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Field Investigation of Wind Speeds in Suburban Terrain

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Motivation for In Situ and Wall of Wind (WoW) Collaboration:

Expand on limited PV pressure loading analysis of 2018

- More recordings including strains, accelerations, rooftop pressures, and rooftop wind speeds
- Increase and match sampling rates

Use data to calibrate the experimental-numerical methodology.

Compare results with existing ASCE7 standards and suggest improvements

Focus in this presentation on in situ wind speed analysis

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Outline

DATA COLLECTION

DATA ANALYSIS

SUMMARY OF PRELIMINARY RESULTS

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Location

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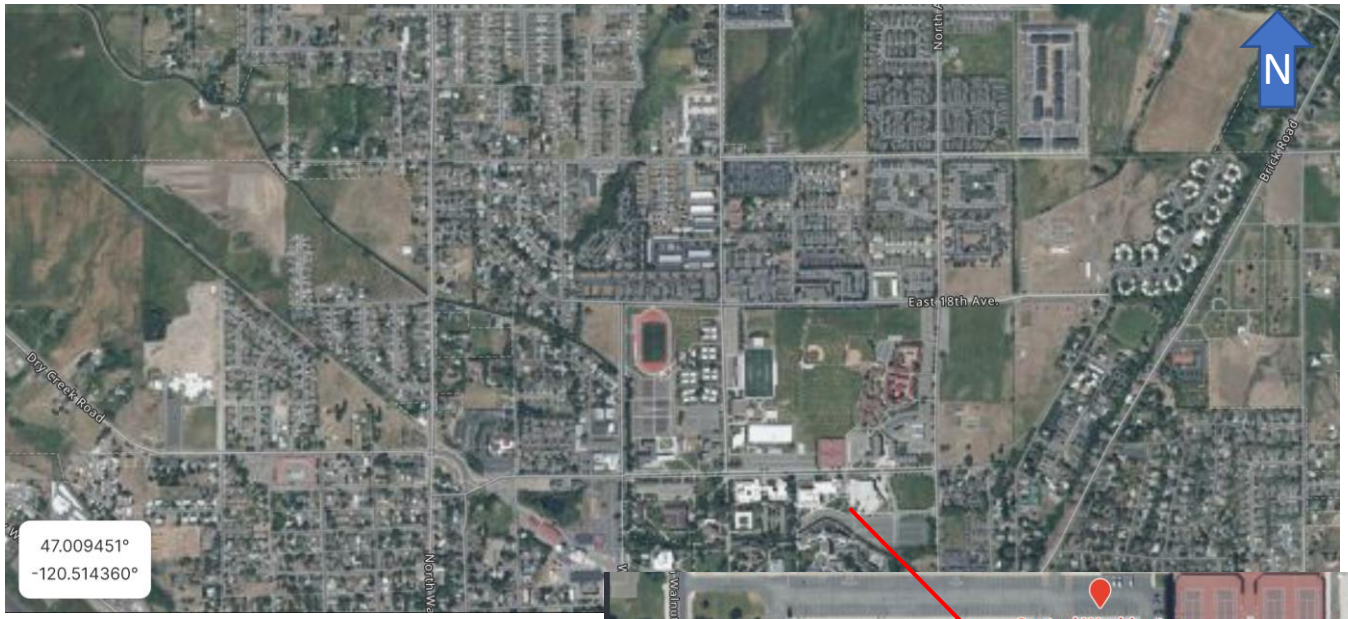

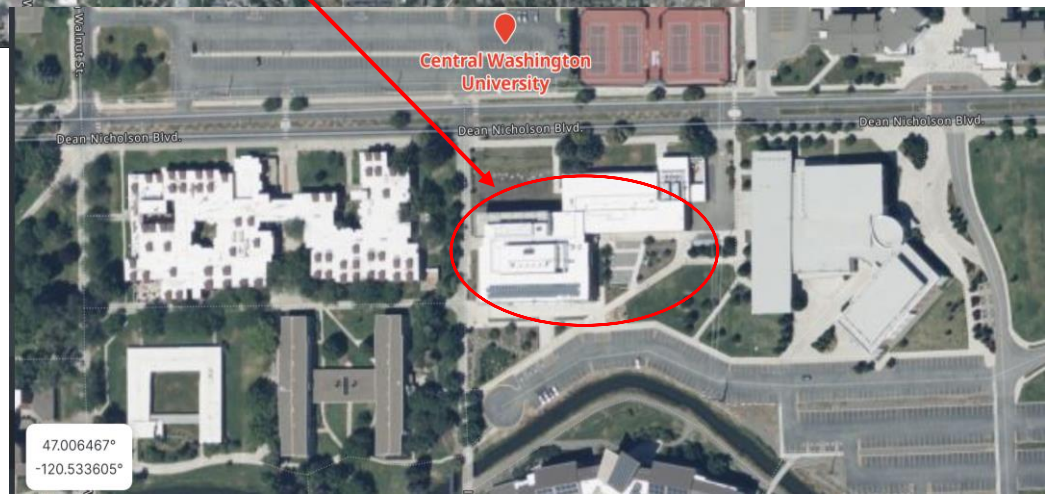

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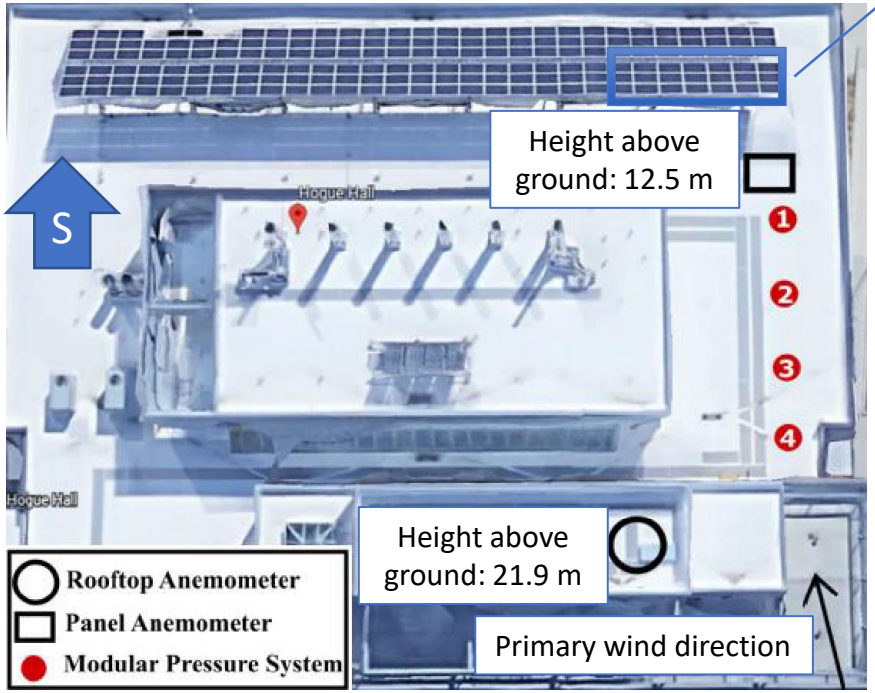
Instrumented array section



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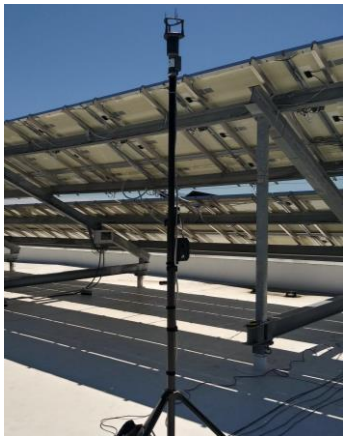
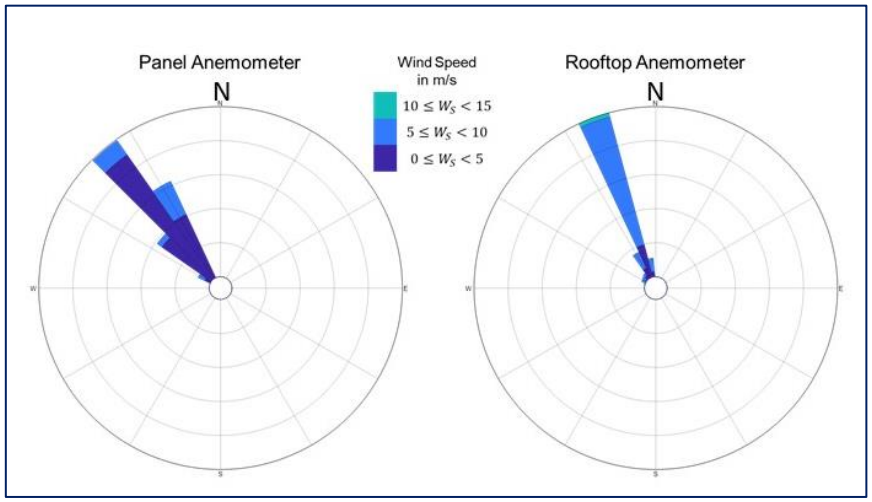
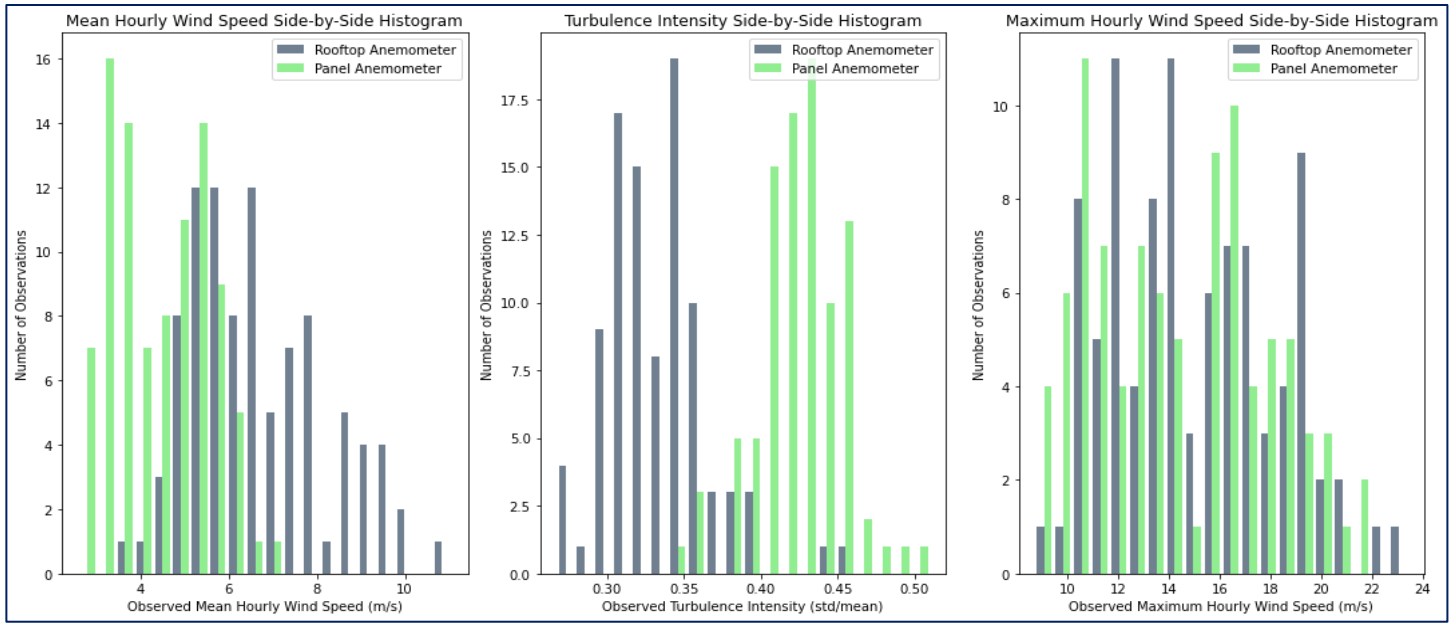




94 hours of data when wind speed > 4.46 m/s [10 mph] for 120 seconds



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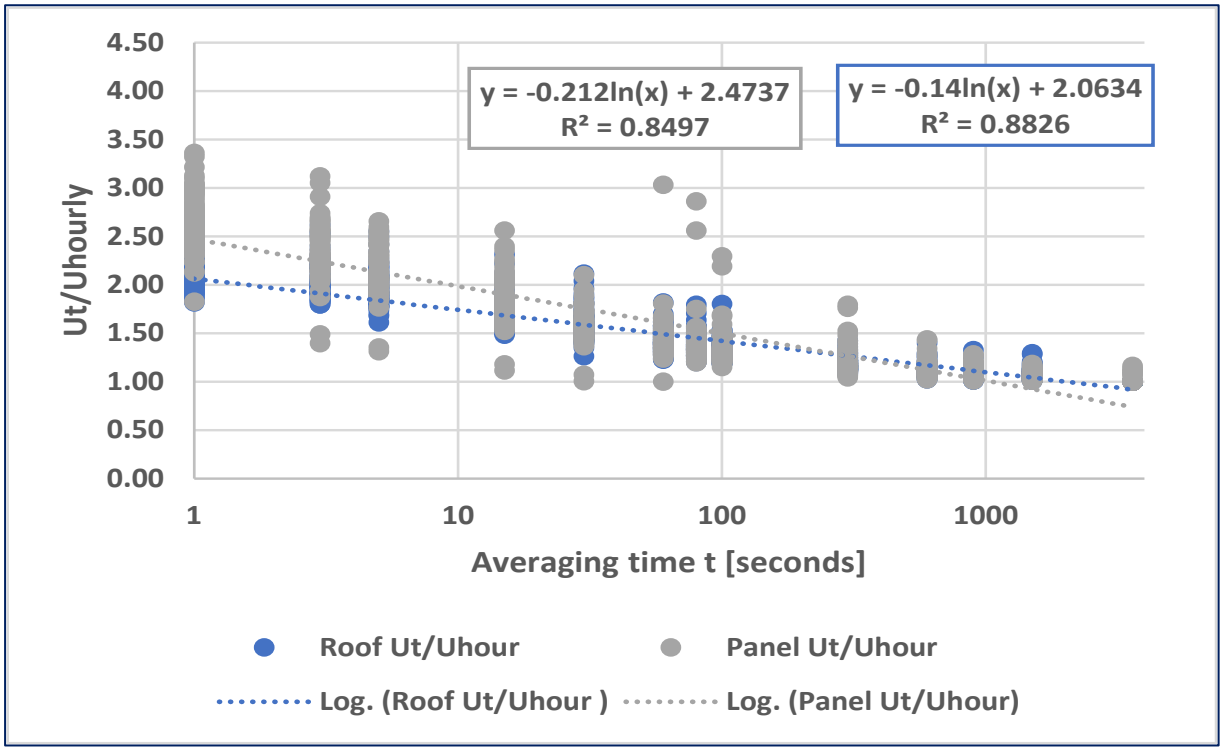
$$\text{Gust Factor } G_U = \frac{U_t}{U_{\text{hourly}}} = \frac{U_{t[\text{sec}]}}{U_{3600}}$$

Wide scatter for lower *t* values.



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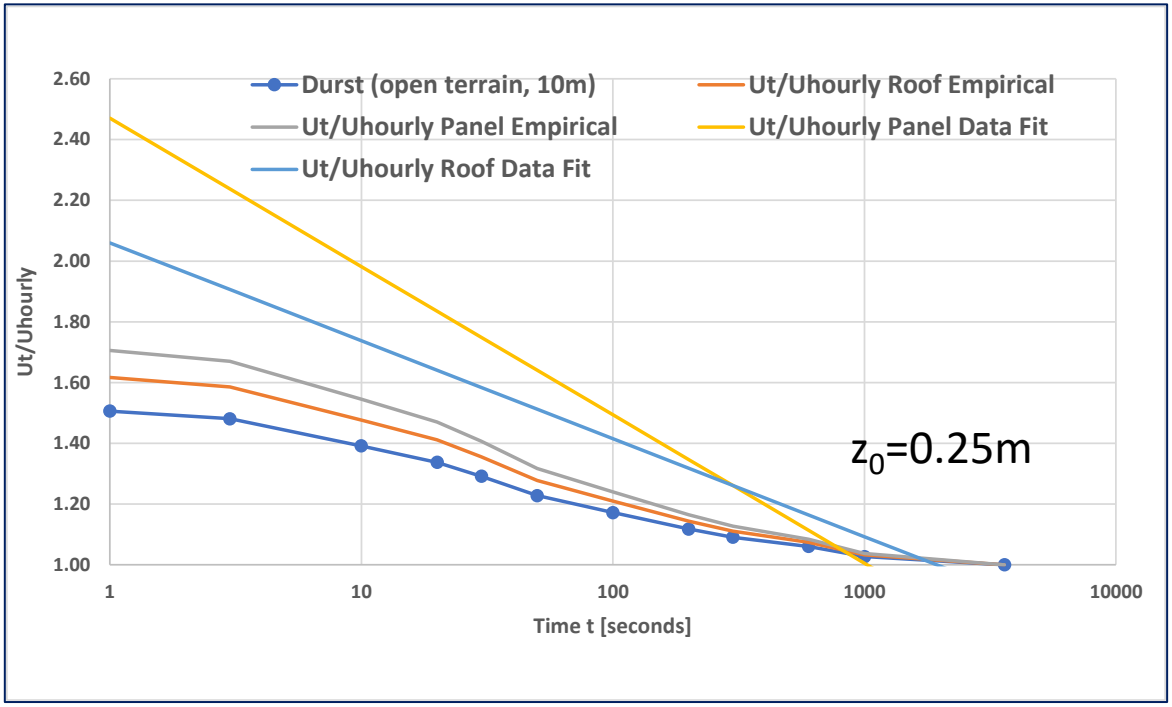
$$G_U = 1 + \frac{\eta(z_0)c(t)}{2.5\ln\left(\frac{z}{z_0}\right)}$$

$\eta(z_0)$ factor for surface roughness

$c(t)$ factor for averaging time

z_0 surface roughness



Source: Simiu & Scanlan (1996)

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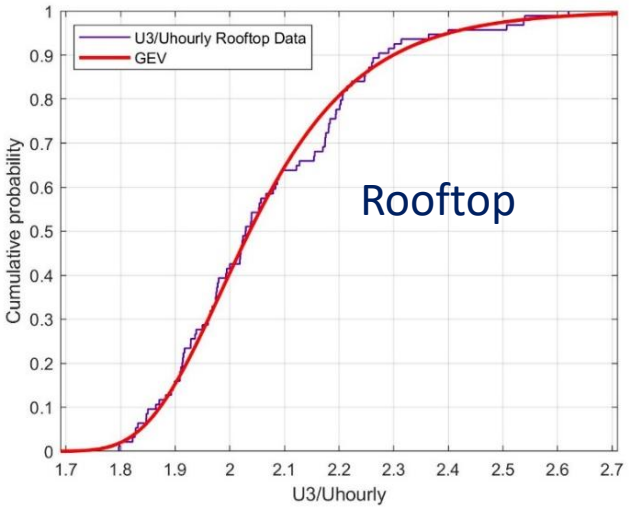
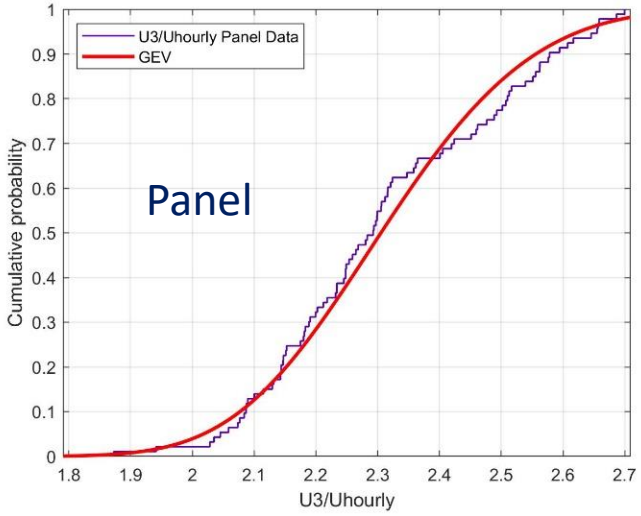
Focus on 3-sec ratios

$$y = f(x \mid k, \mu, \sigma) = \left(\frac{1}{\sigma}\right) \exp\left(-\left(1 + k\frac{(x-\mu)}{\sigma}\right)^{-\frac{1}{k}}\right)\left(1 + k\frac{(x-\mu)}{\sigma}\right)^{-1-\frac{1}{k}}$$

Matlab GEV





Statistic	Rooftop U3/Uhourly	Rooftop U3/U15-minute	Panel U3/Uhourly	Panel U3/U15-minue
Average	2.07	1.88	2.31	2.13
Maximum	2.62	2.32	2.70	2.50
Minimum	1.80	1.2	1.87	1.75
COV	0.09	0.10	0.08	0.08

More comparisons

$$ESDU\ 83045: G_U\ [\text{aka } K_T] = 1 + gI_u$$

$$\text{Davenport; Solari}: G_U = 1 + g_u I_u \sqrt{P_0}$$

$$g_u \cong \left\{ 1.175 + 2\ln\left[\tilde{t}\sqrt{\frac{P_1}{P_0}} \right] \right\}^{1/2}$$

D-S approach

$$P_0 = \int_0^\infty \frac{S_u(n)}{\sigma_u^2} X(n,\tau)\,dn \qquad X(n,\tau) = \frac{\sin^2(\pi n\tau)}{(\pi n\tau)^2}$$

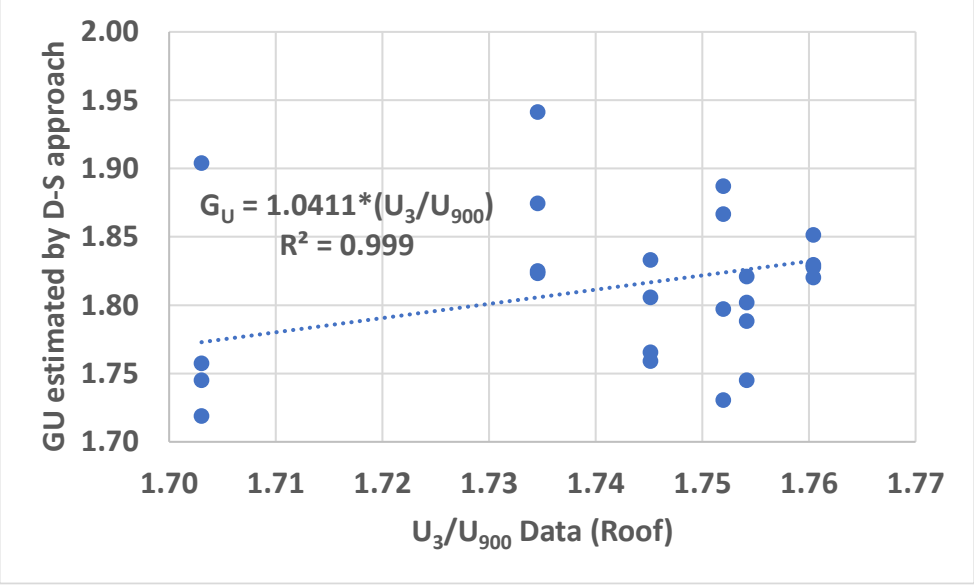
$$P_1 = \int_0^\infty \left[\frac{nL_{ux}}{\overline{U}} \right]^2 \frac{S_u(n)}{\sigma_u^2} X(n,\tau)\,dn$$

$$\tilde{t} = \frac{T\overline{U}}{L_{ux}}$$

Sources: ESDU, Greenway (1979), Liu et al. (2021)

Rooftop data comparisons

- Twenty-five 15-minute time series records were examined.
- Using the D-S approach: G_U=1.81 (mean) with mean g_u = 2.92; P_0=0.85 (mean); P_1=0.26 (mean); for mean I_u=0.30; and mean wind speed = 10 m/s.
- Data: U_3/U_{900} mean = 1.74 for the 25 records
- Calculated G for comparison with ASCE7 is 0.83.



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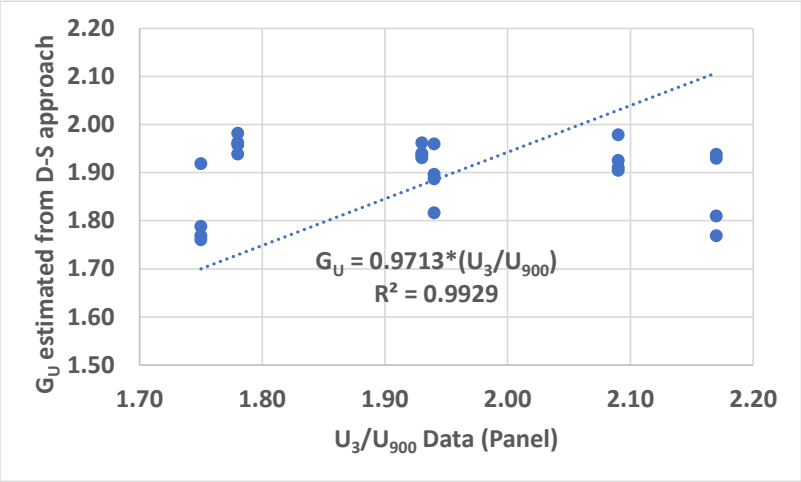
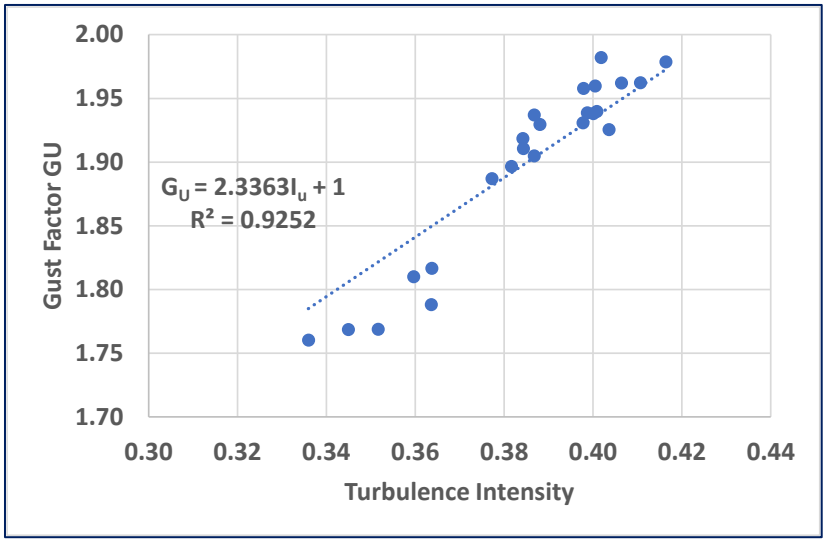
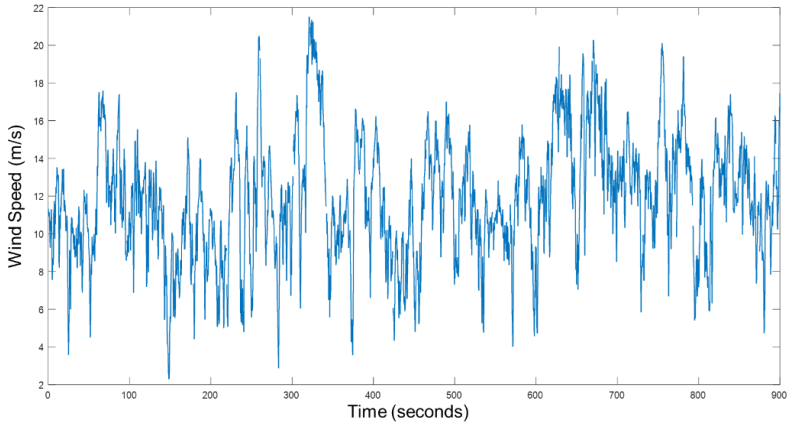
Panel data comparisons

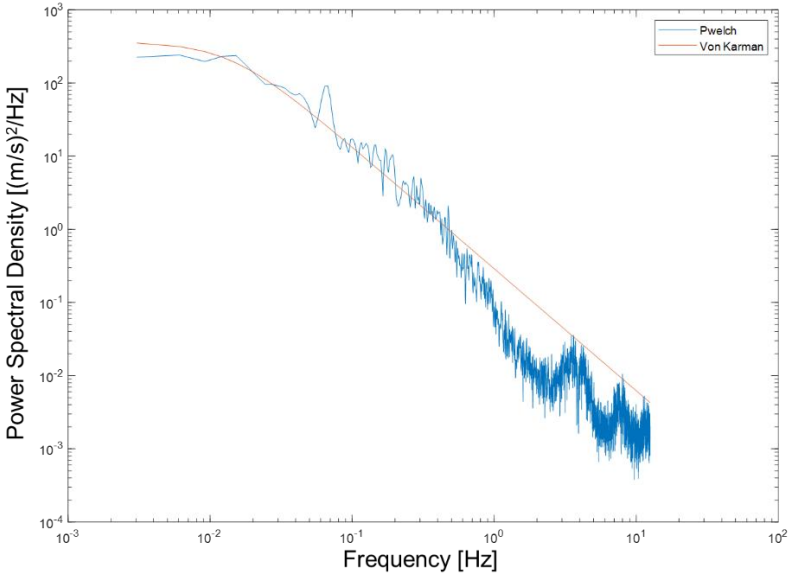
- Twenty-five 15-minute time series datasets
- Using D-S approach: G_U=1.90 (mean) with mean g_u = 3.17; P_0=0.56; P_1=0.01 (mean); for mean I_u=0.39; and mean wind speed = 6 m/s.
- Data: U_3/U_{900} mean = 1.94 for the 25 records





Time Series: Rooftop 15 minute records





Von Karman Spectrum

$$\frac{nS_u(n)}{\sigma_u^2} = \frac{4\frac{nL_{ux}}{\bar{U}}}{\left[1+70.8\left(\frac{nL_{ux}}{\bar{U}}\right)^2\right]^{5/6}}$$

n is frequency in Hz; L_{ux} is the integral length scale of turbulence; $\bar{U}$ is the mean wind speed; σ_u^2 is the variance.

25 records for analysis

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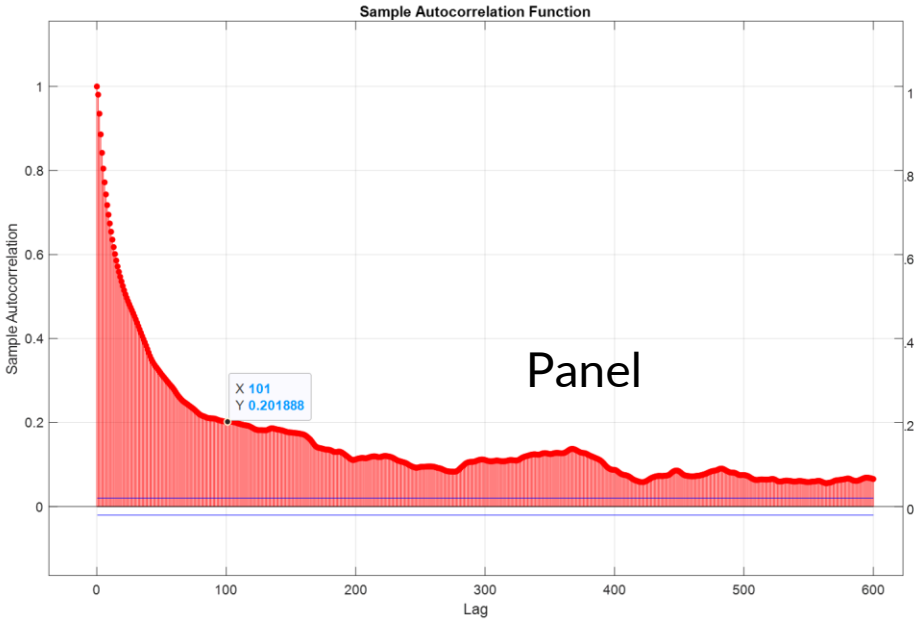
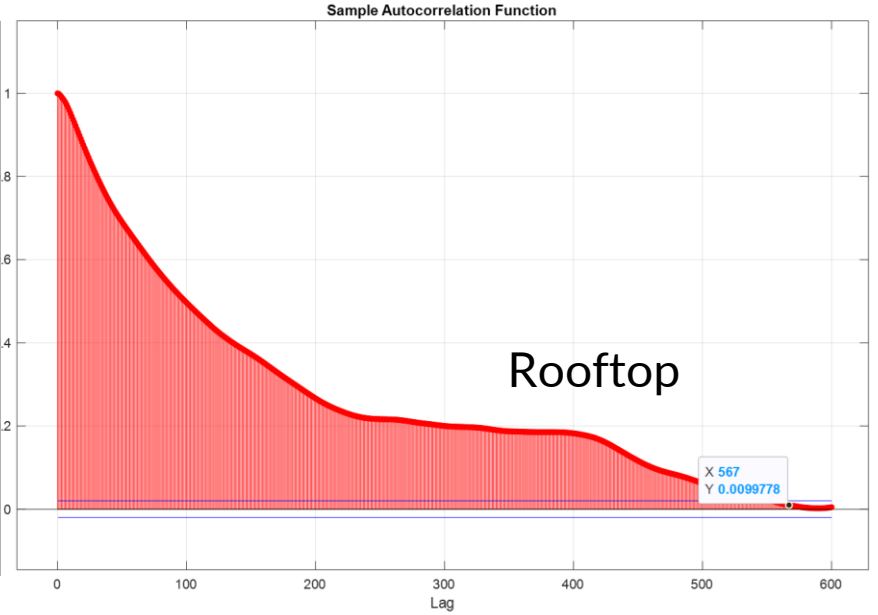
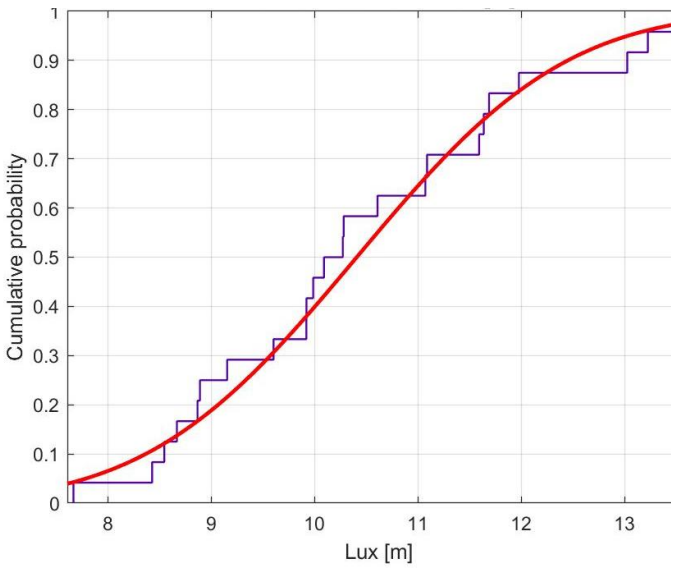
Sample Autocorrelation Function Comparison Lux



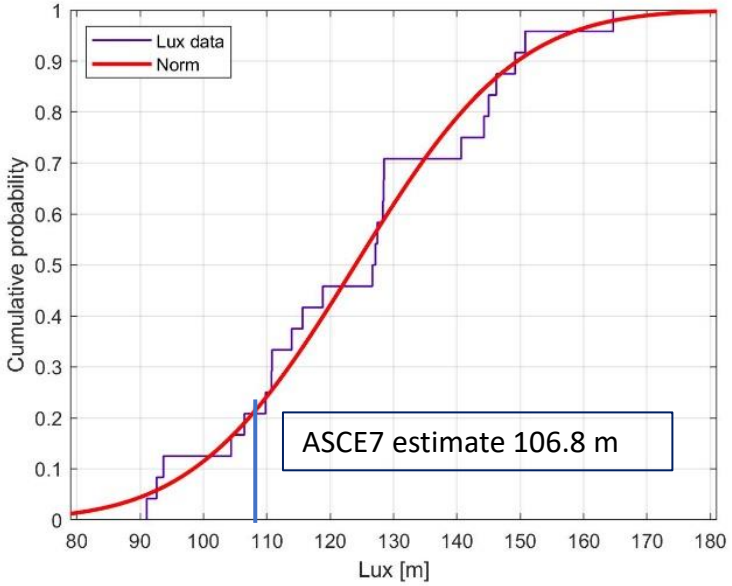


Parameter	Value Panel	Value Rooftop	Comment [Analysis by D. Chen]
LuCov	11.75	78.35	LuCov is length scale from the cutoff integration.
LuFit	13.45	77.18	LuFit is length scale from the exponential fit.
LuVon	10.4	106	LuVon from the von Karman model fitting.

Panel Integral Length Scale Lux



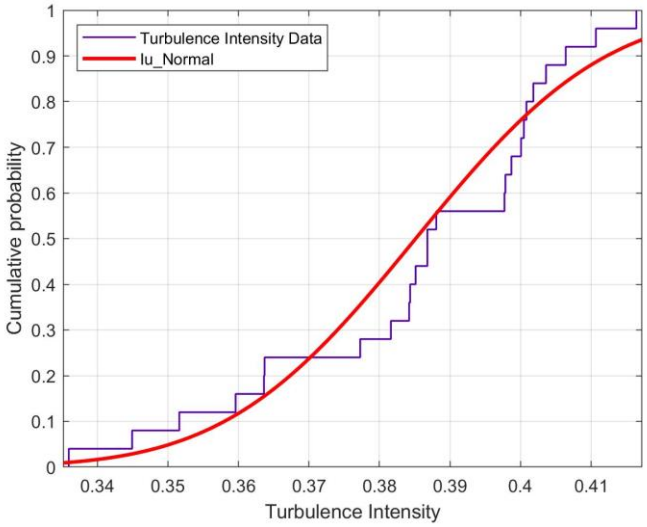
Rooftop Integral Length Scale Lux



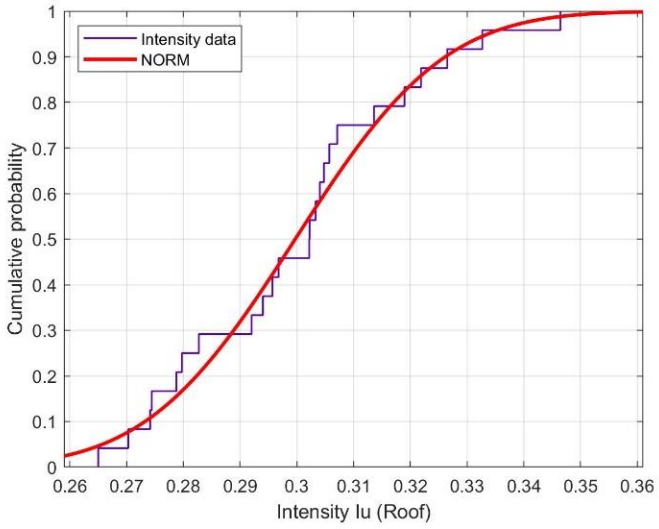
The Normal Distribution is good for both data sets.

Panel Length Scale is smaller than for the Rooftop.

Panel Turbulence Intensity



Rooftop Turbulence Intensity



The Normal Distribution is good for both data sets.

Panel Turbulence Intensity is higher than for the Rooftop.

Summary

- Gust Factors G_U were fit to wind speed data recorded for suburban terrain conditions. (N=94 observations).
- For small averaging times, the G_U values exhibit a wide scatter.
- The wind speeds recorded for the panel anemometer show larger turbulence intensities and reflect the disturbed wind flow in that section of the roof.
- Turbulence intensities and integral length scales were best fit by Normal distributions.
- In situ CWU data are useful in calibrating and validating the experimental-numerical methodology for the estimation of peak wind effects on roofs and rooftop arrays

Acknowledgments

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