

Equivalent Turbulence Profiles from Randomized Terrain in a Boundary Layer Wind Tunnel

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This project investigates whether matching of first and second order turbulence profiles in boundary layer wind tunnel flow is sufficient for producing consistent peak wind pressures. The hypothesis is that multiple roughness configurations can produce equivalent second-order wind fields, but differing higher-order properties that may produce non-equivalent peak loads on test subjects.

This study harnesses the availability of two tools: the boundary layer wind tunnel offers an automated, high degree of freedom, rapidly reconfigurable roughness element grid ('Terraformer'), and an active machine learning algorithm (ML) was developed.

A homogeneous Terraformer configuration was established as a baseline, with each of 1116 roughness elements set at 8 cm height. An automated gantry system was used to move 3 cobra probes to predetermined locations within a measurement plane to quantify the wind field and establish a benchmark second order profile. 25 repeats were conducted to statistically quantify acceptable error bounds among identical experiments.

The Terraformer element grid height scheme was then defined as a single harmonic in the along wind direction, described using wavenumber and amplitude parameters to be identified by the machine learning algorithm. This parameter space was divided into a grid and experiments were conducted for 25 different Terraformer configurations. The second order profile from each was compared to the benchmark profile, and evaluated for equivalence. Outcomes were used to train the ML and inform the initial conditions to further explore the parameter space.

The ML then used the automated instrumentation and Terraformer to find the regions of the Terraformer parameter space that produce profiles statistically equivalent to the benchmark profile. Every subsequent Terraformer configuration was determined utilizing the accumulated outcomes of every previous experiment. After a sufficient number of configurations were conducted, the equivalent second-order parameter space emerged. We have begun to explore this space for higher order characteristics that may differ within the second order equivalent

region, potentially leading to fundamental discoveries regarding the limitations of boundary layer wind tunnel simulations.

To date, studies have been carried out for several Terraformer parameterization schemes. The integrated experimental procedure has been successfully conducted for 1198 unique roughness configurations. Without ML, an estimated $\sim 10\times$ more experiments would be necessary to evaluate the hypothesis. The latest results and implications will be presented during the EMI 2022 minisymposia. The data collected from the experiments is being curated for publication in the NHERI DesignSafe Data Repository within the next 12 months.