Experimental validation of a stochastic simulation model for non-Gaussian and non-stationary wind pressures using stationary wind tunnel data

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Introduction

Modern performance-based wind engineering aims to explicitly evaluate the performance objectives associated with structural and non-structural components of building systems. For the improved prediction of structural responses and cladding damage, it is desirable to simulate the complete evolution of uncertain hurricane events, leading to the better capture of the fluctuating wind field and the non-stationary wind loads. While several hurricane hazard models exist, stochastic non-Gaussian, non-stationary pressure simulation models that can be calibrated to building-specific wind tunnel data are lacking.

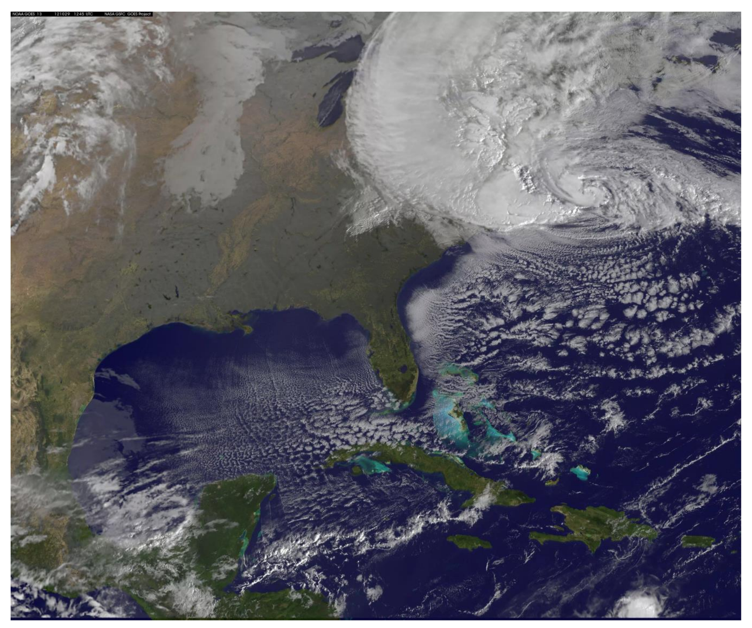

Figure 1: Image from NOAA's GOES-13 of Hurricane Sandy on October 29, 2012.

Stochastic Simulation Framework

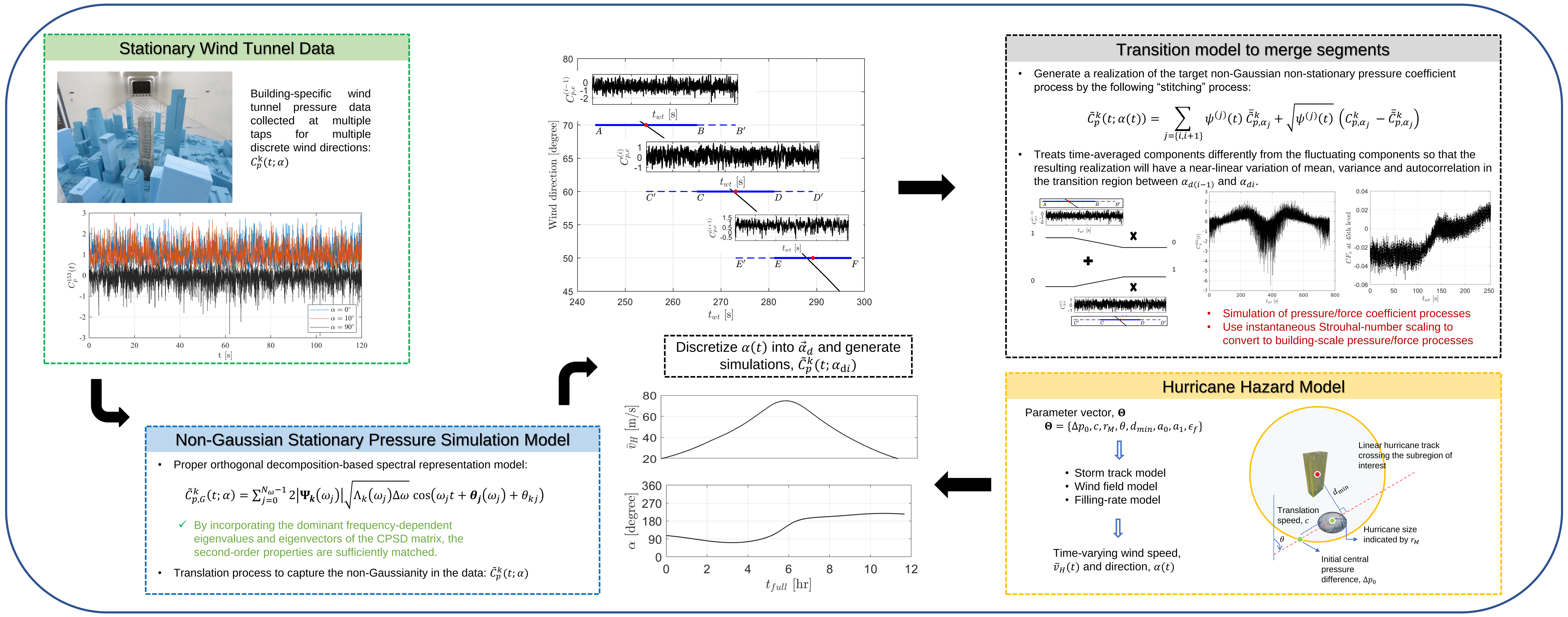

Figure 2: Conceptual flowchart illustrating the simulation of non-Gaussian, non-stationary vector pressure process.

Experimental Validation

- A series of tests were conducted on a scaled model at the NHERI Boundary Layer Wind Tunnel at the University of Florida.
- Pressure data were recorded while continuously varying the wind direction (i.e., rotating the turntable) during the test.
- Different $d\alpha/dt$ were considered together with different rates of change of the mean reference wind speed.
- 20 repetitions were performed for every test combination.
- Test 1: Turntable first rotated to 180^0 from 0^0 counter-clockwise ($d\alpha/dt$= 0.5^0/s and constant mean reference wind speed) and then returned to its initial position through a clockwise motion; $\alpha = 0^0$ wind is incident on Surface 2.

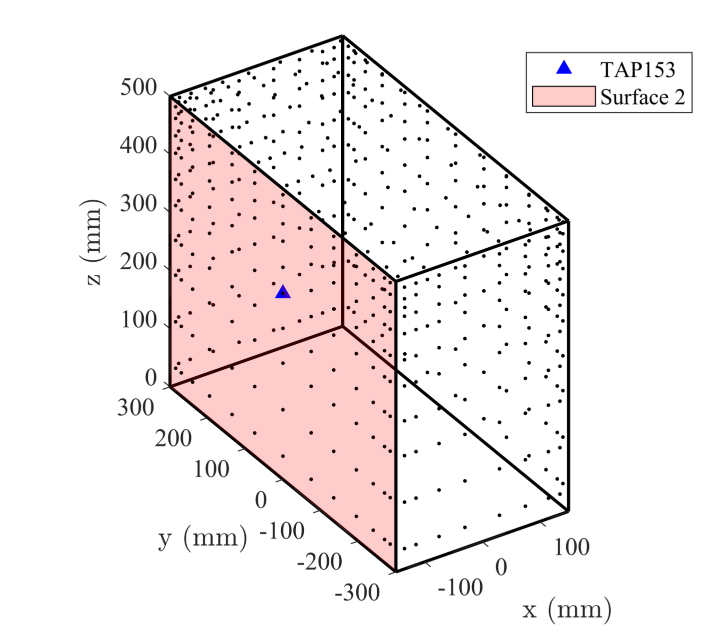

Figure 3: Scaled building model with pressure tap layout.

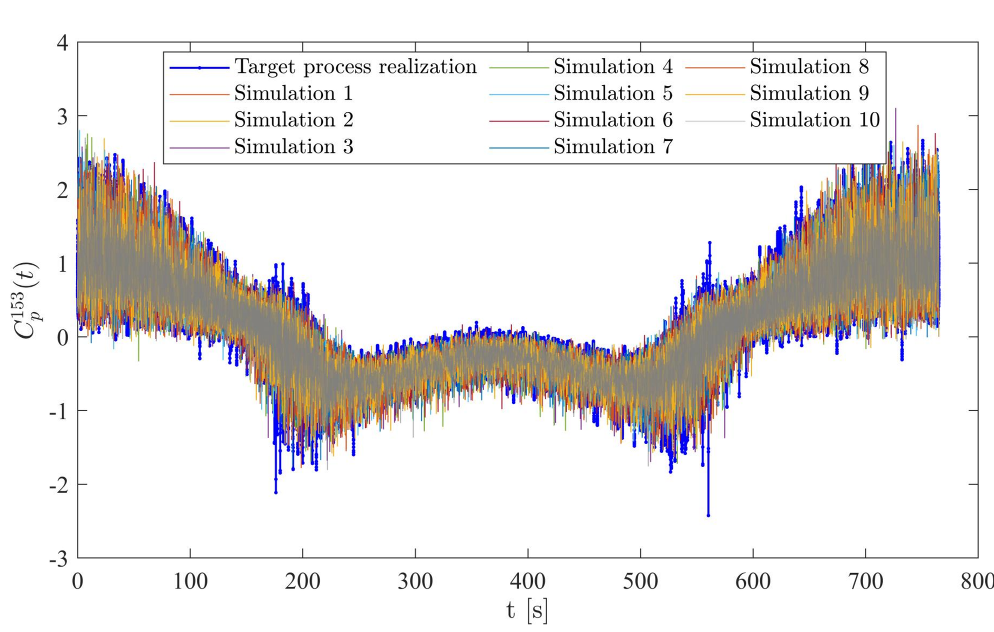

Figure 4: Comparison of $C_p(t)$ for TAP 153, Test 1: Data and 10 computer simulations

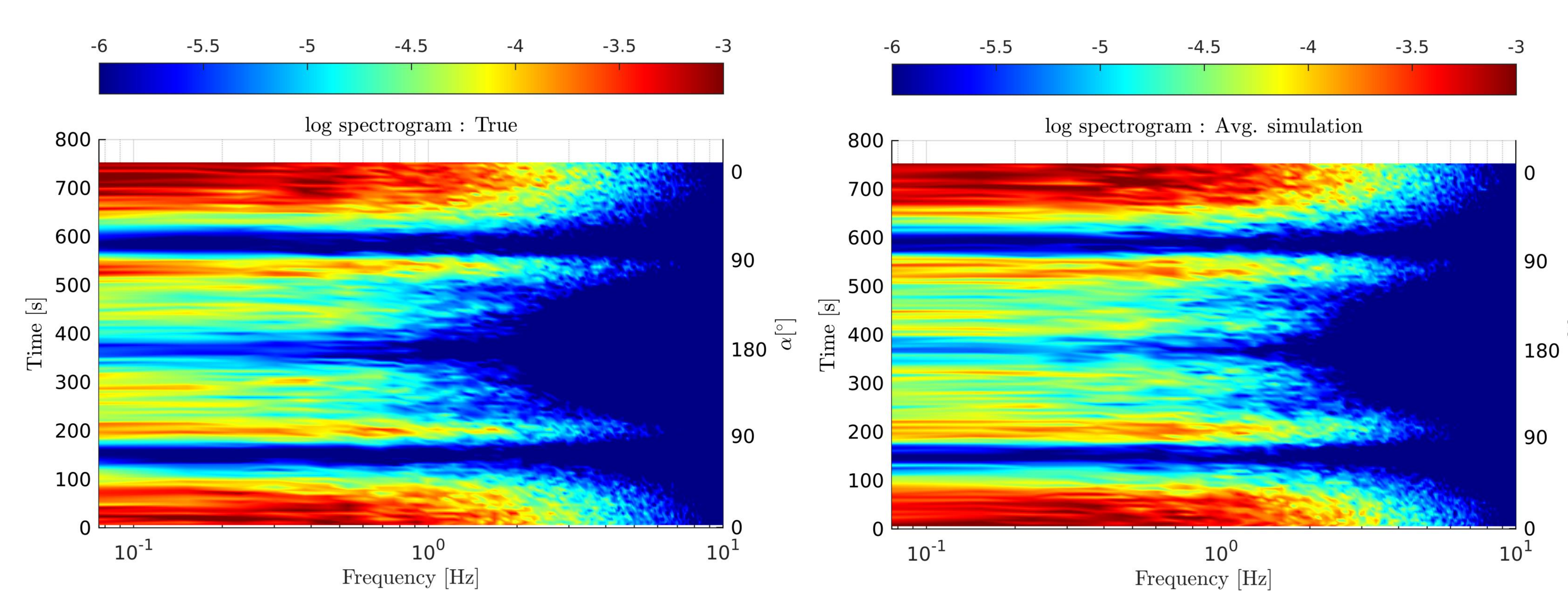

Figure 5: Comparison of data-averaged spectrogram and the simulation-averaged spectrogram for TAP 153, Test 1.

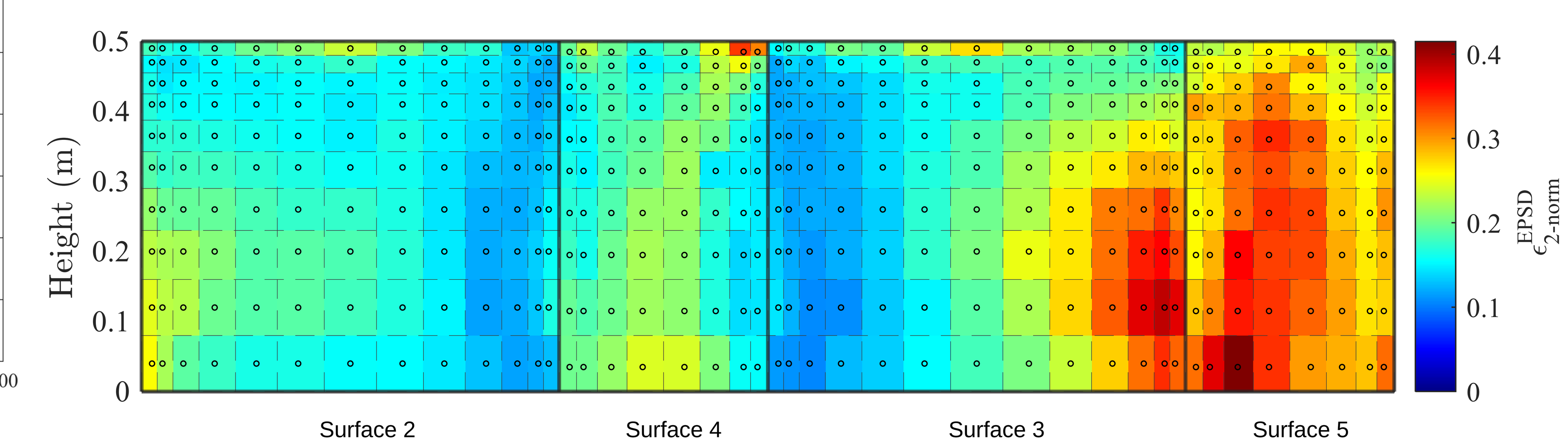

Figure 6: Map of 2-norm errors in the spectrogram for Test 1.

Conclusions

- This work validated a stochastic model for the simulation of correlated non-Gaussian, non-stationary wind pressures using experimental data.
- The results indicate satisfactory performance of the transition model based on errors in the evolutionary spectral density and autocorrelations.
- The simulation framework can enable the faithful modeling of hurricane-induced aerodynamics on the built environment.

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References

Ouyang, Z. and Spence, S. M. J. (2021). A Performance-Based Wind Engineering Framework for Engineered Building Systems subject to Hurricanes, *Frontiers in Built Environment*, 133.