Heliostat Field Design for Atmospheric Boundary Layer Turbulence

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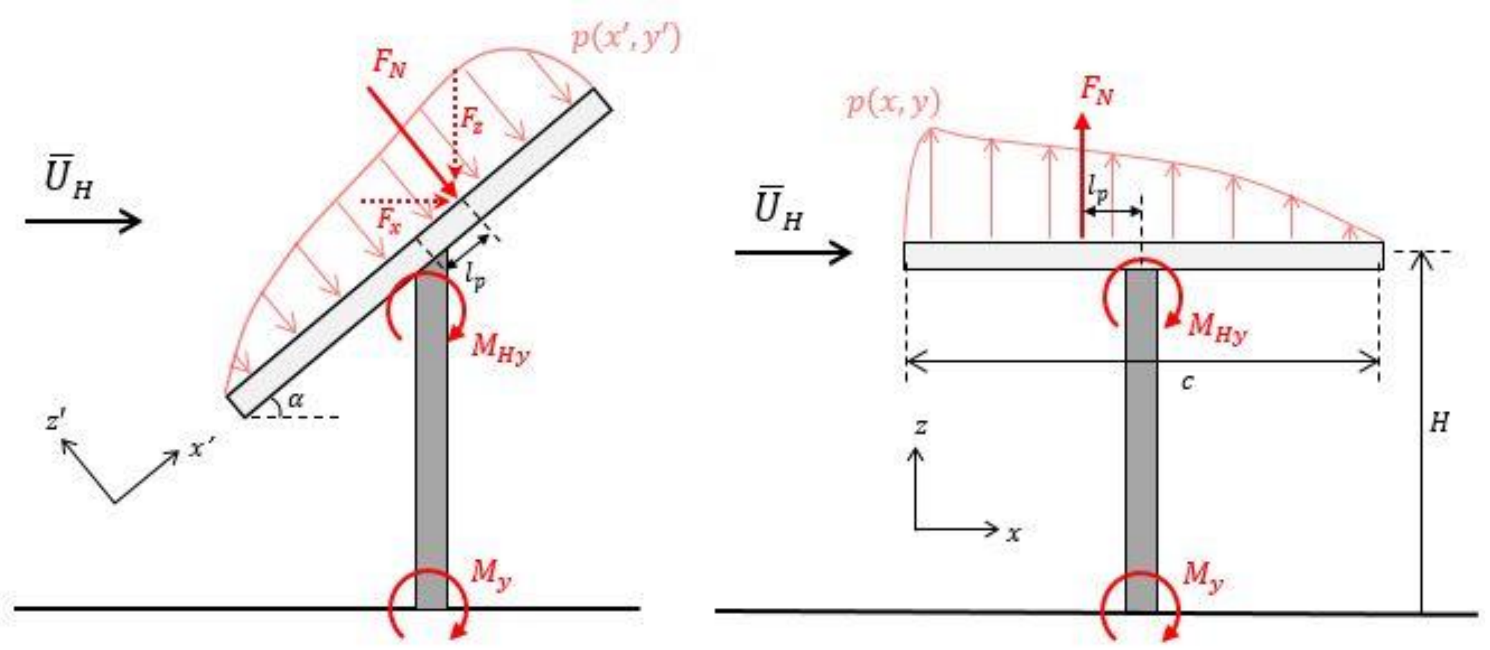
Introduction

- The heliostat field in a concentrating solar thermal system has the largest contribution (40-50%) to the capital cost of a power tower plant
- Sizing of structural components relies on understanding the contribution of ABL turbulence to static and dynamic wind loads that cause deflections to mirror shape for optical performance, and structural failure in the case of extreme loads.
- Analysis and characterisation of unsteady turbulent wind fluctuations and atmospheric stability in the lower surface layer of the ABL, corresponding to variations in surface roughness at heliostat field sites, is required for accurate prediction of maximum wind loads to satisfy structural rigidity and operational performance, but also reduce the cost of over-engineered structural heliostat components.

Wind Loads on Heliostats

Operational and Stow Loading Cases



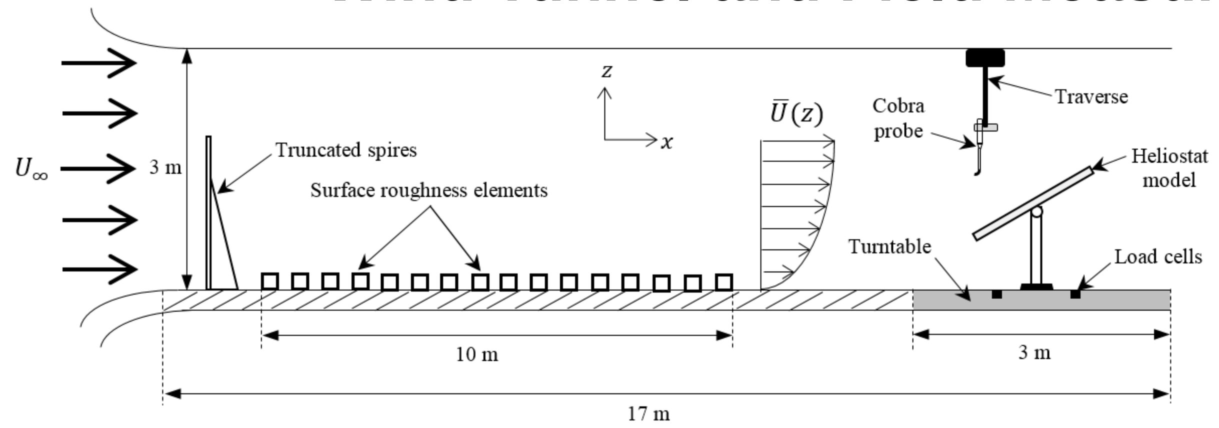
Emes *et al.* 2019, *Solar Energy*

Objectives

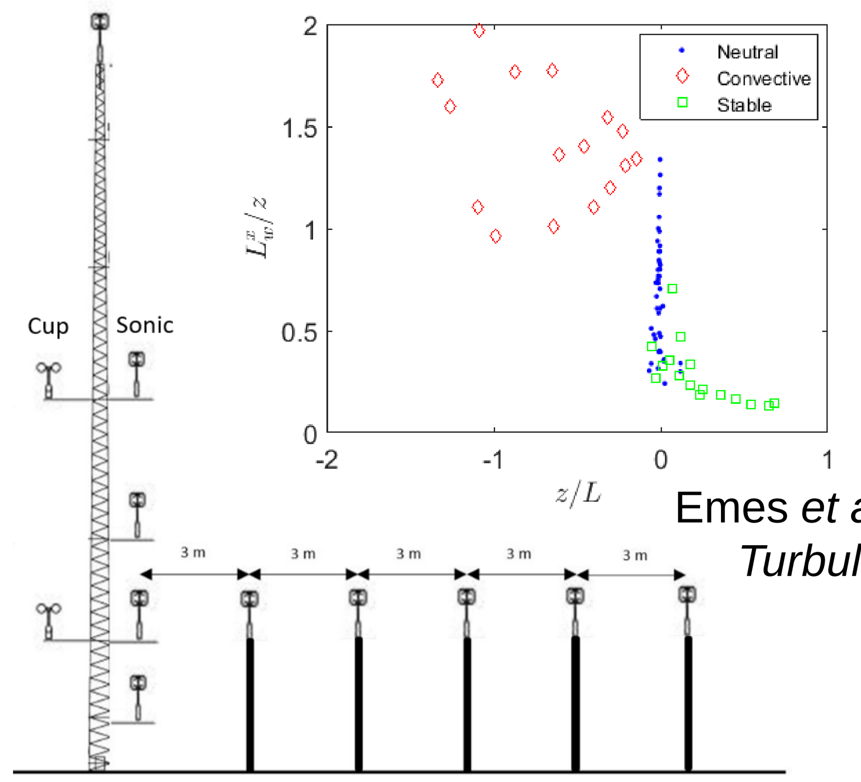
- Investigate the static and dynamic wind loads on individual, tandem and field arrangements of heliostats and their dependence on turbulence intensity $I_u = \sigma_u/\overline{U}$ and integral length scale $L_u^x = \overline{U}\int_0^{\tau_0} R_u(\tau)\,d\tau$
- Develop engineering guidelines with design wind speeds to calculate the design wind loads on heliostats, based on wind tunnel experiments and field measurements of ABL turbulence parameters and load distributions on instrumented heliostats

Experimental Method

Wind Tunnel and Field Measurements of ABL

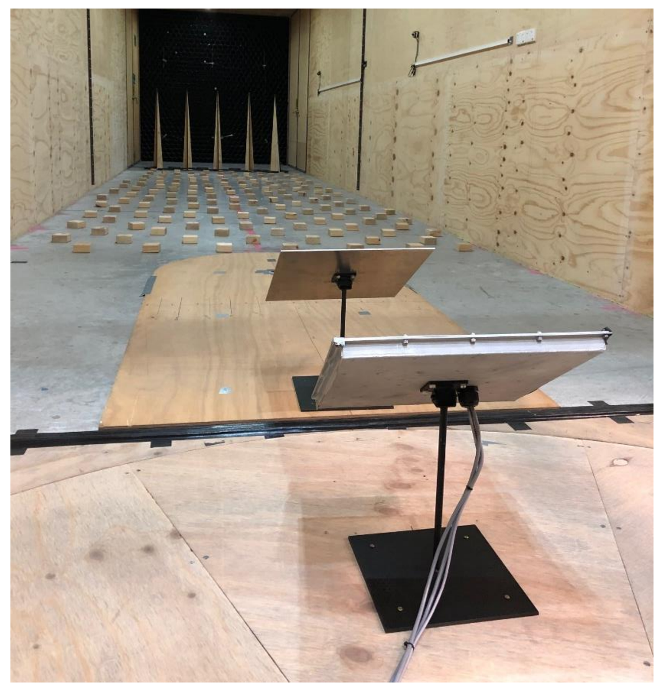


Arjomandi *et al.* 2019, *SolarPACES*



Emes *et al.* 2019, *Turbulence*

Field measurement setup in ASTRI 2.0



Jafari *et al.* 2019, *SolarPACES*

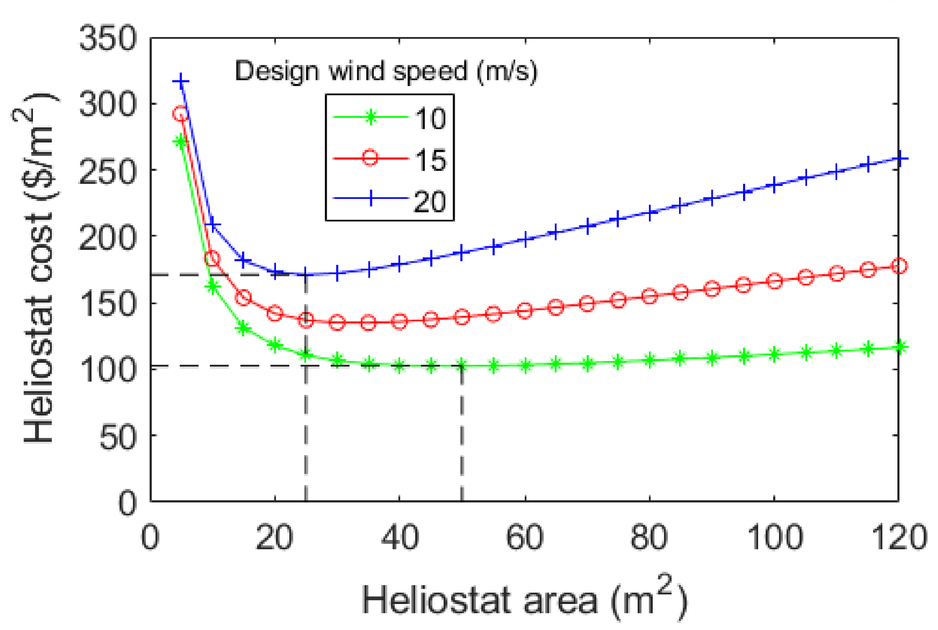
Effect of Turbulence Parameters on Aerodynamic Coefficients

$$c_{Fx,\alpha=90°} = 1.05\ln\left[I_u\left(\frac{L_u^x}{c}\right)^{0.48}\right] + 4$$

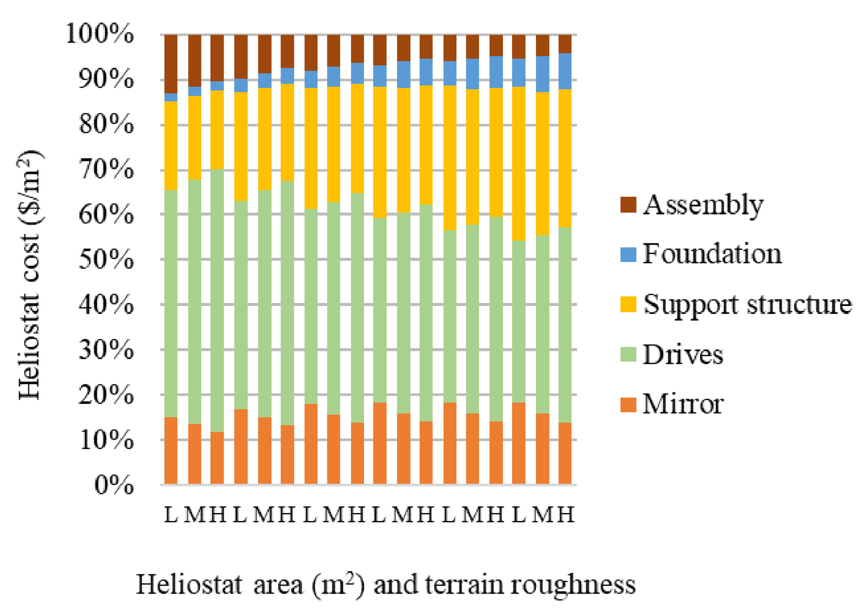
$$c_{Fz,\alpha=0°} = 0.267\ln\left[I_w\left(\frac{L_w^x}{c}\right)^{2.4}\right] + 1.566$$

Jafari *et al.* 2019, *JWEIA*

Effect of Design Wind Speed and Terrain Roughness on Heliostat Cost



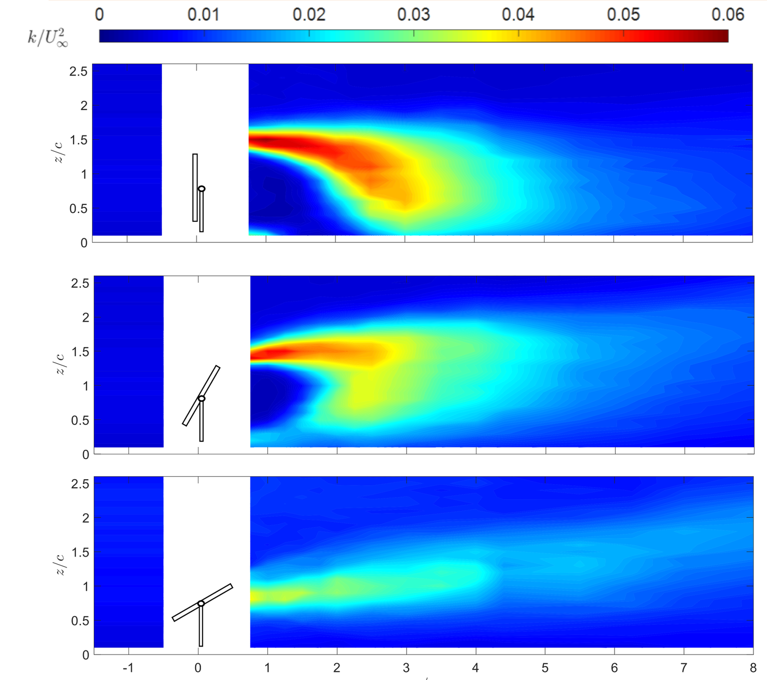
Emes *et al.* 2015, *Solar Energy*



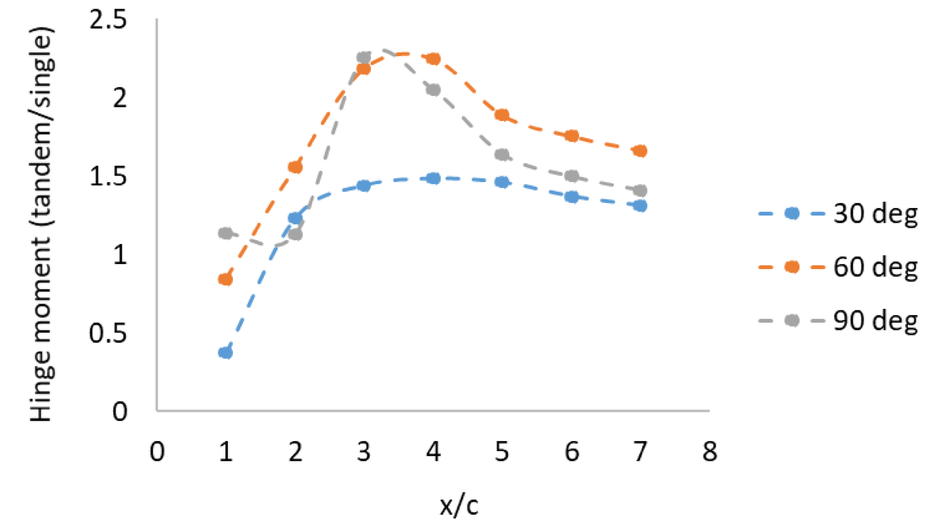
Emes *et al.* 2020, *Solar Energy*

Results

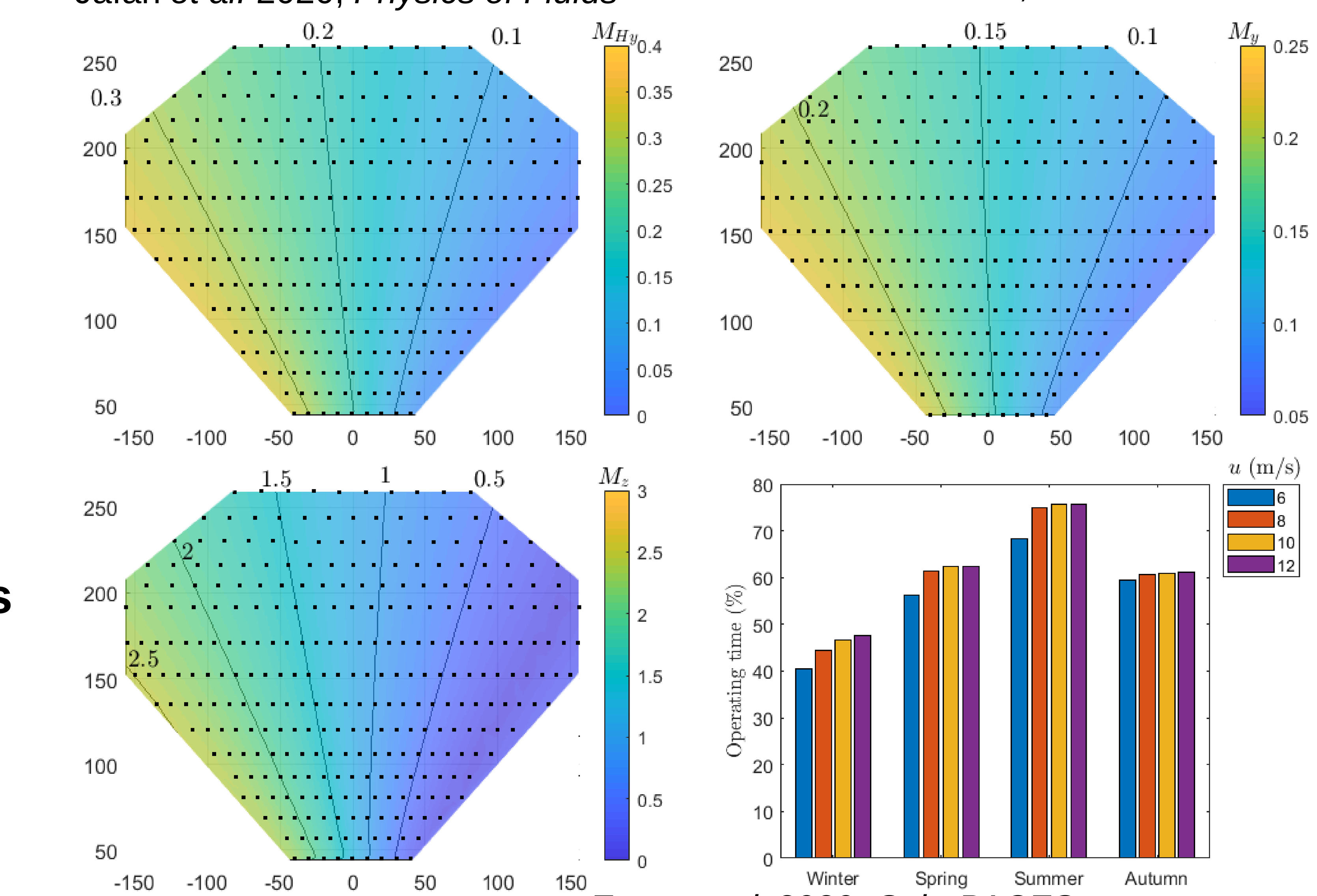
Heliostat Wake, Tandem Loads and Field Load Distributions



Jafari *et al.* 2020, *Physics of Fluids*



Jafari *et al.* 2019, *SolarPACES*



Emes *et al.* 2020, *SolarPACES*

Conclusions and Future Work

- Maximum wind loads and structural cost become increasingly sensitive to terrain roughness with increasing heliostat size.
- Unsteady wind loads are larger for high-density field spacing due to the increased intensity of wake-generated turbulence.
- Wind load predictions on full-scale heliostats due to surface layer turbulence and atmospheric stability require field measurements with increased precision and frequency of horizontal and vertical distributions of gust wind speed and turbulence characteristics.

Acknowledgements

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