

Complexity: Friend not a Foe

Towards an Integrated Framework Connecting Urban Morphology and Wind Engineering

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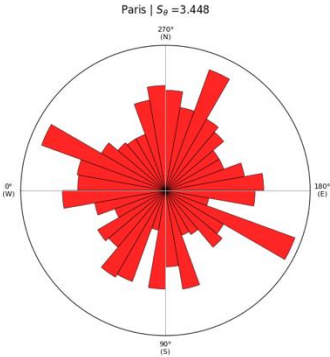
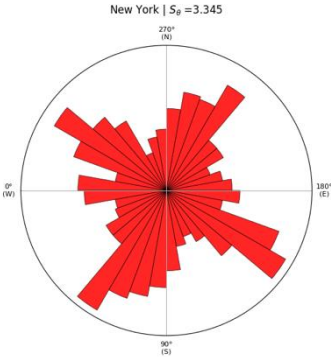
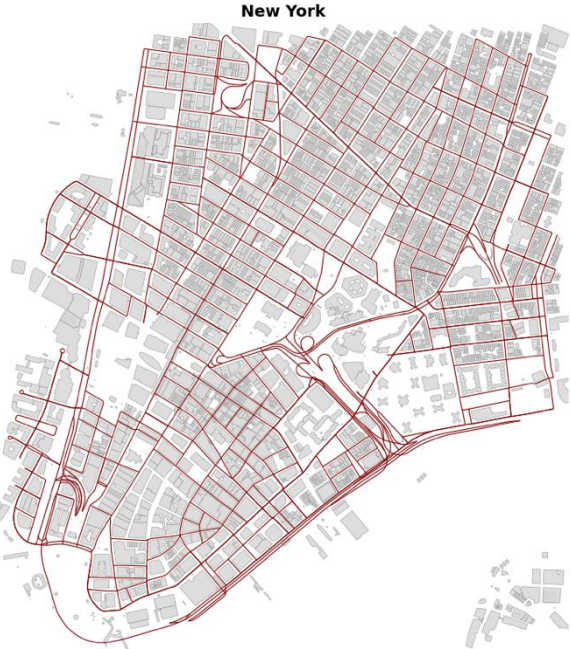
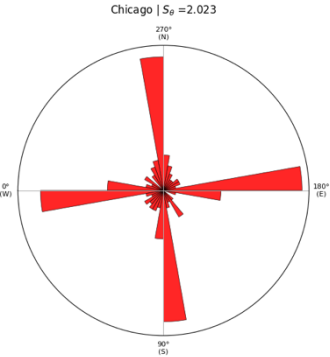
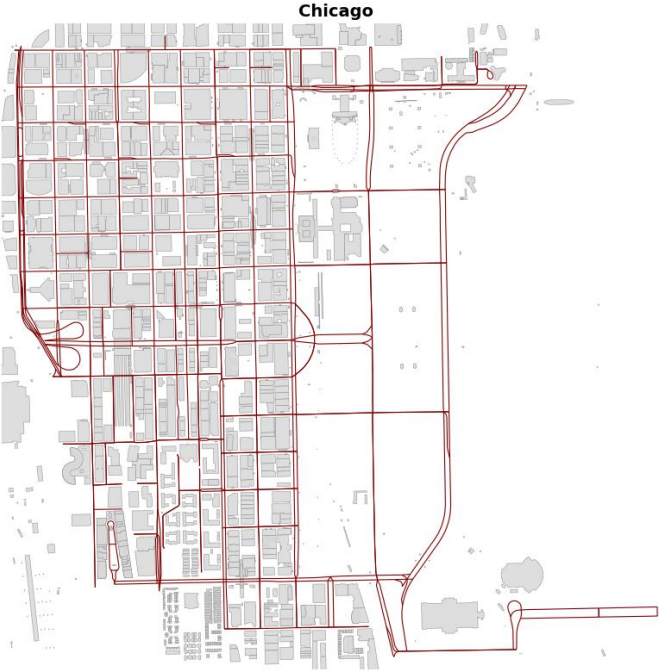


Urban Built Environment



Street Network

Increasing Entropy



Null Hypotheses



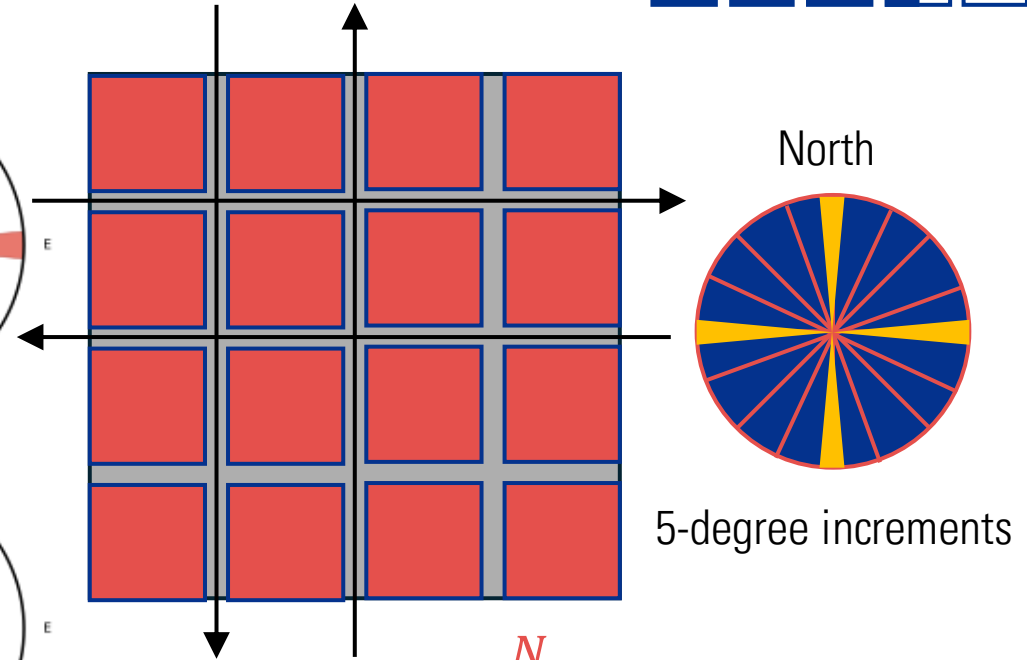
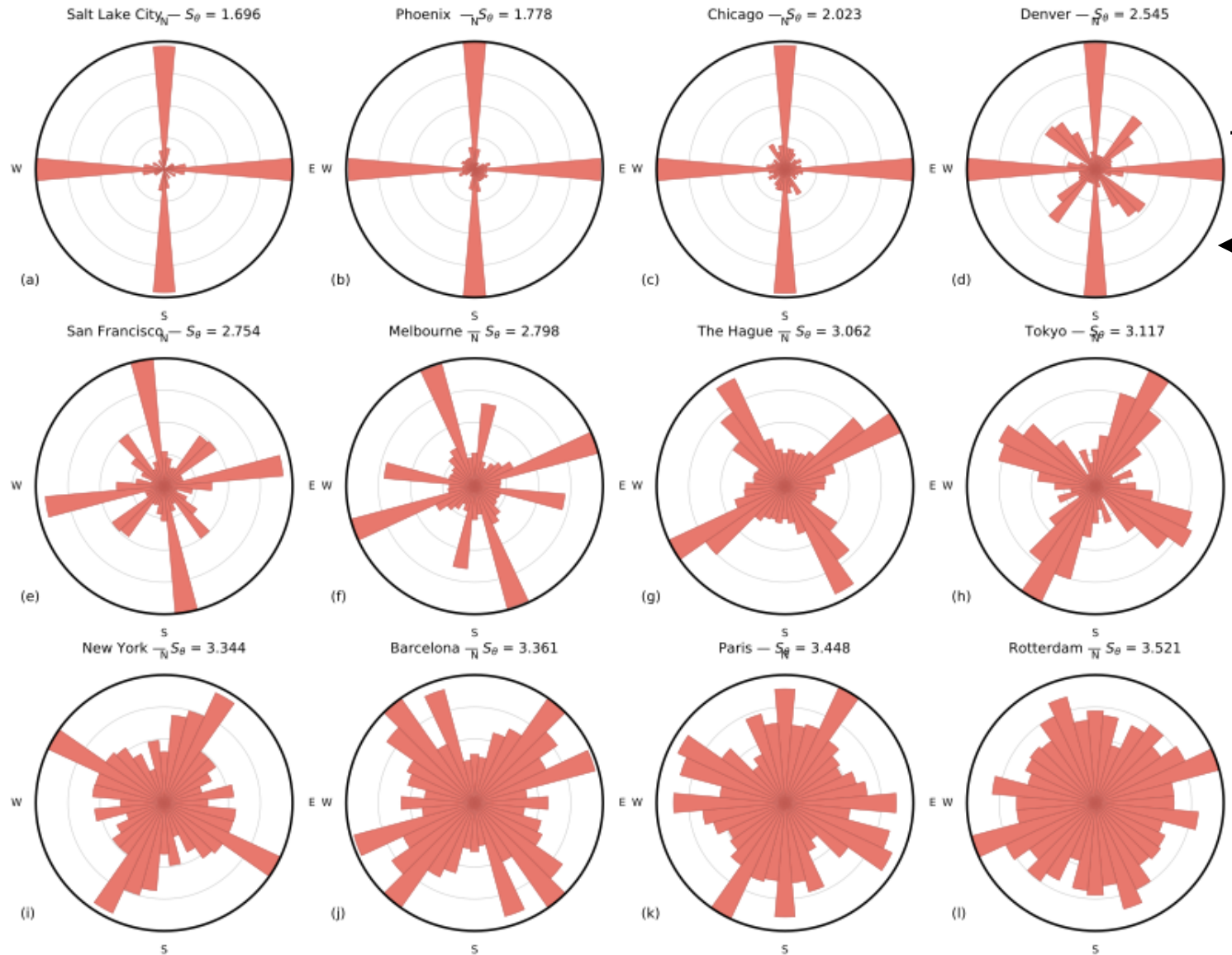
- ❑ Street-network orientation entropy has no relationship with mean wind speed and turbulence levels
 - ❑ Classical bulk morphological parameters* are sufficient predictors of urban wind speed and turbulence levels.
- *Plan area density (λ_p), Frontal area density (λ_f), Mean Building Height ($\bar{H}_b$)

In this talk, all results pertain to 10m above ground

Methodology

$$S_{\theta}^{\min} = 1.39$$

$$S_{\theta}^{\max} = 3.58$$



$$S_{\theta} = - \sum_{i=1}^N p_i \ln p_i$$

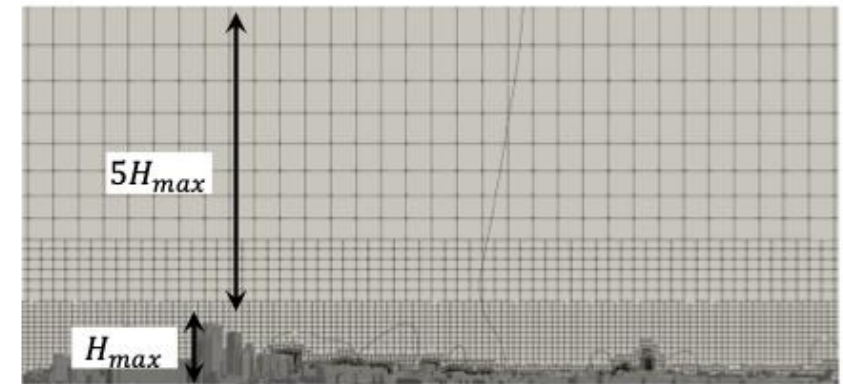
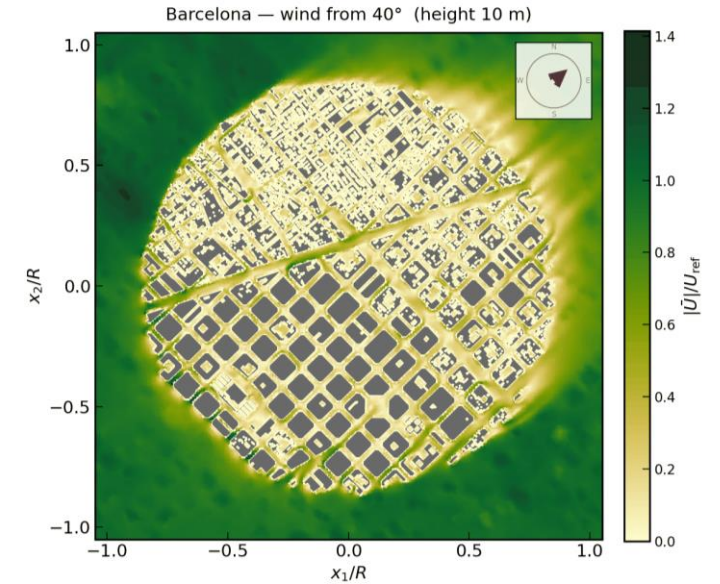
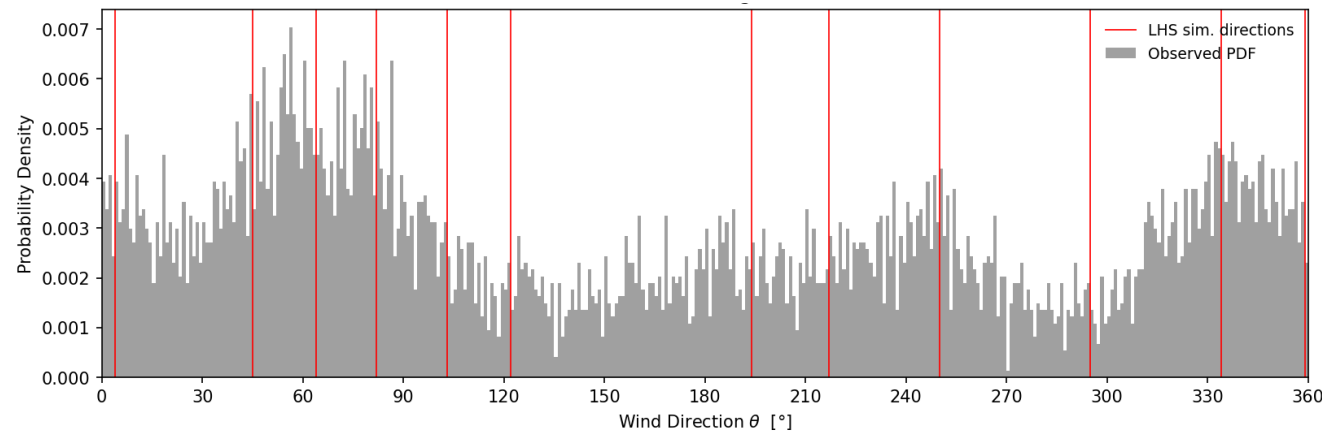
$$S_{\theta} = \underbrace{-\frac{1}{4} \ln\left(\frac{1}{4}\right)}_{\text{N-S}} - \underbrace{\frac{1}{4} \ln\left(\frac{1}{4}\right)}_{\text{E-W}} - \underbrace{\frac{1}{4} \ln\left(\frac{1}{4}\right)}_{\text{S-N}} - \underbrace{\frac{1}{4} \ln\left(\frac{1}{4}\right)}_{\text{W-E}}$$

Methodology



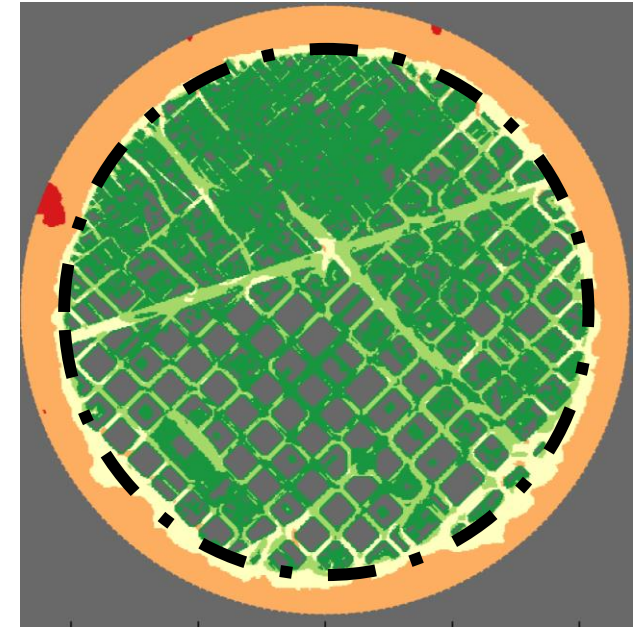
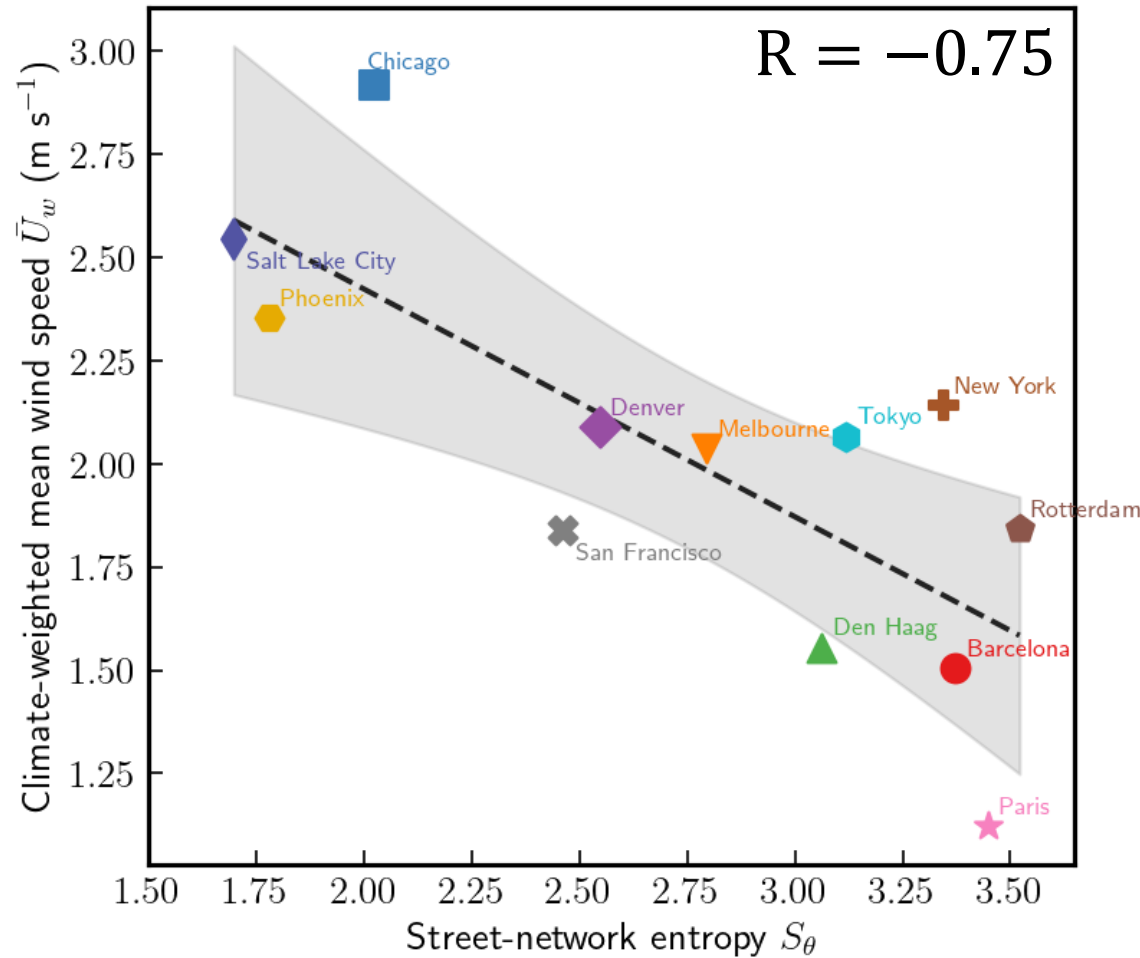
Steady-State RANS equations – Finite Volume + SIMPLE

- Two-equation closure (K-Epsilon)
- Best Practice Guidelines (Franke et al., 2011; Blocken, 2015)
- Neutral Boundary Layer simulations
- Latin Hypercube Sampling - Wind Directions

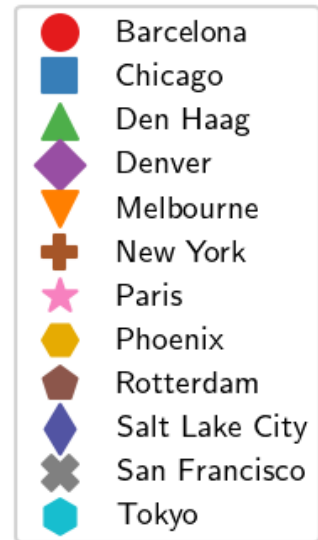
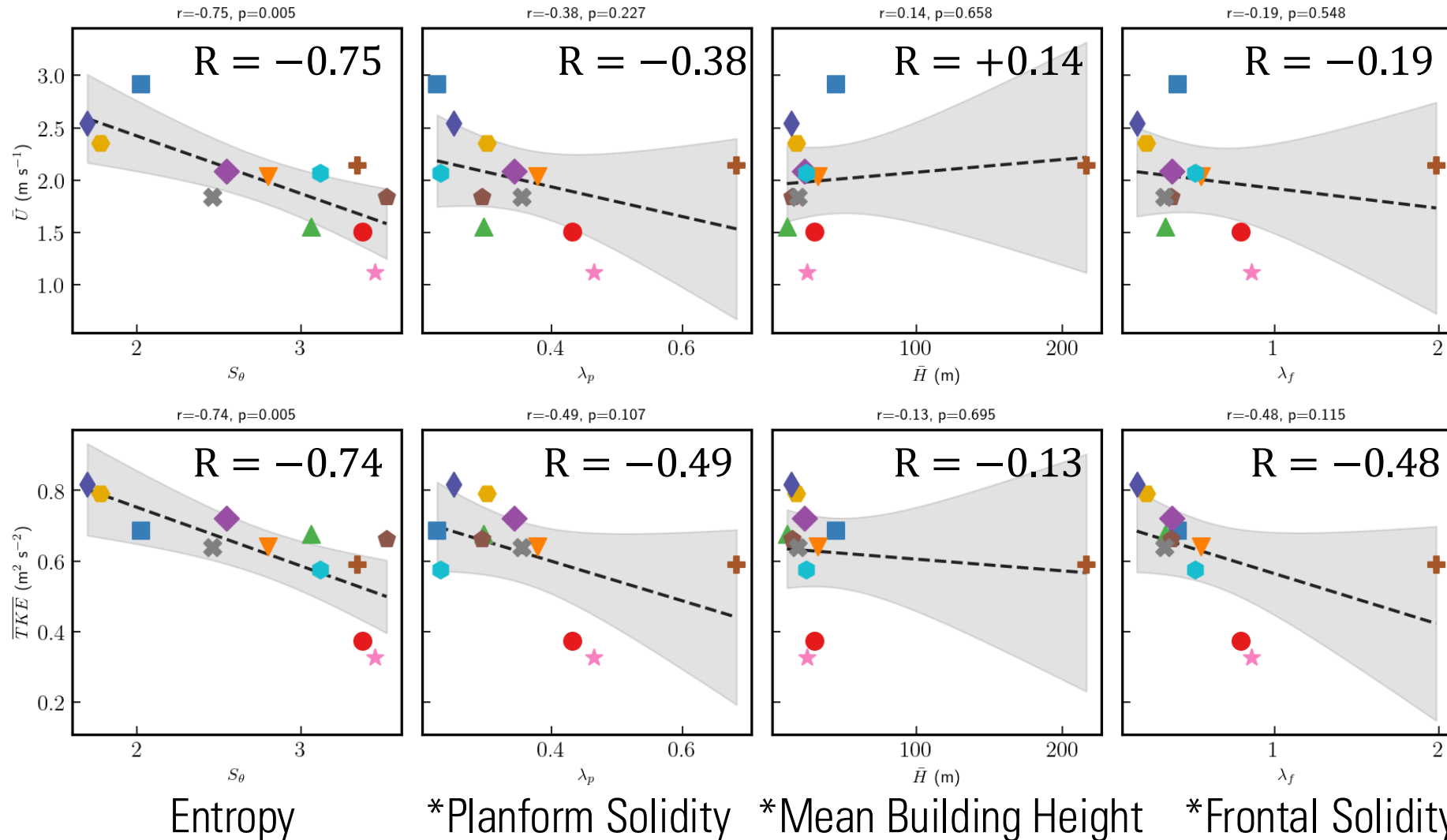


Geometry Generation – City4CFD
(Pađen et al. 2022)

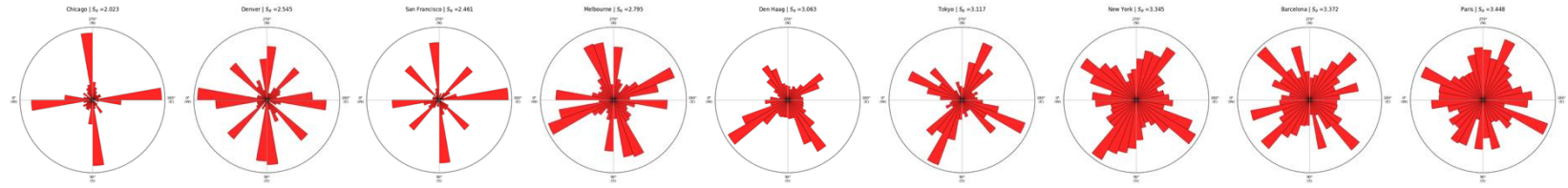
Street-network orientation entropy has no relationship with mean wind speed and turbulence levels



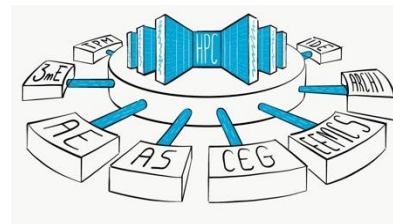
Classical bulk morphological parameters* are sufficient predictors of urban wind speed and turbulence levels.



Key Points



- Street Network Orientation Entropy explains 56% of the total variance in wind speed and turbulence levels ($R = -0.75$)
- Street Network Orientation Entropy outperforms parameters typically used in wind engineering studies by a factor $\sim 3-5$



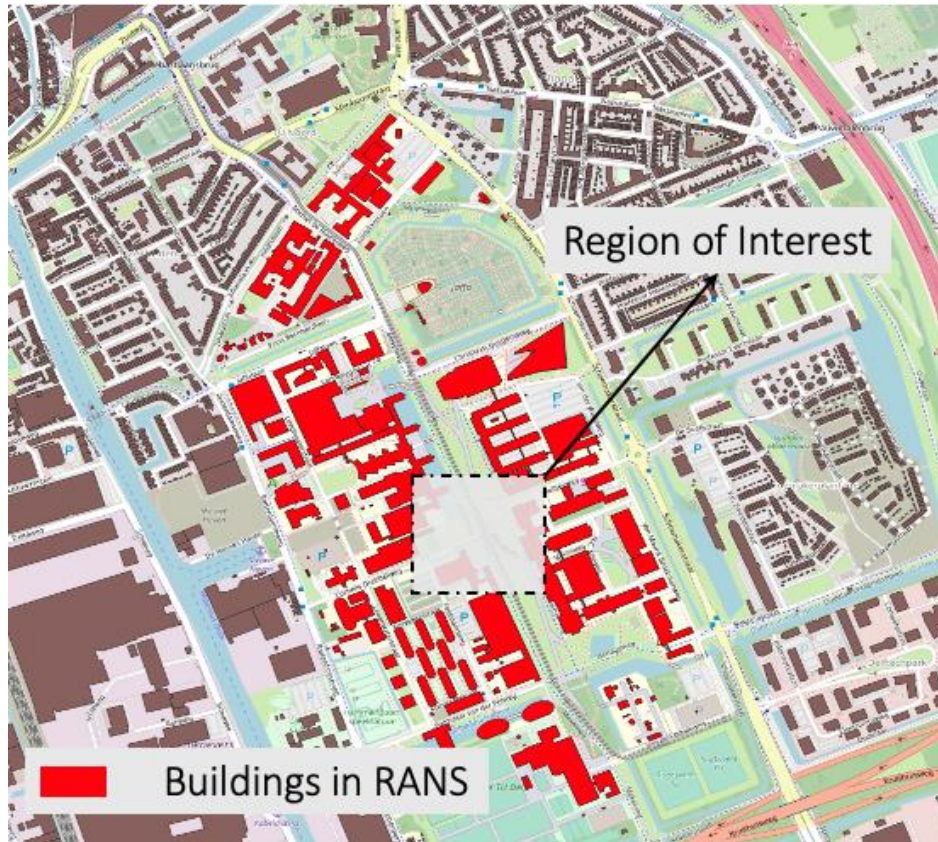
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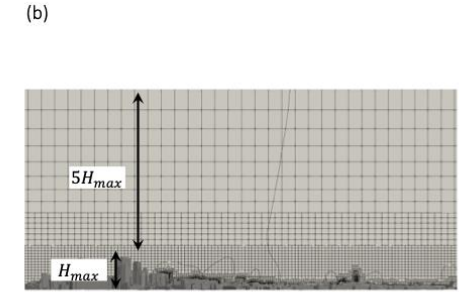
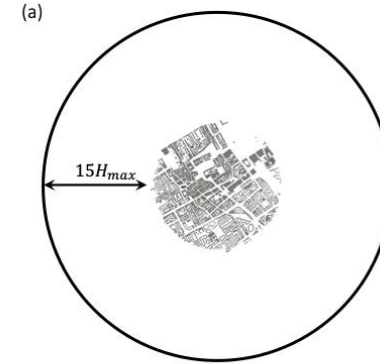
EXTRA SLIDES



RANS – Error Quantification/Validation



Low-Fidelity (RANS)



High-Fidelity (LES)

