

Median represents static wind loading effects

Size of each box represents the dynamic wind loading

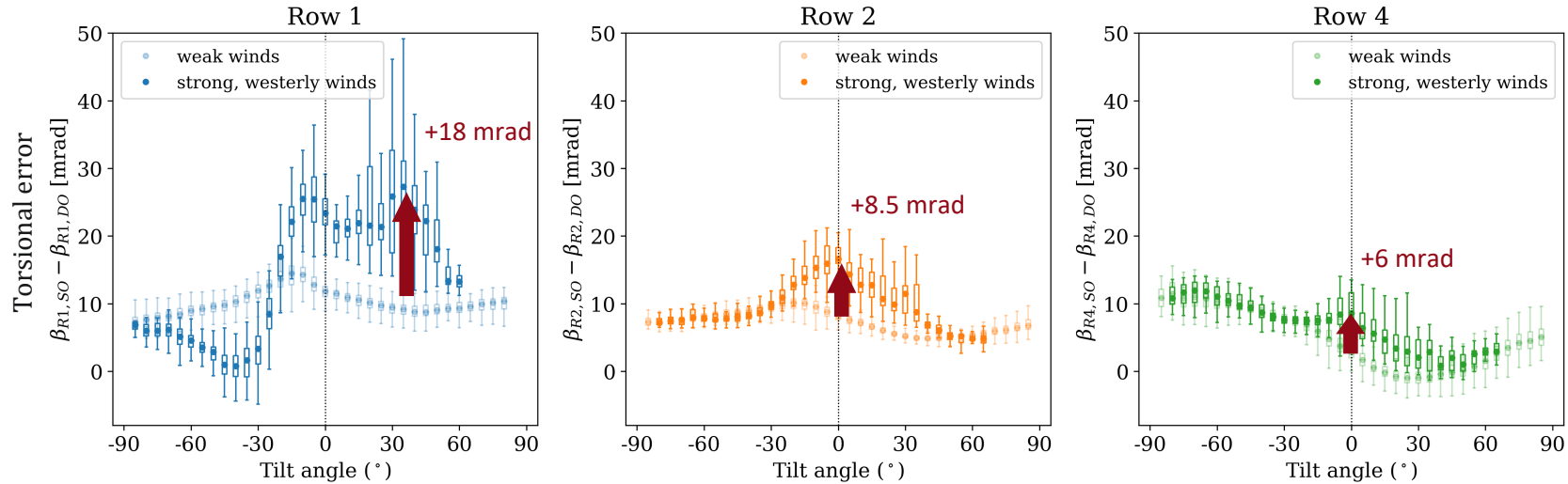


Substantial increase in standard deviation of Row 1 torsional error during south-westerly winds



Strong winds have opposite effects on row 1 torsional error when the troughs face toward versus away from the wind

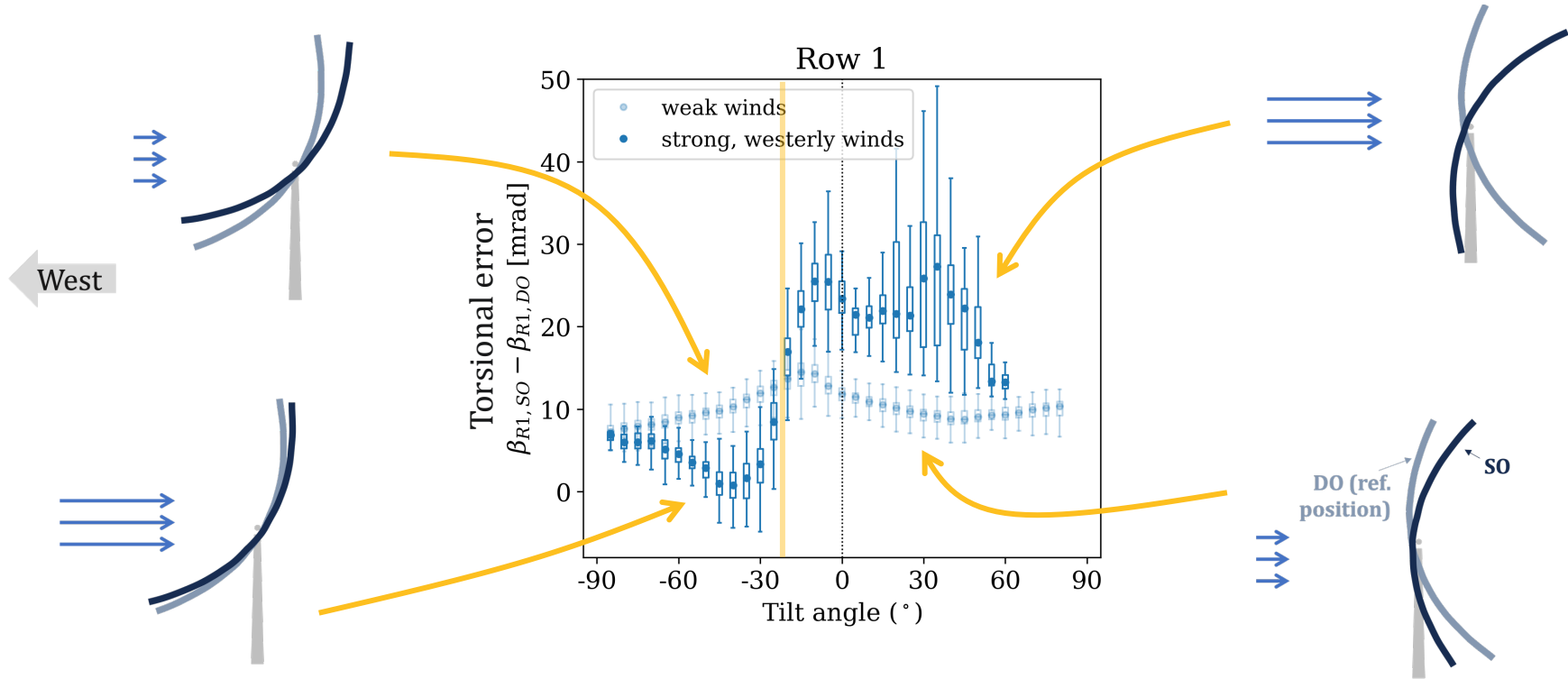
Combined effects of wind and tilt angle



During strong westerly winds, the torsional error could lead to reduced optical performance and non-uniform heating of the receiver tubes.

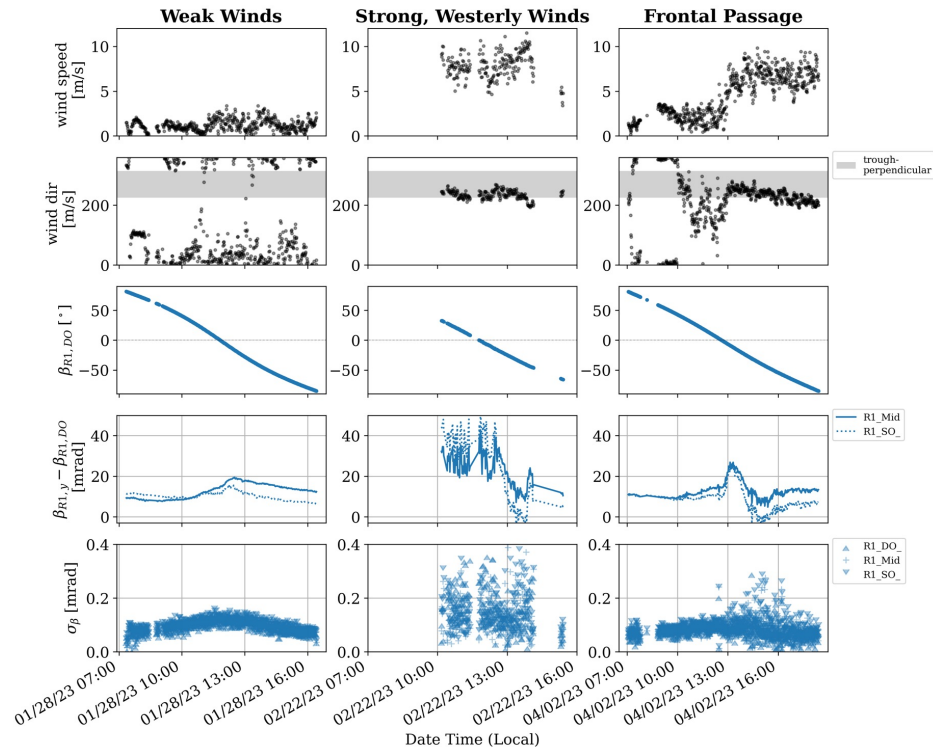
Aerodynamic effects of wind on PTCs

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The parabolic shape causes a transition between reducing and increasing torsional error to occur at a tilt angle of -20 degrees (tilted slightly toward the wind)

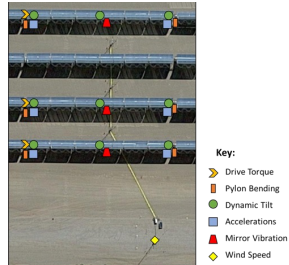
So what does this look like in operation?



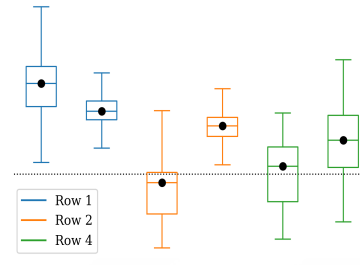
Wind conditions play an important role in torsion and the impact depends on the tilt angle of the PTCs.

Contributions of this Work

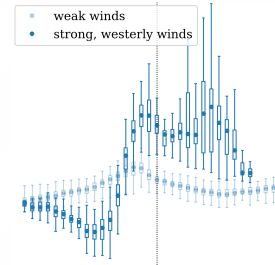
Created first-of-its-kind
long-term field
measurement dataset of
operational CSP plant



Characterized torsional
error at an operational CSP
plant



Quantified the contribution
of wind loading to torsion



Journal article under review

The impacts of tilt angle and wind on tracking error at an operational concentrating solar power plant

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Abstract

Parabolic trough collector (PTC) systems, a type of concentrating solar power (CSP), use parabolic mirrors to reflect the sun's rays toward the absorber tube to heat the fluid inside. The PTCs track the sun throughout the day, but commonly experience tracking error, which reduces optical performance. Tracking error is the angular offset of the collector away from the sun position and occurs due to non-continuous tracking, gravity, heating, wind

Thank You

Brooke Stanislawski (NREL)

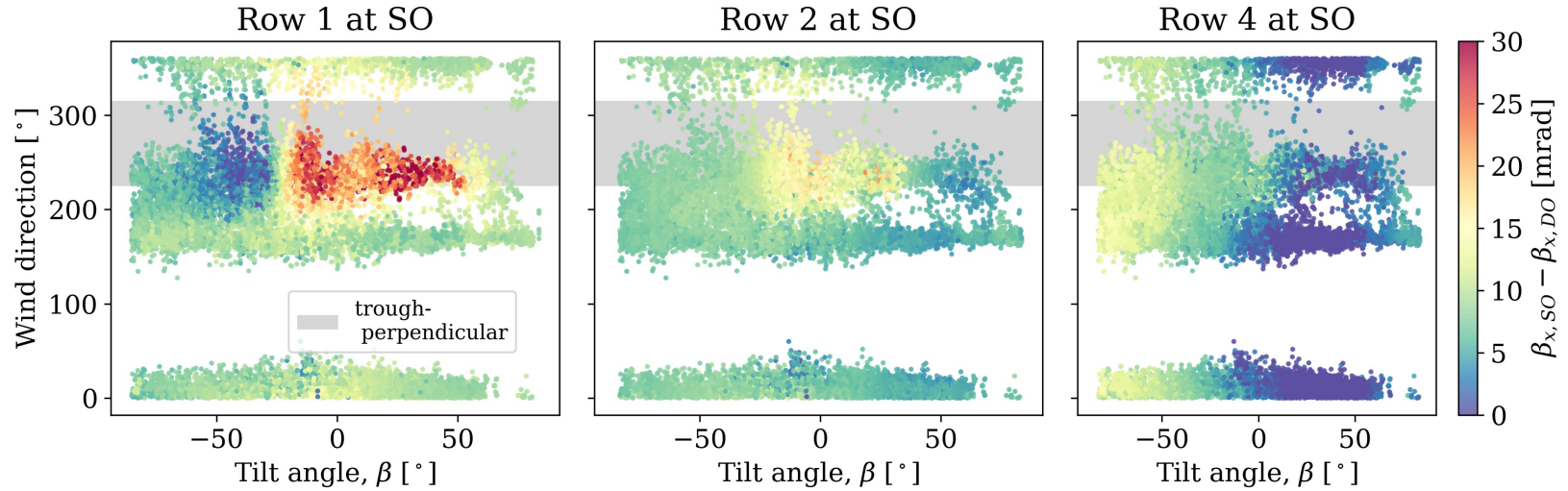
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Back up

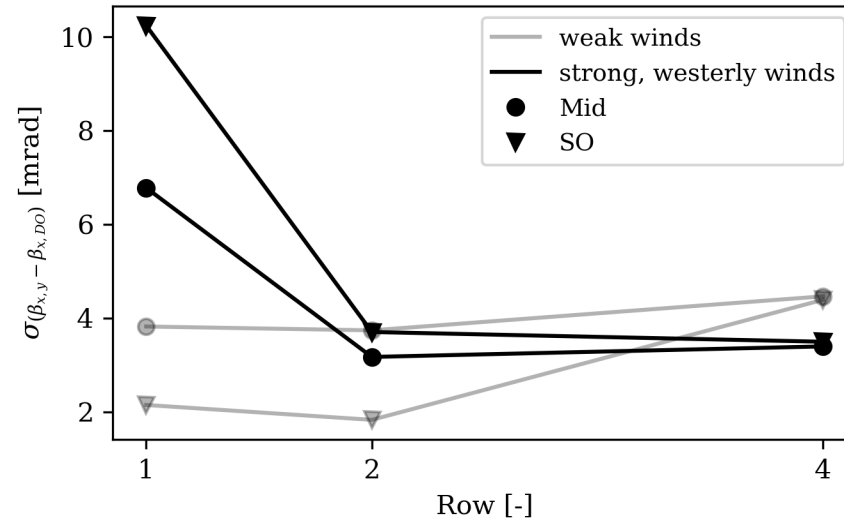
Torsional error

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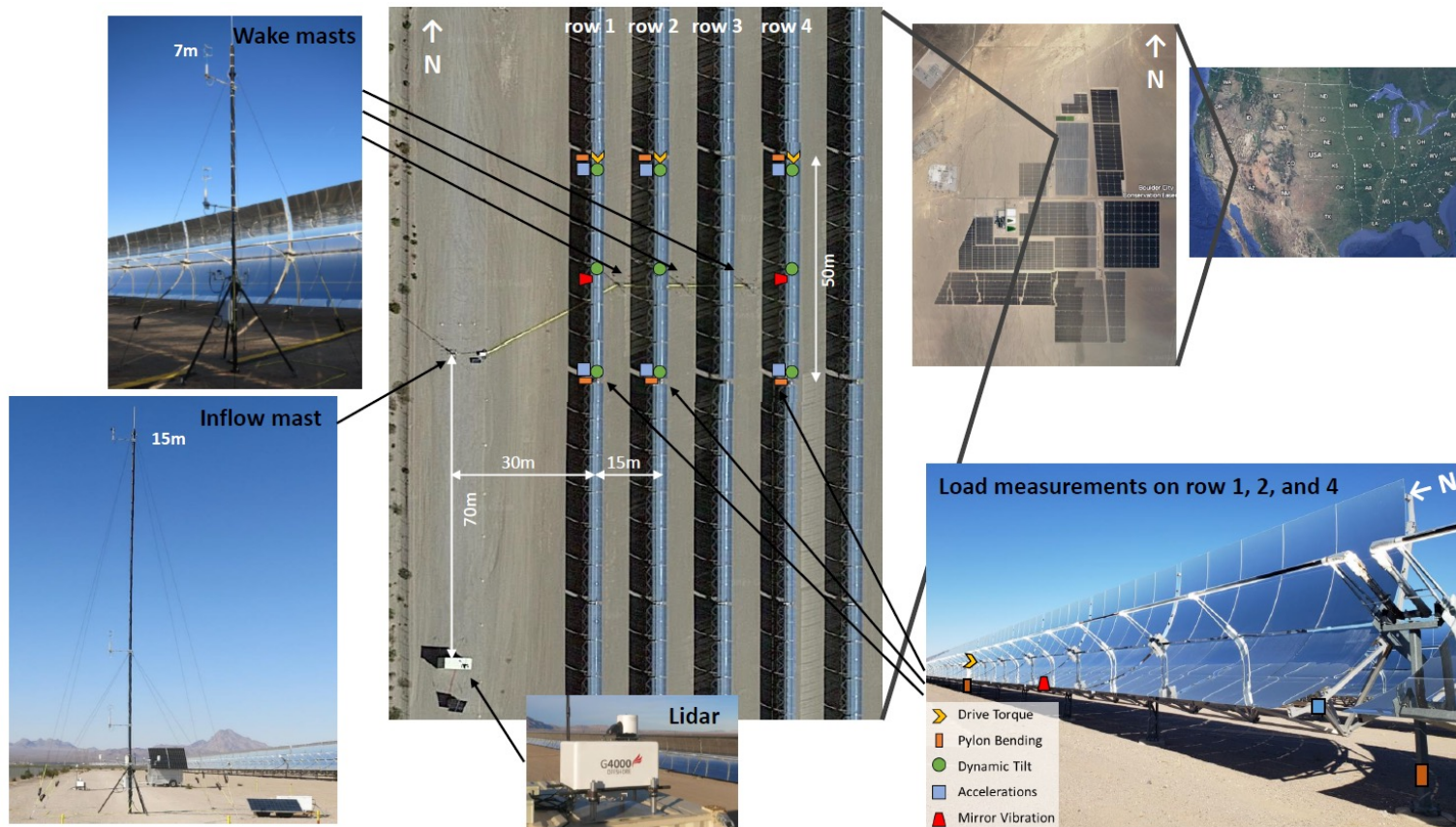


Standard deviation of torsional error

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Measurement set-up at NSO



Met masts: data availability

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