Appendix: RE<C Heliostat Wind Tunnel Experiments

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Datafiles
This appendix document presents a large amount of data obtained from our heliostat wind tunnel experiments. The data is divided into three sections: a single heliostat, a field of heliostats, and wind mitigations. The data files are available in the download section of the RE<C project in code.google.com, the files are identified in the comments.

Single Heliostat
The following is a set of plots relevant to the isolated heliostat tests performed in the wind tunnel.

Wind Tunnel and Coefficient Validation

- **Heliostat Model Used**: 200mm x 200mm x 5mm reflector, HCL = 130mm
- **Test conditions were as follows**:
  - Wind Speed = 12 m/s - 50 m/s (39 ft/s - 164 ft/s)
  - Air Temperature = 23 C (74° F)
  - Air Density = 1.20 kg/m^3 (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (α) tested: 90°
  - Wind incidence angles (β) tested: 0°
Single Heliostat in Uniform Flow Experiments

- **Heliostat Model Used:** 200mm x 200mm x 5mm reflector, HCL = 130mm
- **Test conditions were as follows:**
  - Wind Speed = 42.6 m/s (140 ft/s)
  - Air Temperature = 23 C (74° F)
  - Air Density = 1.20 kg/m^3 (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (alpha) tested: 90, 75, 60, 45, 35, 30, 25, 15, 0 degrees
  - Azimuth angles (beta) tested: 0 - 360 deg in 5 degree increments
Single Heliostat in Atmospheric Boundary Layer Experiments

- **Heliostat Model Used**: 200mm x 200mm x 5mm reflector, HCL = 130mm
- **Test conditions were as follows**:
  - Wind Speed = 18.2 m/s (60 ft/s) (41 MPH)
  - Air Temperature = 23 C (74º F)
  - Air Density = 1.20 kg/m³ (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (α) tested: 90, 75, 60, 45, 35, 30, 25, 15, 0 degrees
  - Wind incidence angles (β) tested: 0 - 360 deg in 5 degree increments

![CFx_cfd - Phase 1 Boundary Layer Flow](image)
Single Heliostat Comparison between Uniform Flow and Atmospheric Boundary Layer

- **Heliostat Model Used**: 200mm x 200mm x 5mm reflector, HCL = 130mm
Single Heliostat with 1.5 Aspect Ratio Reflector

- **Heliostat Model Used**: 100mm x 100mm x 3mm reflector, HCL = 75mm
- **Test conditions were as follows (square 1.0AR reflector)**
  - Q = 1.38 kPa (29 psf)
  - Wind Speed = 48 m/s (158 ft/s)
  - Air Temperature = 8.3°C (47°F)
  - Air Density = 1.20 kg/m³ (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (α) tested: 90, 45, 30, 0 degrees
  - Wind incidence angles (β) tested: 0 - 360 deg in 5 degree increments

- **Heliostat Model Used**: 150mm x 100mm x 3mm reflector, HCL = 75mm
- **Test conditions were as follows (square 1.5AR reflector)**
  - Q = 0.95 kPa (20 psf)
  - Wind Speed = 40 m/s (131 ft/s)
  - Air Temperature = 13.9°C (57°F)
  - Air Density = 1.20 kg/m³ (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (α) tested: 90, 45, 30, 0 degrees
  - Wind incidence angles (β) tested: 0 - 360 deg in 5 degree increments

![CFx_CFD, Single Isolated heliostat, Boundary Layer Flow, Square vs. 1.5AR mirror](image-url)
Heliostat Field
- **Heliostat Model Used:** 100mm x 100mm x 3mm reflector, HCL = 75mm
- **Test conditions were as follows:**
  - Q = 0.95 kPa (20psf)
  - Wind Speed = 40 m/s (132 ft/s)
  - Air Temperature = 23 C (74° F)
  - Air Density = 1.20 kg/m^3 (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (alpha) tested: 90, 45, 30, 3, 0 degrees
  - Azimuth angles (beta) tested: 0 - 360 deg in 5 degree increments
  - Instrumented field positions: 1st row, 2nd row, 4th row

### Heliostat Field Position Experiments

![Graph showing CFD results for different field positions](chart.png)
Heliostat Field Packing Density (25% vs 50%)
- **Heliostat Model Used**: 100mm x 100mm x 3mm reflector, HCL = 75mm
- **Test conditions were as follows**:
  - Q = 0.95 kPa (20psf)
  - Wind Speed = 40 m/s (132 ft/s)
  - Air Temperature = 23 C (74° F)
  - Air Density = 1.20 kg/m^3 (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (alpha) tested: 90, 30, 0 degrees
  - Azimuth angles (beta) tested: 0 - 360 deg in 5 degree increments
  - Instrumented field positions: 1st row, 4th row
Mitigations

Single Heliostat with Upstream Fence

- **Heliostat Model Used**: 200mm x 200mm x 5mm reflector, HCL = 130mm
- **Fence model used**: 114mm tall, 47% open area, installed 571mm (2.85*H) upstream of the heliostat model
- **Test conditions were as follows**:
  - Wind Speed = 18.2 m/s (60 ft/s) (41 MPH)
  - Air Temperature = 23 C (74º F)
  - Air Density = 1.20 kg/m^3 (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (α) tested: 30degrees
  - Wind incidence angles (β) tested: 0 - 360 deg in 5 degree increments
Hemispherical Backed Heliostat Experiments
- **Heliostat Model Used**: 200mm x 200mm x 5mm reflector, HCL = 130mm
- **Hemispherical backing used**: 100mm peak height
- **Test conditions were as follows**:
  - Wind Speed = 18.2 m/s (60 ft/s) (41 MPH)
  - Air Temperature = 23 °C (74°F)
  - Air Density = 1.20 kg/m^3 (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (α) tested: 30 degrees
  - Wind incidence angles (β) tested: 0 - 360 deg in 5 degree increments

![CFx_cfd - Hemispherical backing effect](image)
Fence Height Experiments

- **Heliostat Model Used:** 100mm x 100mm x 3mm reflector, HCL = 75mm
- **Fence Model Used:** 94mm, 125mm, 188mm, 250mm tall, 46% OA
- **Test conditions were as follows:**
  - $Q = 0.95$ kPa (20 psf)
  - Wind Speed = 40 m/s (132 ft/s)
  - Air Temperature = 23 C (74° F)
  - Air Density = 1.20 kg/m^3 (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (alpha) tested: 30, 0 degrees
  - Azimuth angles (beta) tested: 0 - 360 deg in 5 degree increments
  - Instrumented field positions: 1st row, 4th row
Fence Porosity Experiments

- **Heliostat Model Used**: 100mm x 100mm x 3mm reflector, HCL = 75mm
- **Fence Model Used**: 125mm tall, 40%OA, 46% OA, 58%OA
- **Test conditions were as follows**:
  - Q = 0.95 kPa (20psf)
  - Wind Speed = 40 m/s (132 ft/s)
  - Air Temperature = 23 C (74° F)
  - Air Density = 1.20 kg/m^3 (14.85 psia, as reported from tunnel conditions)
  - Elevation angles (alpha) tested: 30 degrees
  - Azimuth angles (beta) tested: 0 - 360 deg in 5 degree increments
  - Instrumented field positions: 1st row