MathWorks® Day – Poster Session
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A MATLAB®-Based Numerical Algorithm for Stochastic Simulation of Structural Load, Response and Damage (MATLAB® SLRD) Induced by Non-stationary Thunderstorm Downbursts

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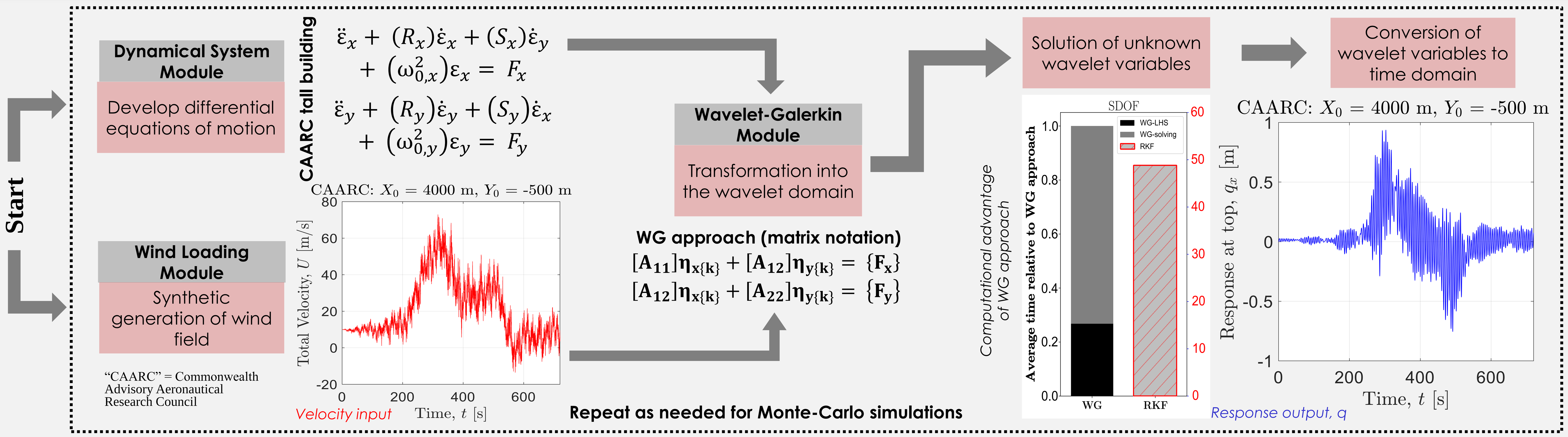
ABSTRACT

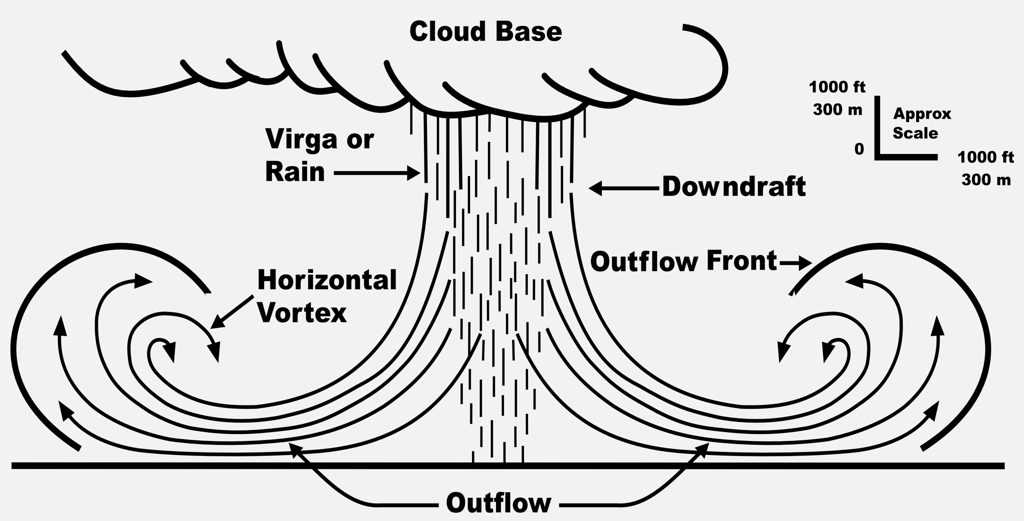
- This poster summarizes recent application of the Wavelet-Galerkin (WG) approach to the stochastic simulation of structural load, response and damage (SLRD) caused by non-stationary wind loads.
- Traditional frequency domain approaches for analysis of SLRD under these non-stationary conditions are inaccurate while time-domain numerical techniques are computationally demanding.
- The WG approach provides rapid approximations of the solution to differential equations that govern structures subjected to downburst wind loads.
- This advantage is crucial for stochastic analysis in a Monte Carlo environment, requiring vast amounts of simulations.
- Exploitation of innovative computational methods will further optimize this technique for stochastic analysis of SLRD induced by non-stationary winds.

2a. OVERVIEW OF WAVELET-GALERKIN MONTE-CARLO SIMULATION APPROACH



1. INTRODUCTION

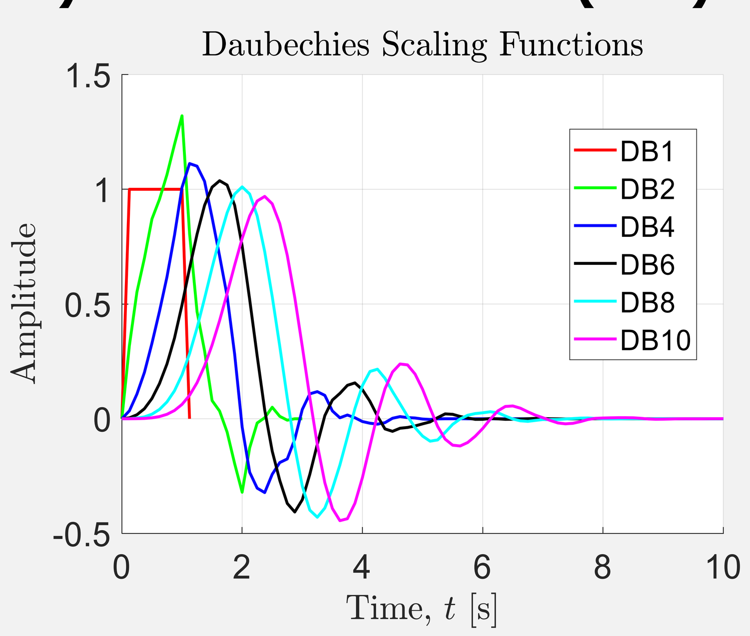
a) Thunderstorm Downburst



(Top) Photograph of thunderstorm downburst captured by Jerry Ferguson, helicopter reporter of Chopperguy Aerial Productions in Arizona, USA (Source: http://chopperguy.com/phoenix-microburst)

(Bottom) Illustration of cross-section of thunderstorm downburst from United States Federal Aviation Administration (FAA) (Source: Wikipedia)

b) Wavelet-Galerkin (WG) Approach [1,2]



$$\ddot{\eta} = \mathbf{\Omega}^{0,2}\boldsymbol{\eta}_{\{\mathbf{k}\}}$$
$$\dot{\eta} = \mathbf{\Omega}^{0,1}\boldsymbol{\eta}_{\{\mathbf{k}\}}$$
$$\eta = \mathbf{\Omega}^{0,0}\boldsymbol{\eta}_{\{\mathbf{k}\}}$$

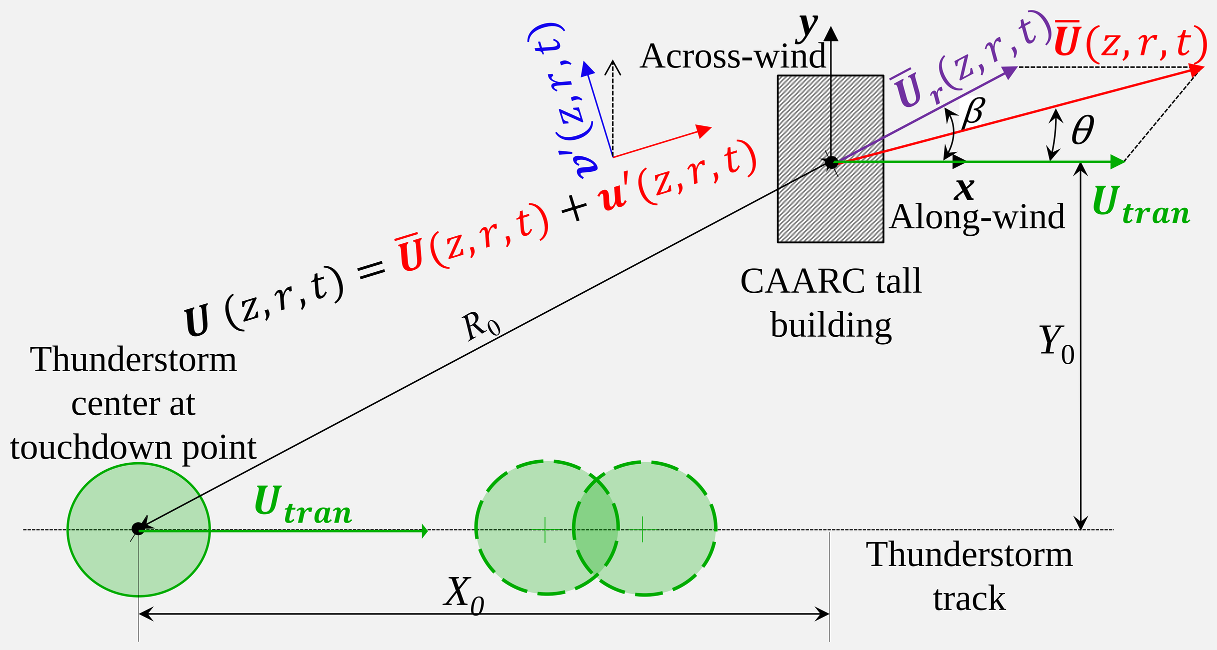
(Above) Connection coefficients to replace derivatives of differential equations

(Left) Examples of Daubechies scaling functions at various orders

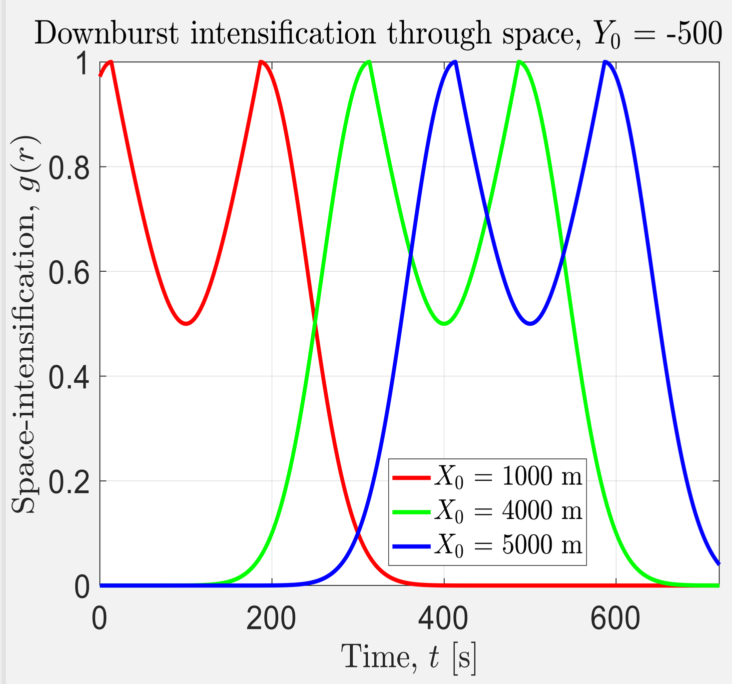
2b. WIND FIELD SIMULATION

Intensity of a thunderstorm downburst is dependent on various parameters, e.g. [3]:

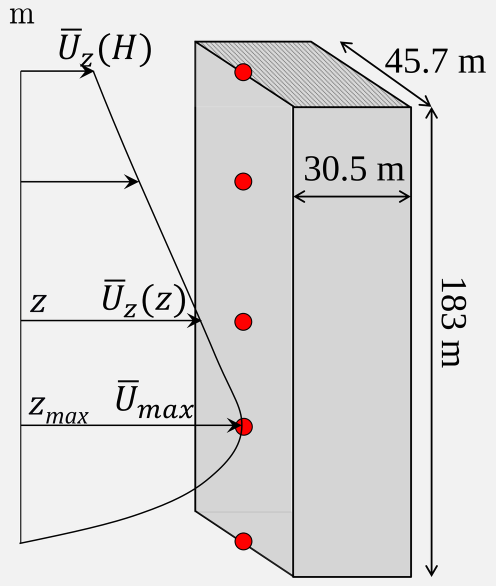
- Initial touchdown location
- Inner/Outer radii
- Time of max intensification
- Translational speed
- Nose-like vertical wind profile



Schematic showing the placement of the structure with respect to the thunderstorm's path of travel



Examples of spatial intensification of the downburst as it touches down at various locations



Nose-like vertical wind profile unique to thunderstorm downbursts

3. STOCHASTIC ANALYSIS

Engineering Demand Parameter (EDP)

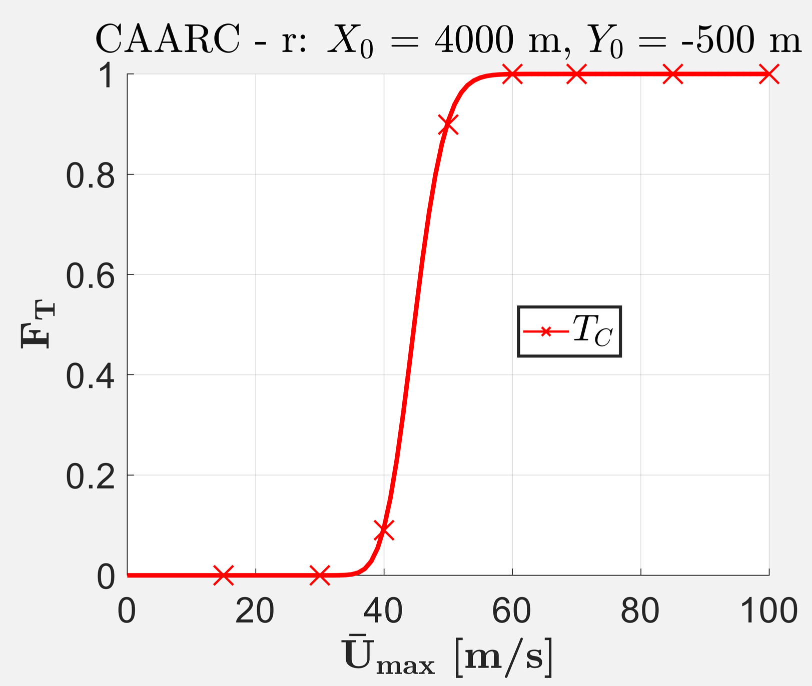
$$q^{max} = \max(q)$$

Limit State

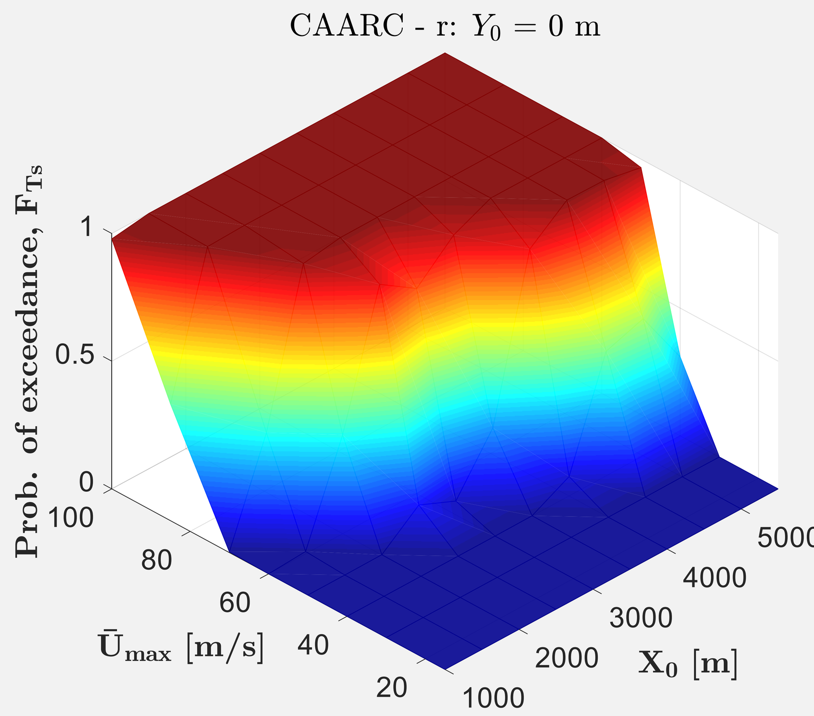
$$T_C = 183 \text{ m} \times \frac{1}{400}$$

Complementary Cumulative Distribution Function (CCDF)

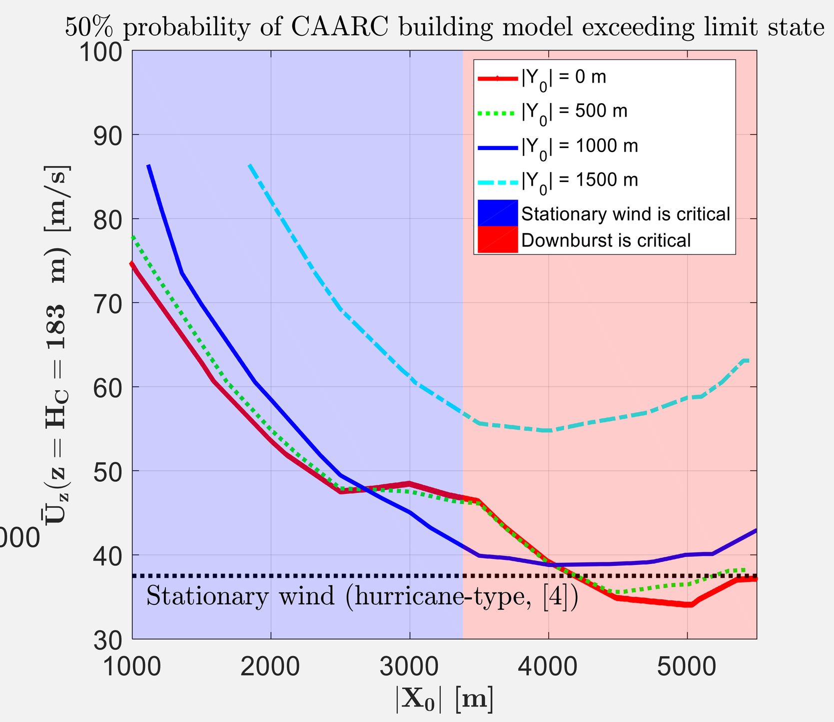
$$F_T(\bar{U}_{max}) = P[q^{max} > T_C|\bar{U}_{max}]$$
$$F_{Ts}(\bar{U}_{max}, |X_0|) = P[q^{max} > T_C|\bar{U}_{max} \wedge |X_0|]$$



Example fragility curve



Example fragility surface



Fragility surface cut at 50%

4. RESEARCH HIGHLIGHTS

- Digital simulation of the wind field of a thunderstorm downburst is feasible with space-time intensification functions for amplitude of mean wind speed and random turbulence
- Wavelet-Galerkin approach yields significant savings in computational time for Monte Carlo simulation of structural load, response and damage (SLRD) due to non-stationary wind phenomena such as thunderstorm downbursts
- Fragility curves and surfaces, using maximum mean wind speed of the downburst as an intensity measure, illustrate system' likelihoods for exceeding structural limit states in stochastic analysis of SLRD

5. REFERENCES

[1] A. Latto, H. Resnikoff, E. Tenebaum, The evaluation of connection coefficients of compactly supported wavelets, in: Proceedings of the French-USA workshop on Wavelets and Turbulence, Princeton University, June 1991.
[2] T.-H. Le, L. Caracoglia, Computer-based model for the transient dynamics of a tall building during digitally simulated Andrews AFB thunderstorm, Computers and Structures 193 (2017) 44-72.
[3] V. Le, L. Caracoglia, A preliminary examination of structural fragility for a cantilever structure subjected to a thunderstorm downburst loading, in: Proceedings of the 13th Americas Conference on Wind Engineering (ACWE13), University of Florida, Gainesville, Florida, USA, 2017.
[4] W. Cui, L. Caracoglia, Simulation and analysis of intervention costs due to wind-induced damage on tall buildings, Engineering Structures 87 (2015) 183–197.

6. ACKNOWLEDGEMENTS

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