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TOWARDS A ROBUST WIND TUNNEL BASED EVALUATION OF EXTREME WIND LOADS

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ABSTRACT

Proper modeling of the boundary layer flow is essential for wind load evaluation under extreme events such as hurricanes. This layer is formed due to the interaction of wind with natural or man-made obstacles over the surface of the earth. Such interactions generate drag forces proportional to the roughness of the ground which shape the characteristics of the boundary layer, including mean velocity and turbulence intensity profiles, as well as the spectral contents and correlations. In the current study, a robust technique for evaluating extreme wind loads using wind tunnels is proposed and validated. The technique is based on automatic identification of effective ground roughness at a site of interest using aerial Google images and reproducing it through automated roughness blocks mounted on the wind tunnel floor, dynamic turntable to recreate the wind direction effects, and high resolution pressure and load measurements. In addition to enhancing the efficiency, these automations limit the subjectivity involved in this type studies.

The main steps are summarized as follows (also shown in the accompanying flowchart): (1) Site location is identified using longitude and latitude. Then, Google images at the site location are downloaded and combined to form two maps; a large scale map covering distances ± 10 km (to characterize close details to the site) and a small scale map covering distances of ±100 km (to characterize far details from the site). Information such as angle of the illumination and time of image capture are also considered. (2) The two maps are segmented into zones based on the gradient of the gray-scale image. Then each zone is classified into a water, vegetation, building or non-building zone and roughness of each zone is estimated. (3) Each map is divided into roughness sectors, to represent various wind directions approaching the site, and each sector is divided into roughness patches. Effective roughness within each patch is estimated based on the roughness of all subzones identified in *Step 2*. (4) Applying the Engineering Standard Data Unit (ESDU) methodology (based on the Harris-Deaves atmospheric boundary layer model), the target boundary layer characteristics at the site are identified for wind approaching from each direction. An automatic selection routine is developed and used to find the best match between the expected full-scale and simulated boundary layer profiles. This technique reduces the subjectivity involved with characterizing ground roughness. Consideration of the quality and completeness of the location-specific satellite imagery remains an important component of this process. Also, detailed models of surrounding buildings are included to simulate the local effects due to adjacent structures. (5) Wind load is measured either using aerodynamic (e.g., pressure taps, force balance) or aero-elastic models for wind approaching from a full range of directions. (7) The measured loads are combined with the local climate data to evaluate the predicted load or response corresponding to the nominal return period of the extreme event.

1-Define the site longitude and latitude, time when images where taken, and shadow angle. Download images near the site within ±10 km (large scale map) and ±100 km (small scale map).

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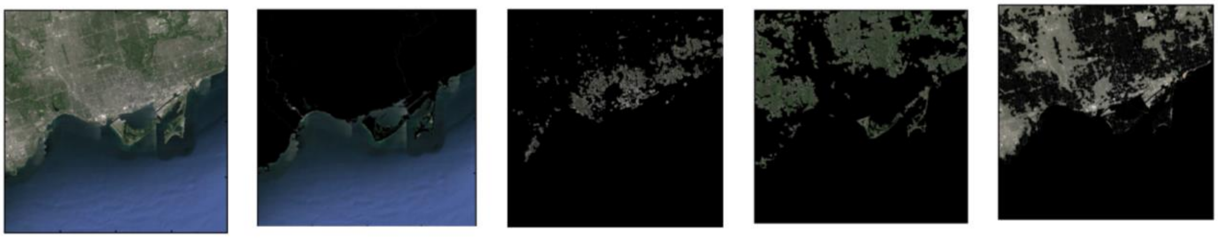
2-Segment the maps into zones based on the gradient of the gray scaled image, then categorize each patch to (water, vegetation, building (using shadow information) and non-building zones and estimate the roughness of each zone.



Google large scale map | Water zones | Significant building zone | Vegetation zone | Urban/suburban zone

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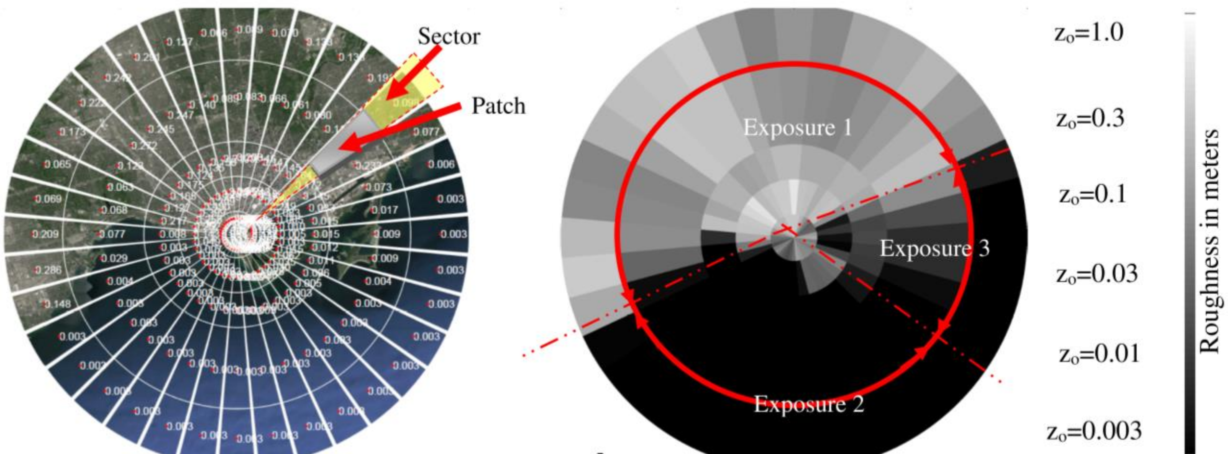
3-Divide the map into **sectors** (at different angles) and each sector to roughness **patches** (at various radii), then estimate the effective roughness for the patches based on the contribution of different subzones within the patch.



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4-Obtain wind profiles at the site for wind blowing from various angles and find the best matching wind tunnel profile. Reproduce all the geometry of all the surrounding buildings within a half kilometer of the study building

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5-Measure wind loads from the aerodynamic or aeroelastic wind tunnel tests

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6-Evaluate wind load by synthesizing the measured loads with the climate data