SimCenter Community Roundtable
"Fostering Computational Wind Simulations in Research and Practice"

April 14, 2025

This SimCenter Community Roundtable meeting is organized by the **Working Group on Wind and Water Simulation**. The primary objective of the roundtable is to identify pathways to accelerate the use of computational fluid dynamics (CFD) simulations for wind load analysis both in research and practice.

First, presentations by researchers and practicing engineers will provide examples of the opportunities and challenges that arise when using CFD simulations for a range of wind engineering applications. Next, an update on new Simcenter tutorials for WE-UQ and the related educational module will be provided, including lessons learned from using the module in an undergraduate architecture course and a graduate structural wind engineering course. Subsequent roundtable discussions will focus on identifying alternative pathways for fostering the use of CFD for wind engineering applications.

Moderator: Catherine Gorlé, Stanford University

Presentations and Key Ideas

1. **"An aerodynamic dataset for AI-driven wind-resistant design optimization of bridges"**
   Presenter: Miguel Cid Montoya, Clemson University.
   This presentation showcases a method for aerodynamic shape optimization of bridge decks. It involves generating a comprehensive aerodynamic database using CFD simulations and then training surrogate models on the data to expedite efficient evaluation of aerodynamic performance of different shapes.

2. **"From wind tunnels to CFD and machine learning - the road to improving urban resilience and building sustainability via wind engineering"**
   Presenter: Goncalo Pedro, RWDI.
   The path to improving resilience and building sustainability via wind engineering was elaborated on with a three stage roadmap: (i) wind tunnels, (ii) CFD simulations, and (iii) machine learning. Driving this roadmap is the desire to optimize carbon reduction potential and min-maxing cost and ahead-of-schedule delivery. In the context of professional projects which are highly cost-driven, the use of machine learning models trained on wind tunnel data as a fast analysis method for early stage design was highlighted. Work done with OrbitalStack and RWDI Labs was highlighted.

3. **"Extreme winds, stagnation zones, and ventilation solutions for urban canopies"**
   Presenter: Elie Bou-Zeid, Princeton University.
   Urban areas currently account for approximately 75% of global energy consumption and 80% of greenhouse gas emissions, with projections indicating that 70% of the world's population will reside in cities by 2050. In response to these trends, improving our understanding and the prediction of urban fluid mechanics is a pressing grand challenge. Recognizing that challenges and solutions vary across spatial scales—from individual buildings to entire cities—the presentation focused specifically on neighborhood-scale simulations of urban canopy ventilation. It examined the influence of roof geometry on wind flow patterns, highlighting how variations in roof shape modify flow fields, including zones of stagnation and regions of elevated wind speed.

4. **"Educational module: LES for Wind Loading Predictions"**
   Presenters: Catherine Gorlé, Stanford University, and Abiy Melaku, UC Berkeley.
   This talk, presented by the SimCenter wind engineering team, introduced a recently developed graduate-level educational module on **Computational Wind Engineering**. The presentation provided an overview of the module's structure and content and highlighted its focus on applying Computational Fluid Dynamics (CFD)

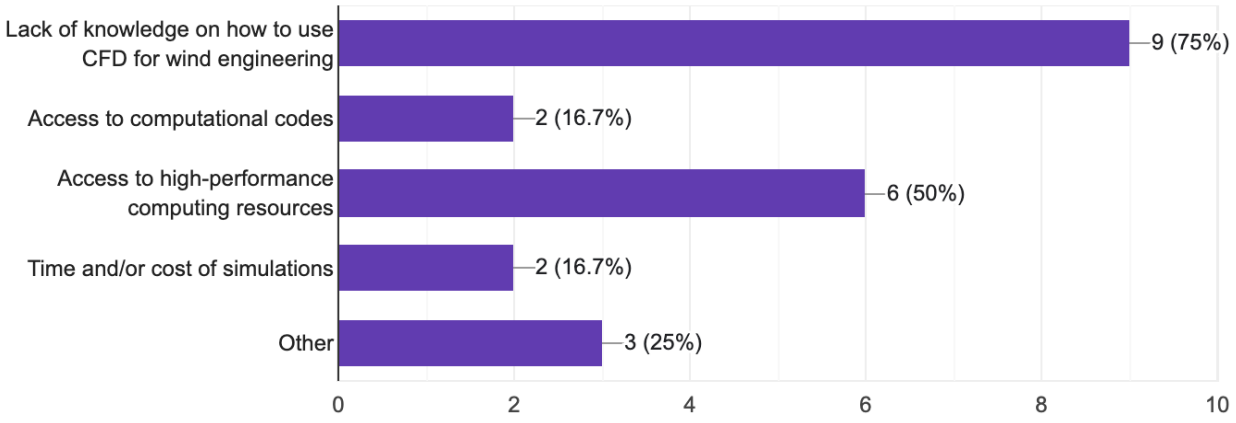
for wind load evaluation. The presentation outlined the key topics covered in the lectures, including wind effects on buildings, sources of flow unsteadiness, and turbulence modeling with an emphasis on Large-Eddy Simulation (LES). Also, it described the hands-on tutorials and assignments that use the WE-UQ tool to give students practical experience in configuring CFD simulations for wind engineering applications. Finally, experiences learned from adopting the module in an existing wind engineering course at University of Auburn is shared.

Discussion Highlights

- **CWE Educational Module**: The group discussed the potential for adapting the Computational Wind Engineering module for undergraduate students. Catherine shared her teaching experience, highlighting that while the fundamental concepts are not too difficult for undergraduates to understand, incorporating practical homework, assignment or project remains a challenge. Consensus was reached on focusing on graduate students at this point.
- **Handling Inhomogeneity in Building Geometry**: Two presentations in the roundtable highlighted the use of machine learning (ML) models trained on aerodynamic databases. A key question raised was how to manage the complexity of diverse shapes and configurations with their surroundings for urban simulations. While basic forms can be systematically parameterized, incorporating a wide range of geometries still remains computationally demanding. It was also noted that even small geometric variations can significantly impact wind loads due to sensitivity of flow separation and wake size to geometric details.
- **Simulation Data and Machine Learning Integration:** The discussion also explored the idea of developing a shared and homogenized CFD database to support machine learning (ML) models. While such a resource could enhance data-driven approaches, concerns were raised about the significant effort required to generate sufficient high-quality simulation data. It was suggested that existing practices for archiving aerodynamic data from wind tunnel experiments could be adapted to CFD workflows to streamline this process. However, given the data-intensive nature of ML and its current limitations, the group noted that focusing on well-calibrated RANS models may be a more practical and effective path forward for advancing simulation-based applications in wind engineering.

Post Community Roundtable Survey

- *What do you see as the main barriers for the use of CFD in wind engineering? (Select your top 1 to 2)*



This material is based upon work supported by the U.S. National Science Foundation under Grant No. 2131111.

Other responses:

A user-friendly predictive framework benefitting the industrial side.
A greater push/more marketing for CFD being shown as a robust alternative to wind tunnel experiments.
Maybe the accuracy and reliability of CFD.

More Information

Additional SimCenter Community Roundtable meetings can be found at https://simcenter.designsafe-ci.org/collaborate/scr/.

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