Variation of Heliostat Wind Loads in a Radial Field Array Model

Matthew Marano, Matthew Emes, Azadeh Jafari, Maziar Arjomandi

SolarPACES
13th October 2023
Sydney

make history.

THE UNIVERSITY of ADELAIDE

Introduction

- Heliostat arrangement optimised for optical performance

- Arrangement based on wind loading is not considered

- Heliostats identical in design throughout field

- Design can be optimised for location in field

- Possible for wind loading to vary across a CSP field

Crescent Dunes 110MW. Photo captured by Hegen (2016)
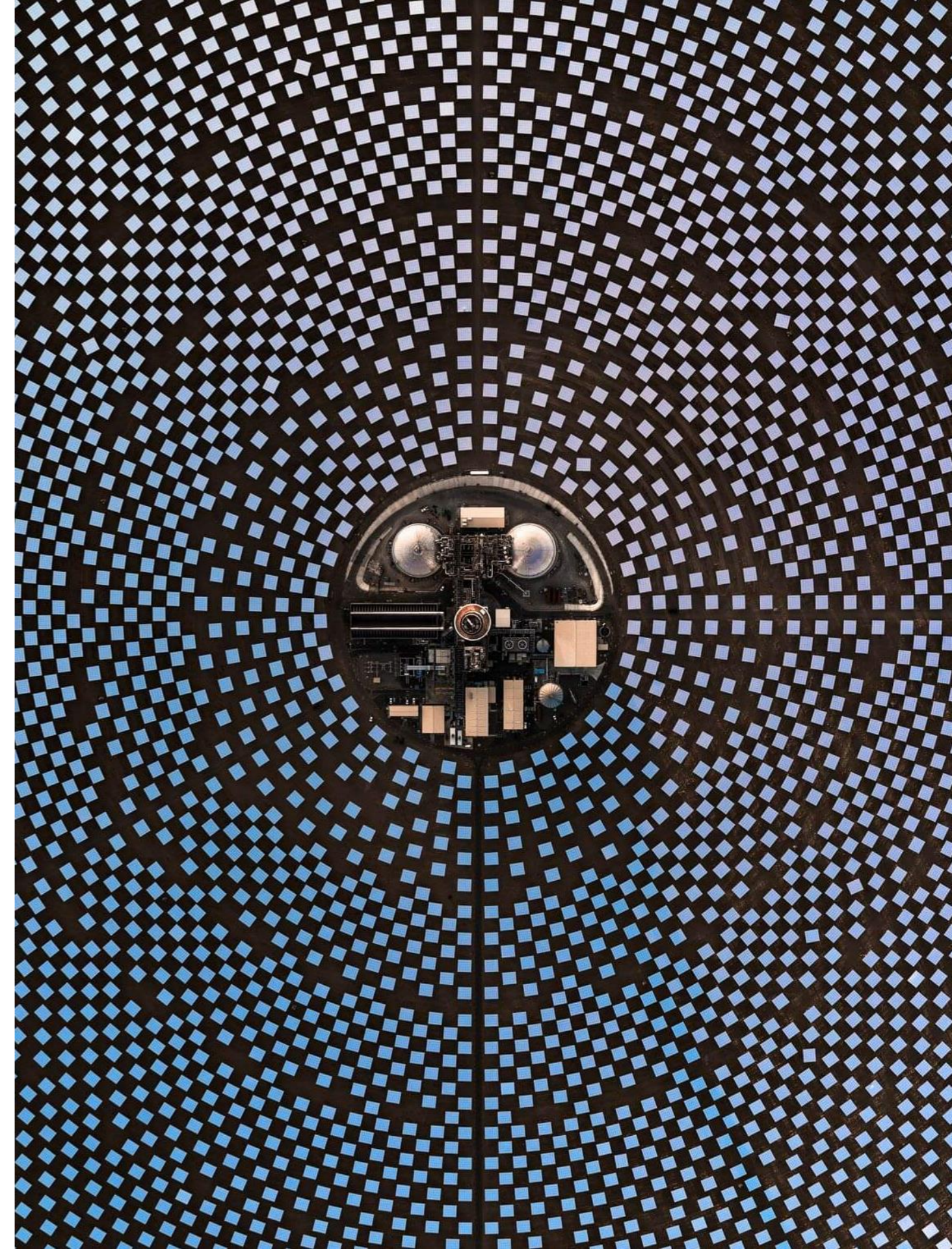
Question

How does heliostat wind loading vary throughout a heliostat field array?
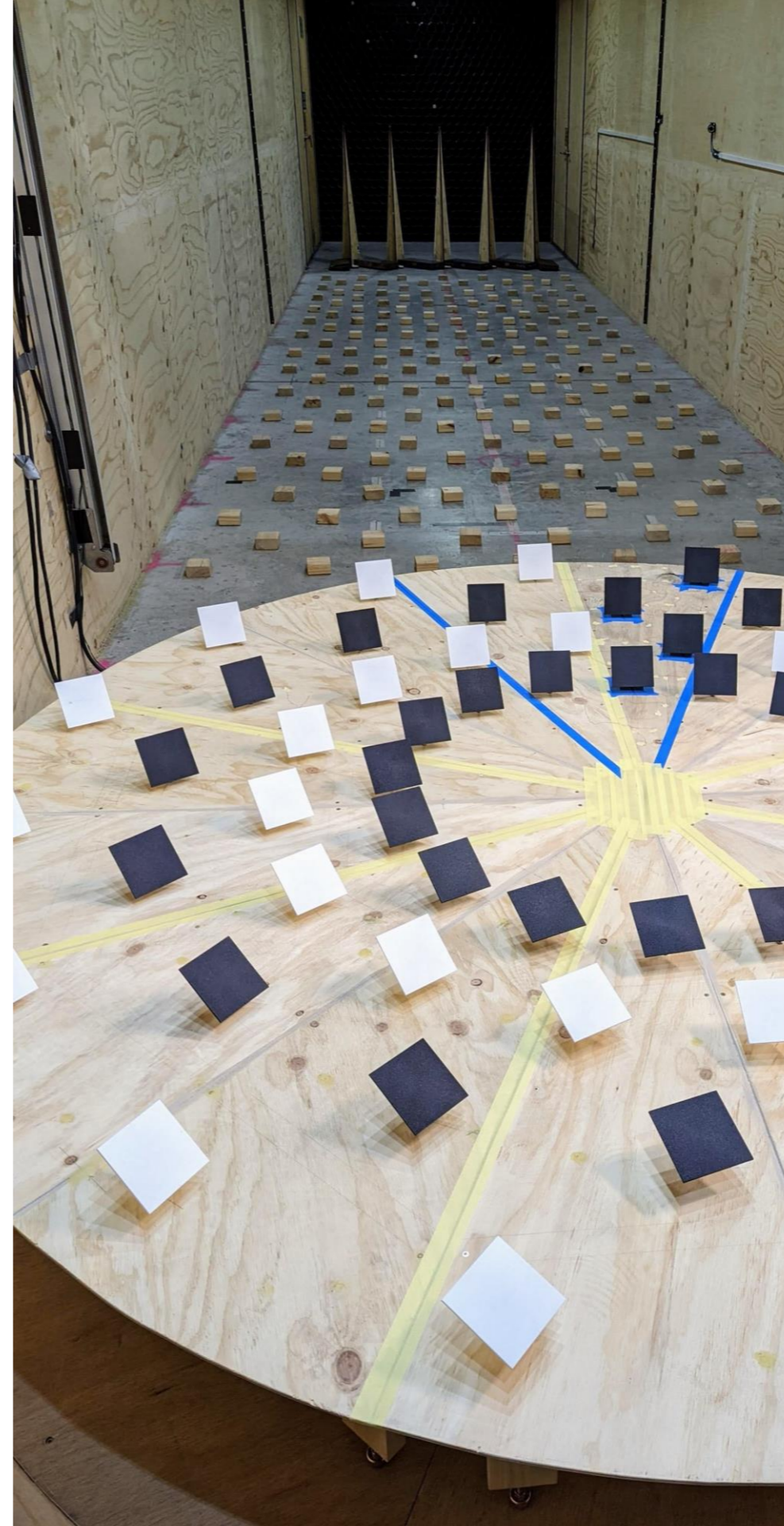
Experimental Setup

- Circular model 2.7 m diameter

- 64 heliostats

- Four rows from centre

- 1 m tall central tower

- Central tower removable to analyse effects

- Four instrumented heliostats repositioned around field

Wind tunnel ABL generation

- Generate part depth atmospheric boundary layer (ABL)

- 9.6 m/s at hinge height

- 3 x 3 x 17 m test section

Heliostat load coordinates

- Four 3-axis $\pm 2N$ load cell (K3D40)

  - Sampled at 1 kHz simultaneously

- Sheltered beneath surface

- Relocated around the field

- Adjustable about 3-axes

  - Azimuth angle (β)
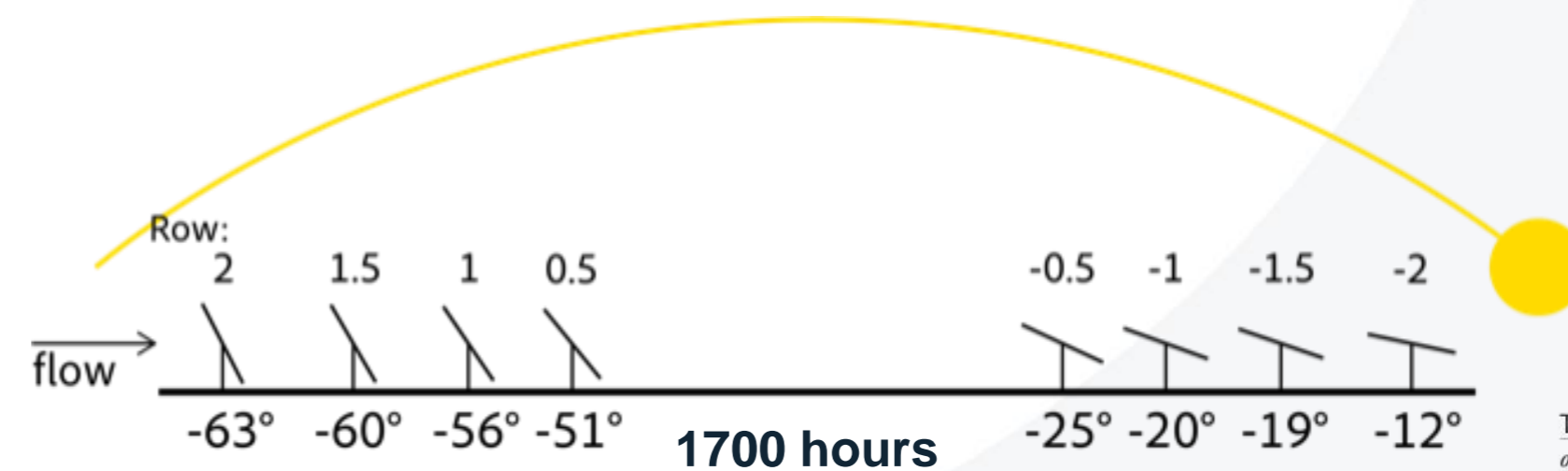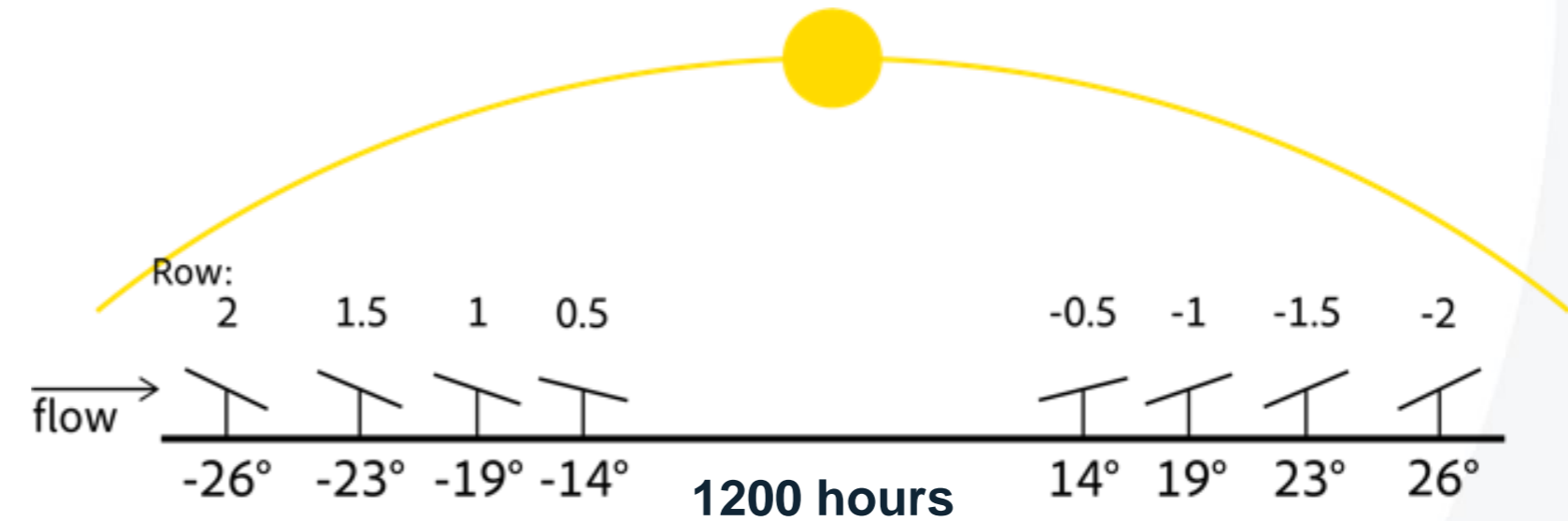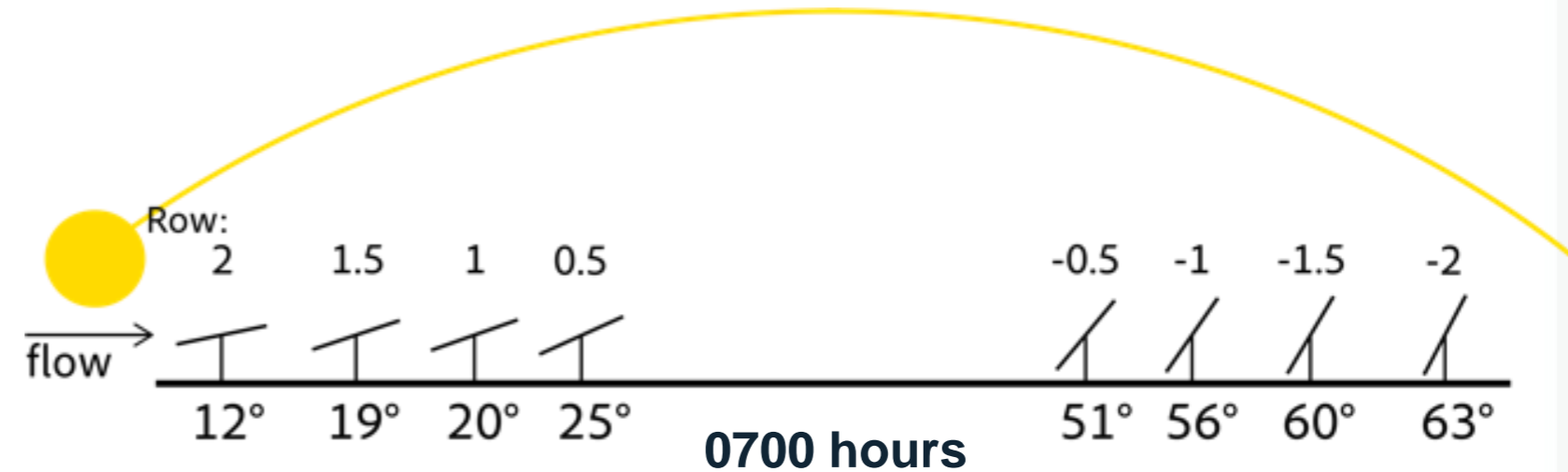
  - Elevation angle (α)
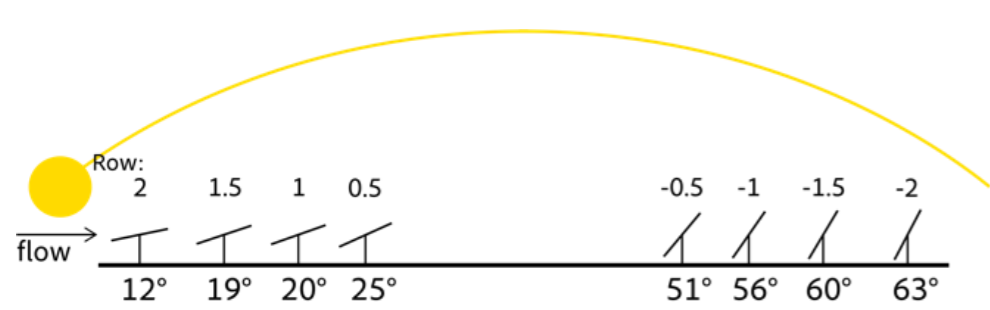
  - Hinge height
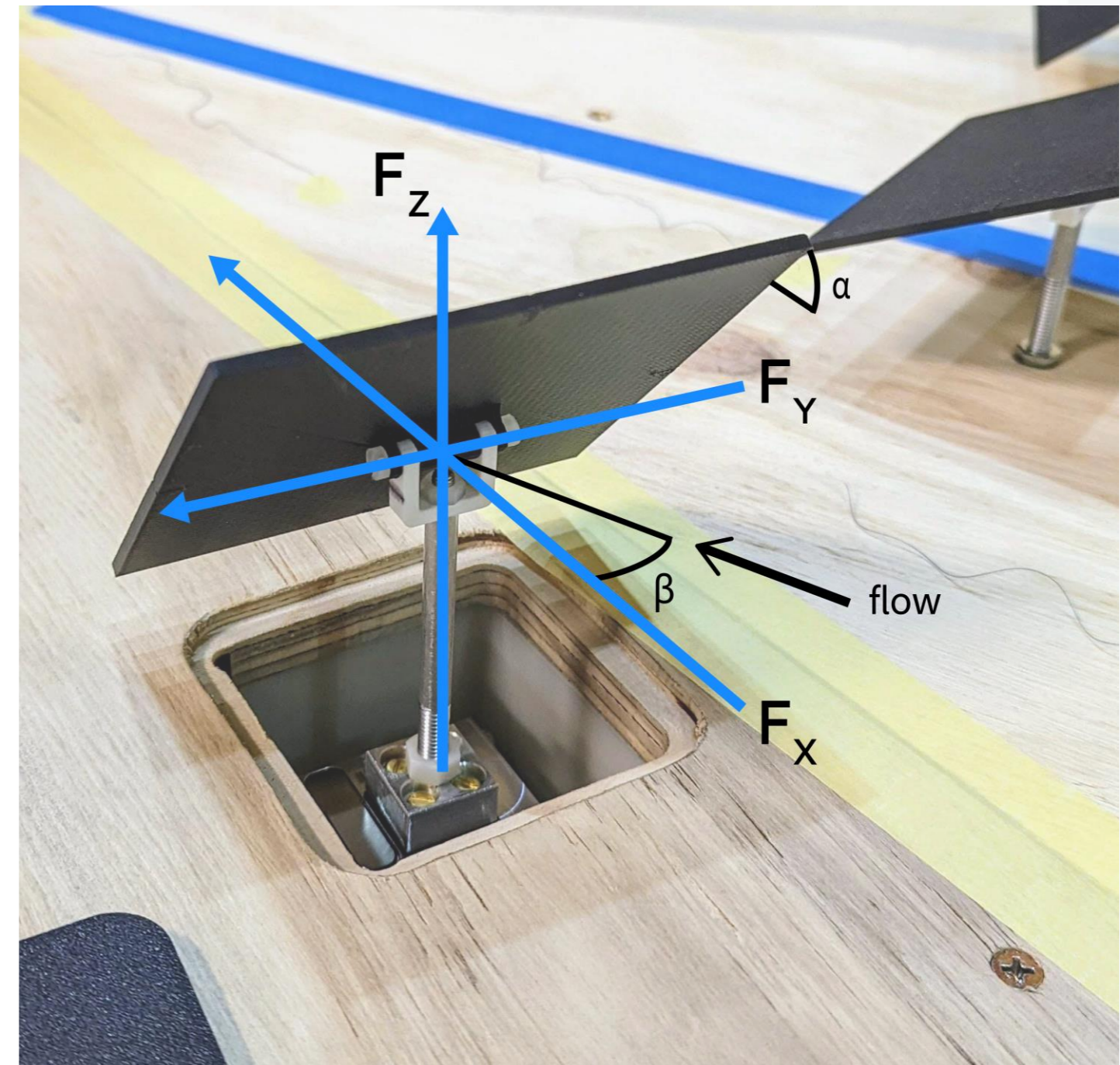
Heliostat array layout

- Maximum flow speed 12 m/s

- Heliostat

  - 100 x 100 mm

  - 0.01 m^2

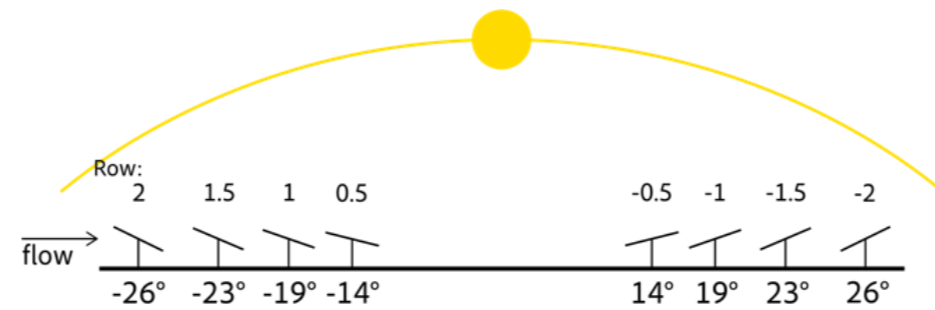- Radial non-blocking

  - 64 heliostats total
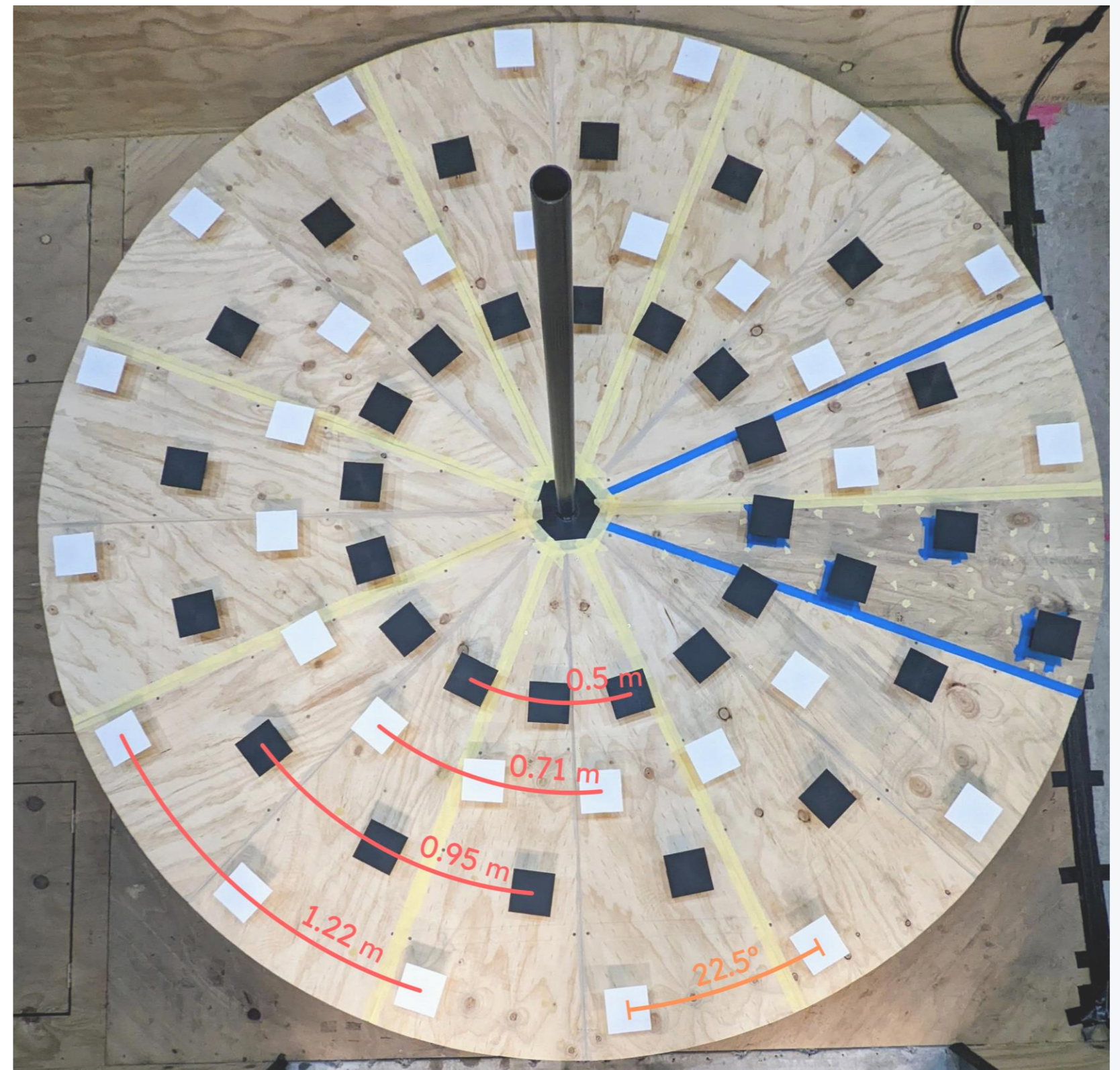
Configurations

- Test cases for surround field with central tower at equator

- Angles set for sun path on 21st March (equinox)

- Upstream and downstream sections instrumented

- Low and high blockage regions

Row:
2   1.5   1   0.5   -0.5   -1   -1.5   -2

flow

12° 19° 20° 25°   **0700 hours**   51° 56° 60° 63°

Row:
2   1.5   1   0.5   -0.5   -1   -1.5   -2

flow

-26° -23° -19° -14°   **1200 hours**   14° 19° 23° 26°

Row:
2   1.5   1   0.5   -0.5   -1   -1.5   -2

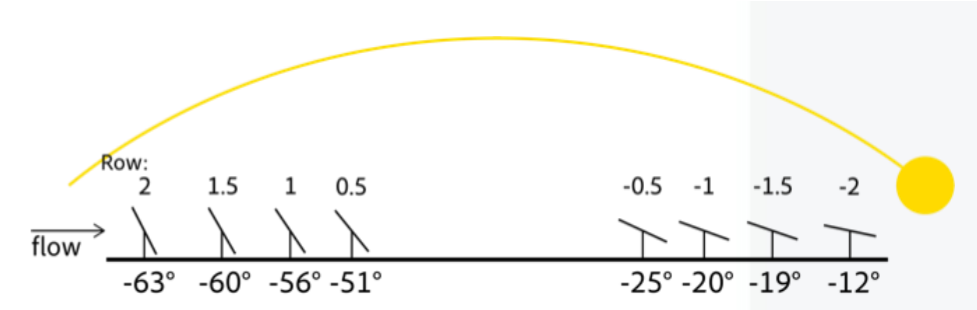flow

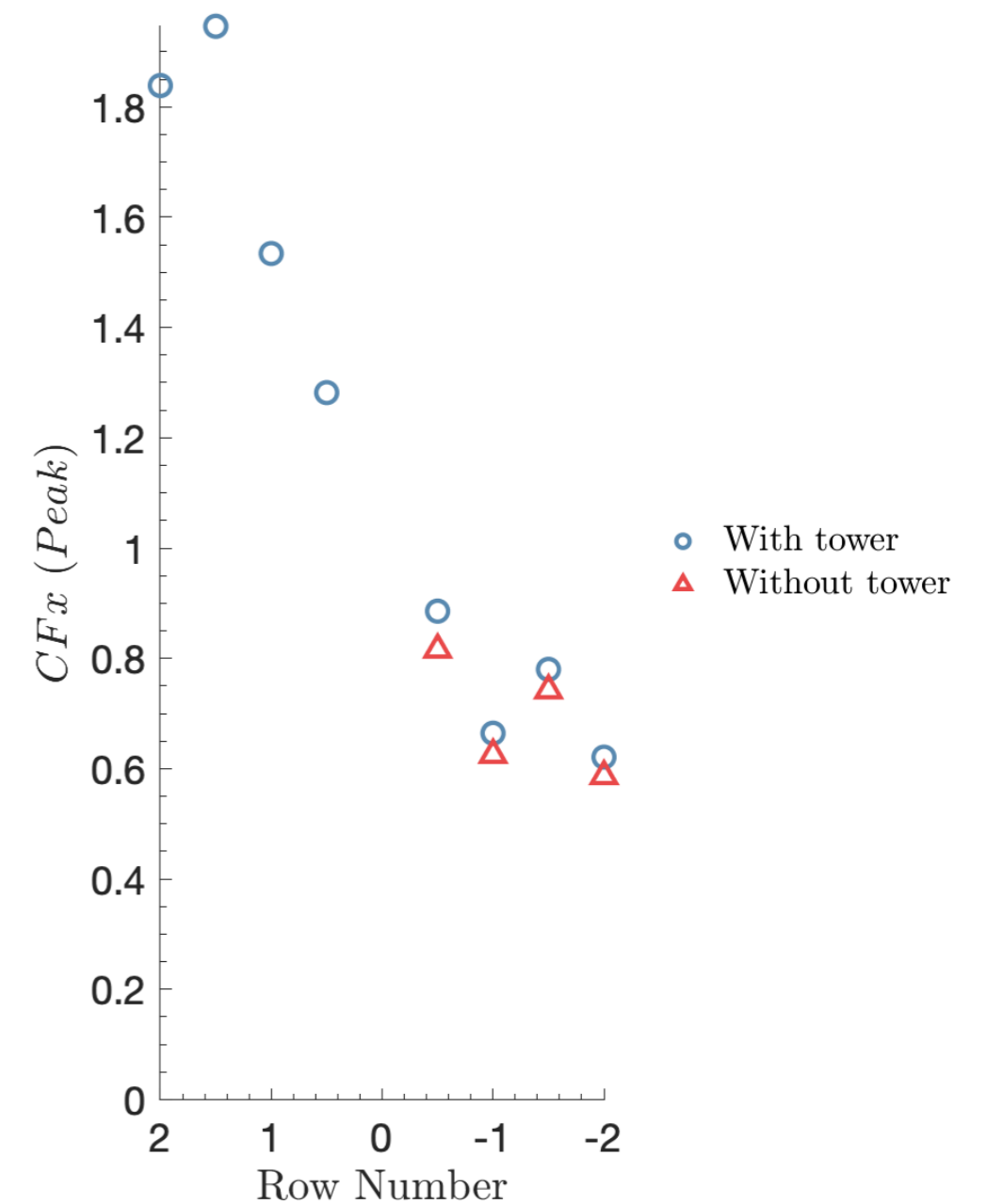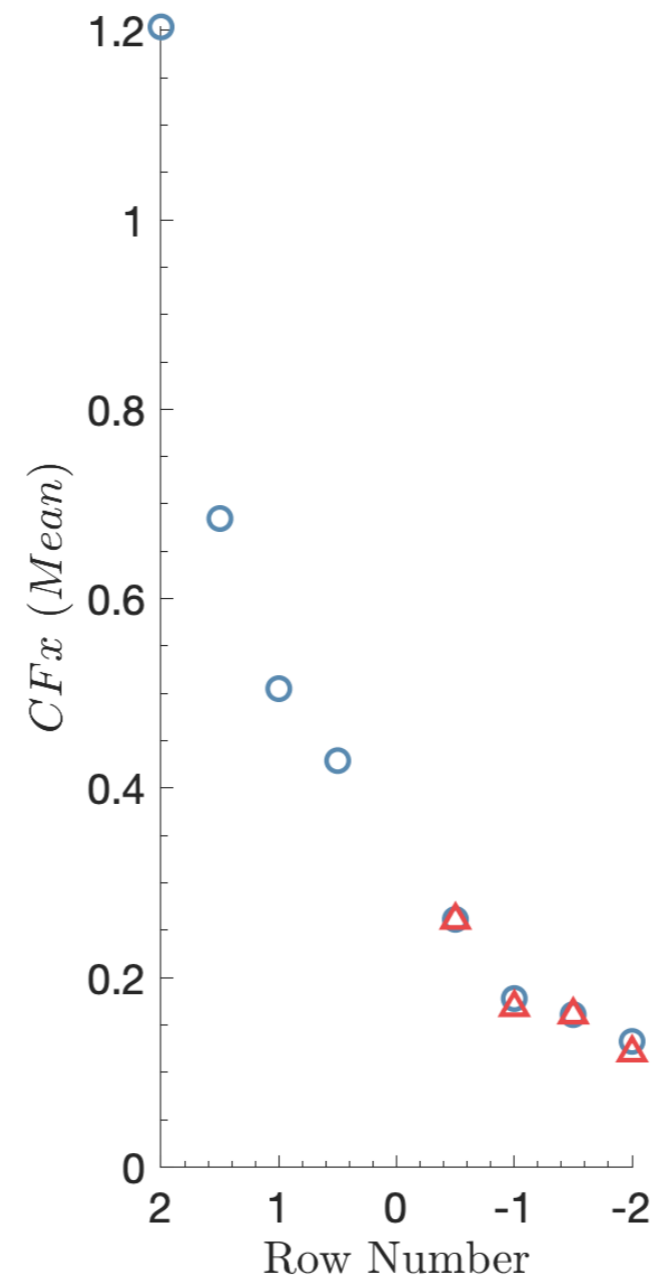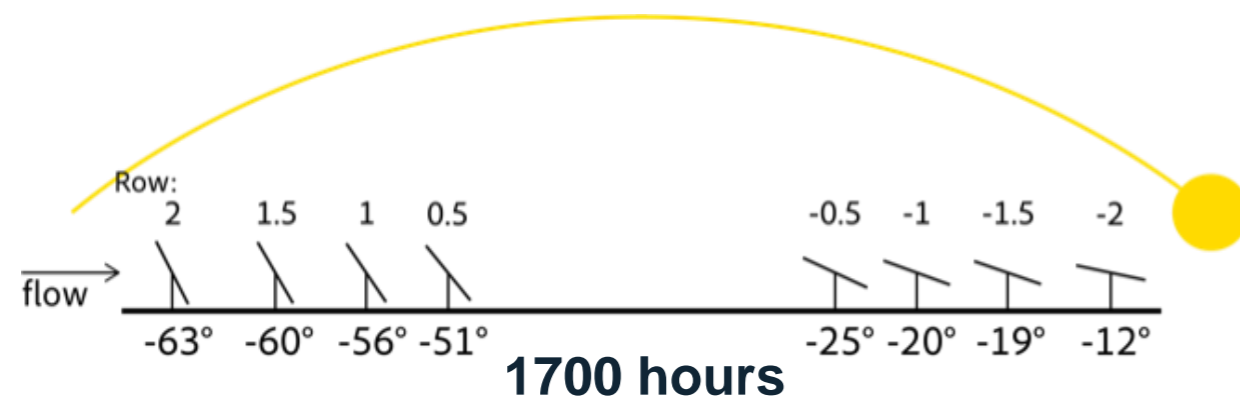-63° -60° -56° -51°   **1700 hours**   -25° -20° -19° -12°

0700 – eastern sun
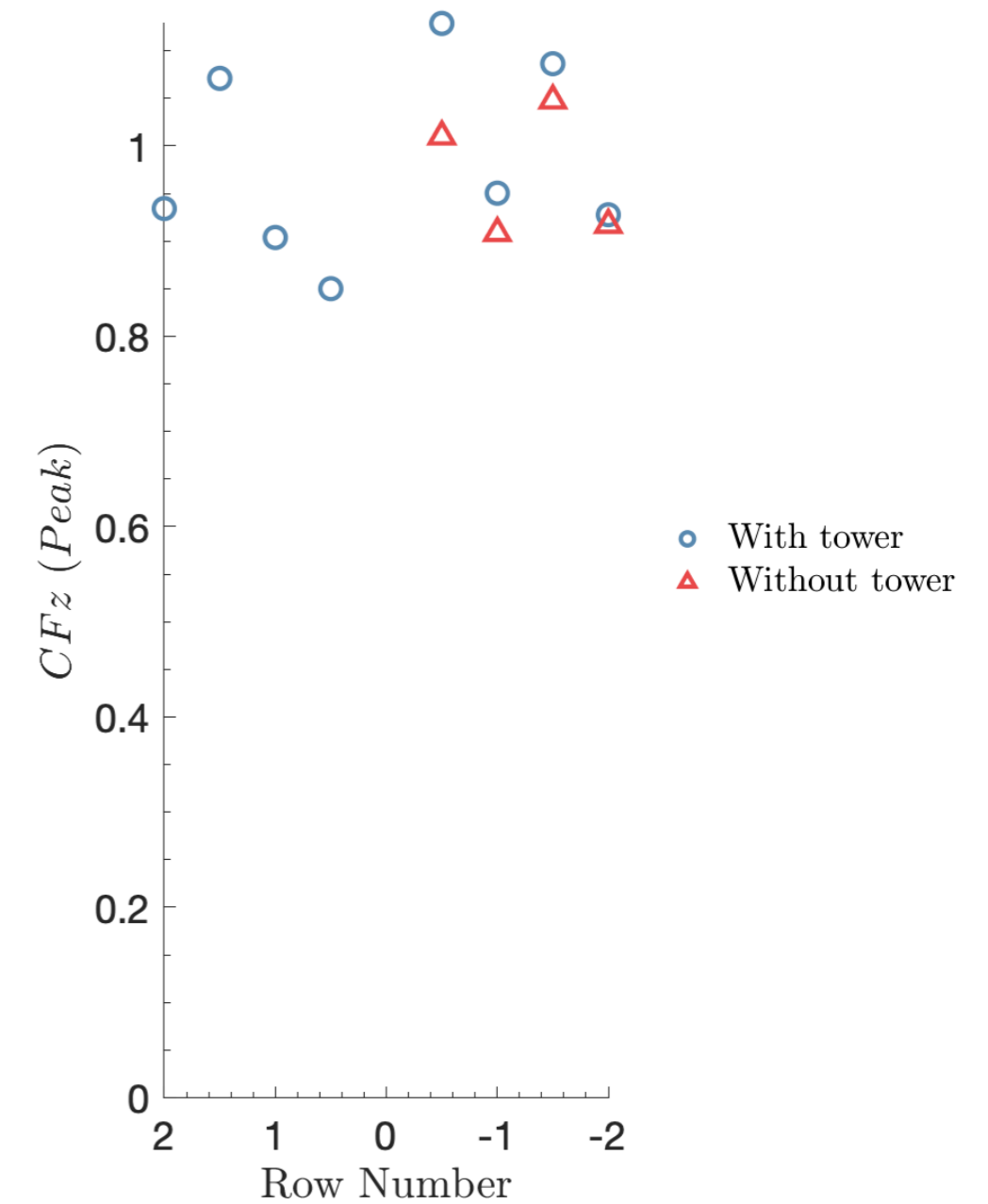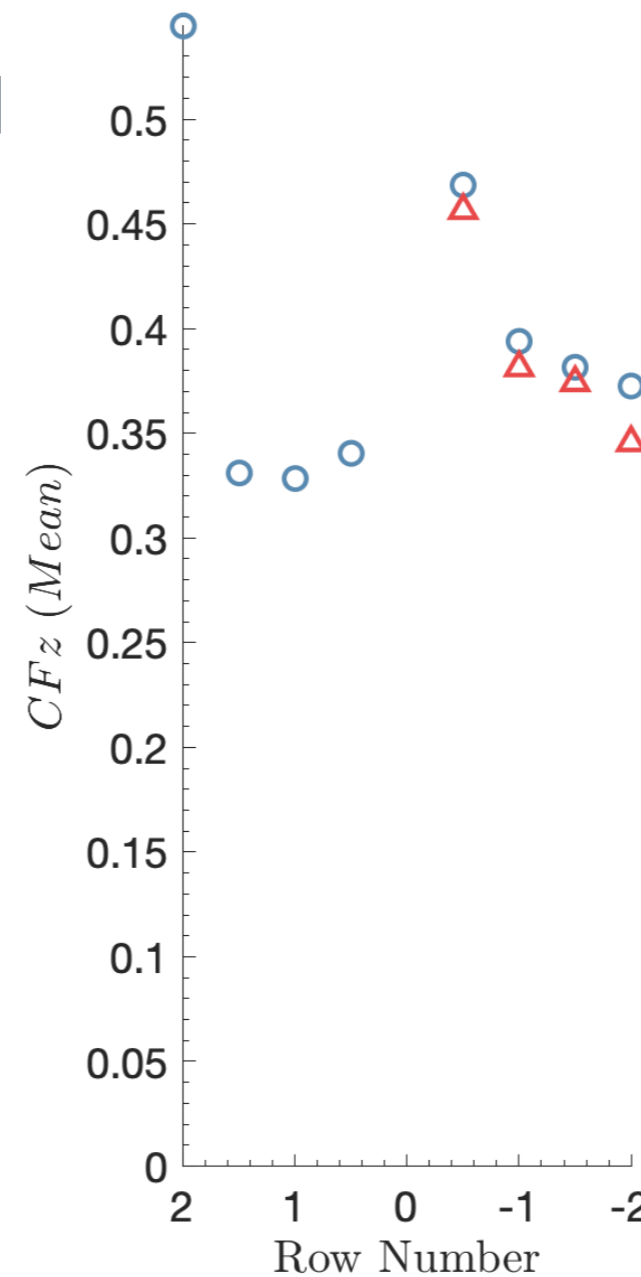
1200 hours

1700 – western sun

Theoretical field located on the equator with angle accuracy ±1°

Drag coefficient variation in field

- High upstream blockage

- Reduce mean windspeed

- Elevation angles reducing

- Greater fluctuation at row 1.5

- Reduction without tower

Lift coefficient variation in field

- Large decrease from first to second rows

- Flow partially recovers at centre

- Converging effects lead to reduction in lift

- Reduction in mean and peak without tower
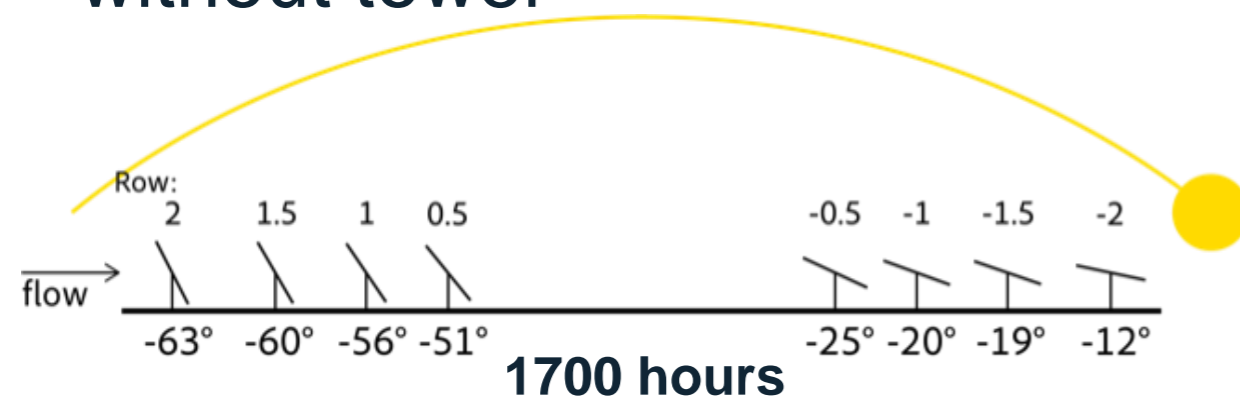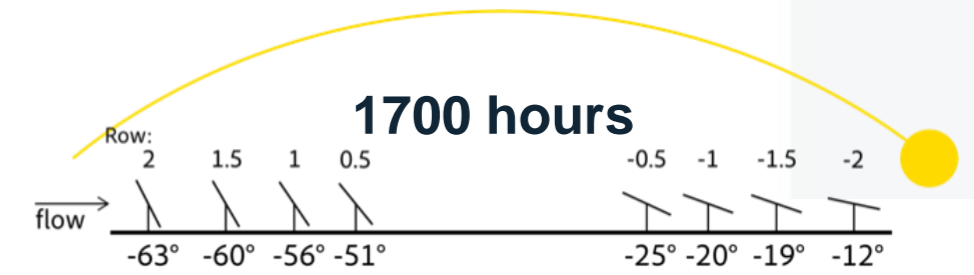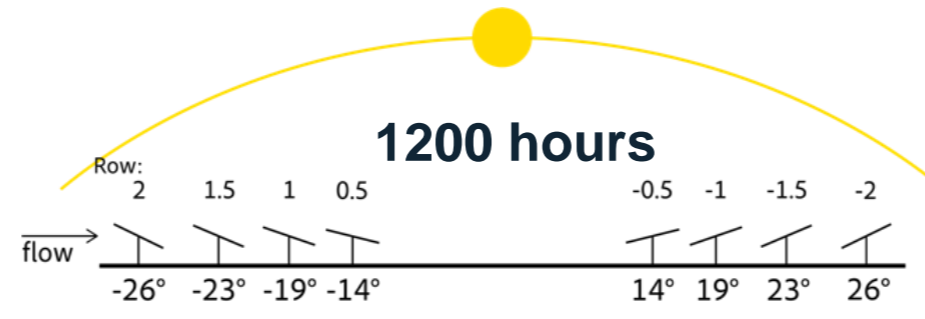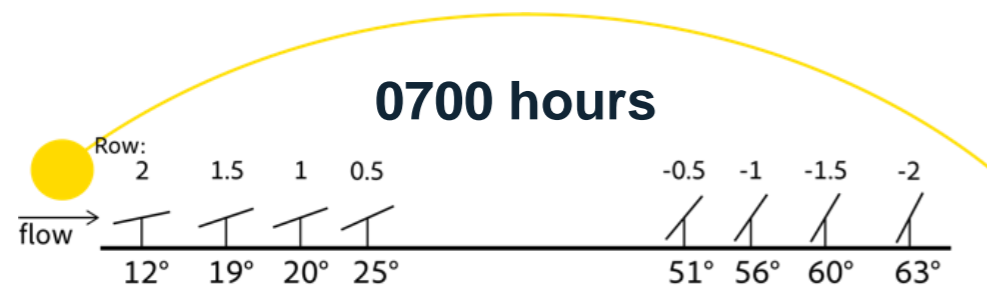
Hourly coefficients

- 1200 hour coefficients increase downstream

- Relatively low blockage throughout the field

- Change in elevation angle

- Indicates time of day influences wind loading
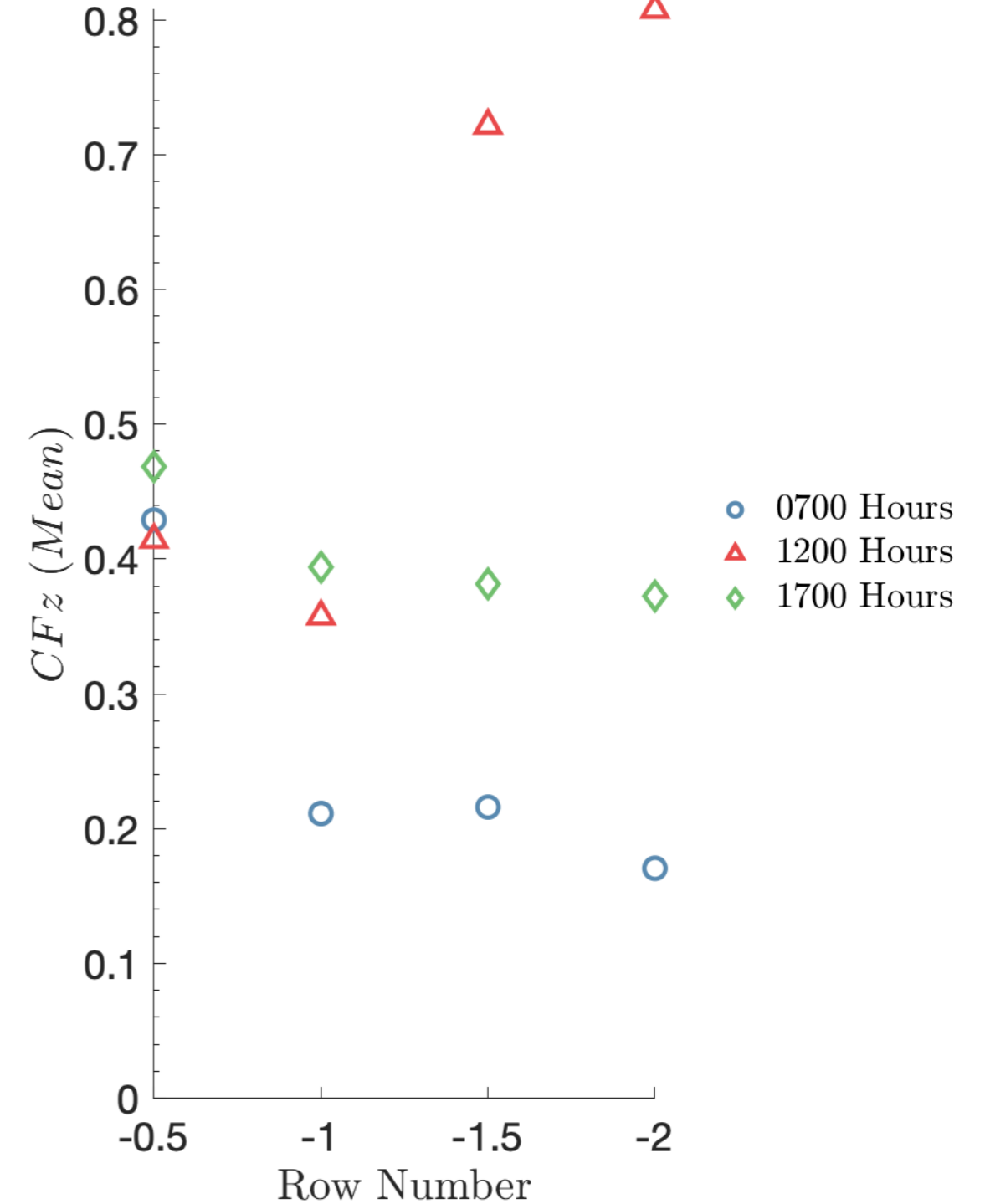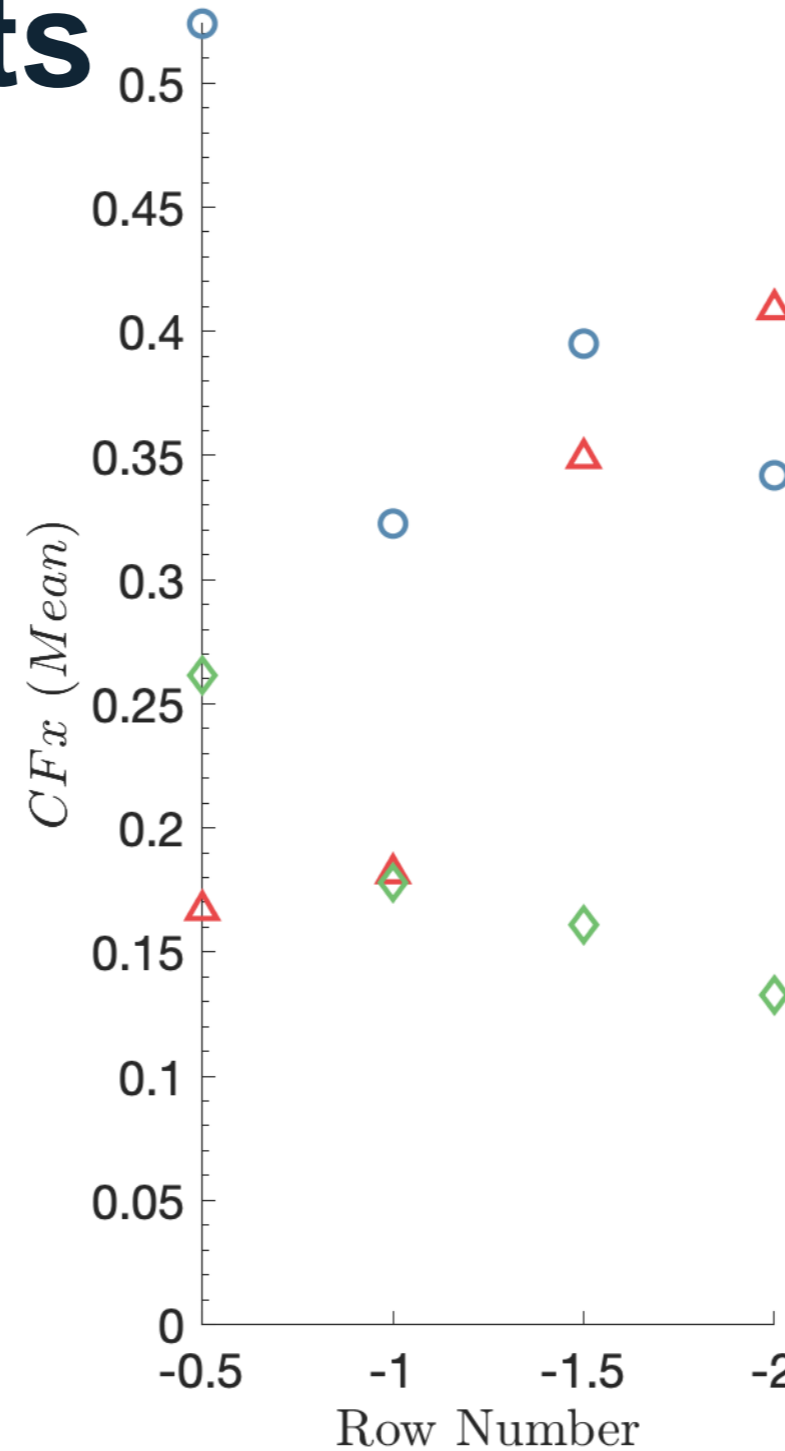
Conclusion

- Upstream first row heliostats experience highest wind loads

  - Wind loading varies throughout a field

- Central tower effects downstream wind loading

- Field configuration changes wind loading within the field

  - Time of day determines amount of upstream blockage

Acknowledgements