# WE-UQ Application Summary (V3.1.0)

The Wind Engineering with Uncertainty Quantification (WE-UQ) application creates and launches simulation workflows to assess the response of a structure under wind loading. The application provides different methods to generate histories of wind-induced forces, multiple approaches to create a numerical model of the structure, and various options to perform the numerical simulation of the response. Both deterministic and probabilistic simulations are supported. In probabilistic simulations, random variables can represent uncertainties in the wind event, the structural model, and the numerical simulation solver. These uncertainties are automatically propagated through the simulation to arrive at a probabilistic description of structural response. Probabilistic simulation results can be further processed to perform sensitivity analysis or train surrogate models.

USE CASES

Run a Probabilistic Assessment

Wind loads on the structure can be simulated using stochastic techniques, experimental databases, or computational fluid dynamics (CFD) models. The recently implemented CFD-based workflow provides a versatile tool to simulate unsteady wind loads on the structure for any building geometry and wind exposure condition. For structural models, the user can import OpenSees models defined in Tcl or Python. After running the analysis, the user can evaluate the response of the structure to the wind loading with propagated uncertainties.
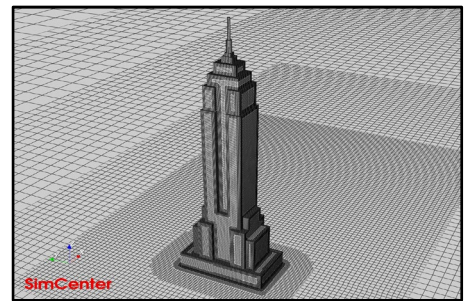

Virtual Wind Tunnel Simulation

WE-UQ enables the user to run a digital wind tunnel simulation by reproducing relevant flow characteristics of a particular testing facility. A recently implemented capability allows the user to replicate the test section of the wind tunnel with the model of the building placed in it. Using the **TInf** tool, the created model can be calibrated to a given target wind profile. Wind loads on the building, such as integrated story loads or local pressure fluctuations on its façade, can be calculated for different wind directions. This tool can be helpful when designing actual wind tunnel experiments, as well as for validation of CFD modeling to enable additional wind tunnel 'tests' to be run virtually.
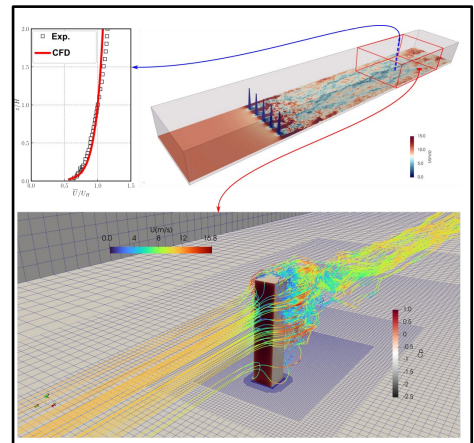
Develop Structural-Response Surrogate Models

Built-in uncertainty quantification engines enable the user to train surrogate models that aim to reproduce the results of complex numerical simulations at a fraction of the original computation time. For example, if the user has a high-fidelity OpenSees model of a structural system, WE-UQ can assist in selecting a robust set of aerodynamic databases, preparing high-quality training data, and developing an appropriate surrogate model for building response.
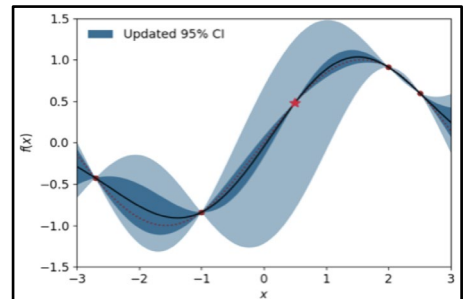
CURRENT CAPABILITIES

Characterize Wind Field Effects: Select a method for generating unsteady wind loads on the building. Each wind event creates a time history of wind forces measured at each floor level. The following options are available in WE-UQ for wind load generation:

- Generate wind loads using stochastic techniques that take the surrounding exposure conditions, associated turbulence characteristics, and wind speed as inputs.
- Obtain wind force time history from existing aerodynamics databases.
- Generate integrated loads and point pressures on buildings from CFD simulations using OpenFOAM

Structural Model: Defines the structural modeling approach and returns the scripts required to perform the response simulation. One or more models can be assigned to a workflow. Using more than one model allows for benchmarking and epistemic uncertainty analysis. The following options are available:

- Provide your own OpenSees model in Tcl or Python format.
- Provide a Python script that prepares a structural model and performs the response simulation.
- Automatically generate an idealized shear column model in OpenSees from basic building information.
- Utilize a multi-model approach, which allows multiple combinations of the above models.

Response Simulation: Defines the analysis options that will be used to perform the numerical simulation, e.g., time integration strategy, convergence criteria, and damping options. The user-specified modeling tool is used to perform the simulation and collect the requested response quantities.

Uncertainty Quantification: Samples the prescribed random input variables and obtains realizations of the outputs by executing the workflow with each input realization from the generated sample. The underlying UQ engines let you leverage the following techniques in your research:

- Forward propagation: Define a set of random input parameters and perform Monte Carlo simulations to obtain a corresponding sample of output parameters.
- Sensitivity analysis: Measure the influence of the uncertainty in each input on the uncertainty of outputs.
- Reliability analysis: Algorithms to estimate the probability of exceeding a failure threshold.

UPCOMING CAPABILITIES

- Aerodynamic Database Creation: Generate an aerodynamic database employing CFD simulations. (Oct 2023)
- Digital Wind Tunnel IV: CFD model for evaluating wind loads on a building with a complex surrounding environment including multiple buildings. (Jan 2024)
- Multi-fidelity Monte Carlo techniques to allow users to bring models with different fidelity. (Jan 2024)
- Surrogate Base Response Estimation: surrogate models for predicting the response of a building subjected to wind loading for several wind and structural parameters. (Mar 2024)

MORE INFORMATION

The software application, examples, and Information about previous releases can be found in the documentation accessible from the WE-UQ website at https://simcenter.designsafe-ci.org/research-tools/we-uq/.