NHERI SimCenter

Center for Computational Modeling & Simulation

WE-UQ Tutorial

Wind load evaluation on an isolated high-rise using large-eddy simulation

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Outline

- **Introduction**
  - ✓ WE-UQ's CFD workflow
  - ✓ Target experimental data
- **CFD Setup in WE-UQ**
  - ✓ Geometry & domain setup
  - ✓ Mesh generation
  - ✓ Boundary conditions
  - ✓ Numerical setup
  - ✓ Run simulation on DesignSafe
- **Results and post-processing**
  - ✓ Display results in WE-UQ
  - ✓ Flow visualization using Paraview
  - ✓ Compare with the experimental data

CFD workflow in WE-UQ: wind load simulation

Empty Domain Simulation
Calibrate the incident wind profiles
to match the target values

Step-by-step procedure to create CFD model in WE-UQ

Geometry Definition
- Computational domain
- Building
- Surroundings

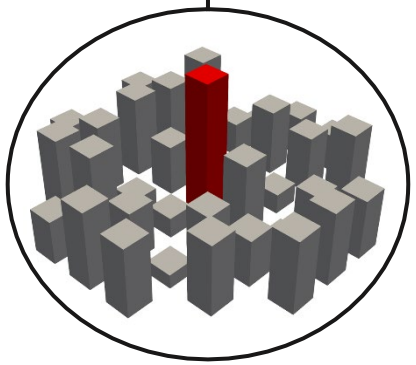
Mesh Generation
- Base mesh
- Refinements

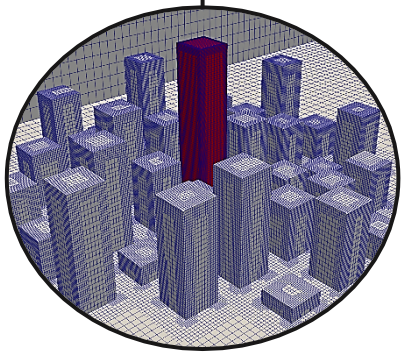
Boundary Conditions
- Inflow
- Surface roughness

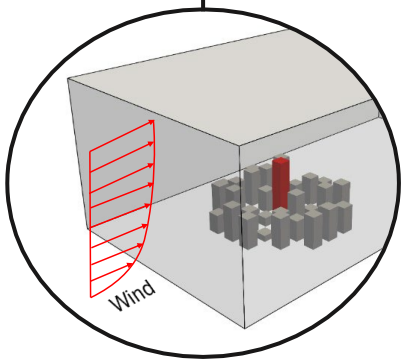
Numerical Setup
- Turbulence model
- Solver

Result Monitoring
- Wind profiles
- Local loads
- Integrated loads

Result Analysis
- Wind loads
- Wind profiles
- Flow field

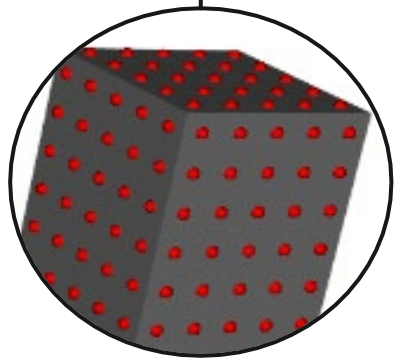


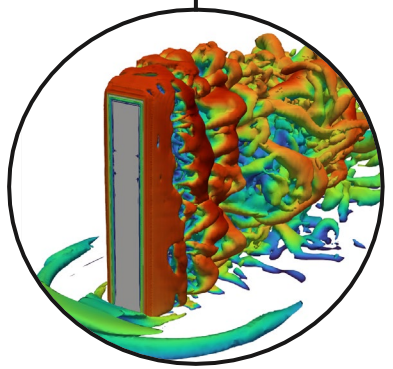




OpenFOAM

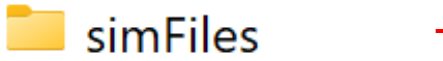
```
>Turbulence model
>Solver
>Time step
```



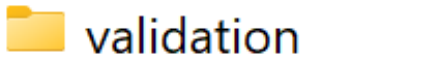


ParaView

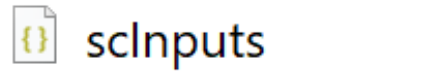
Tutorial-2: Simulation input and case files



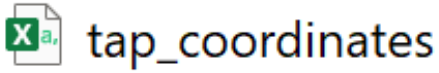
→ OpenFOAM case directory containing the mesh data



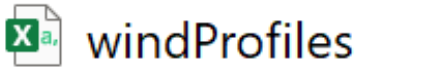
→ Directory containing validation data and Python script for plotting Cp



→ Input JSON files that define all the setup needed in WE-UQ

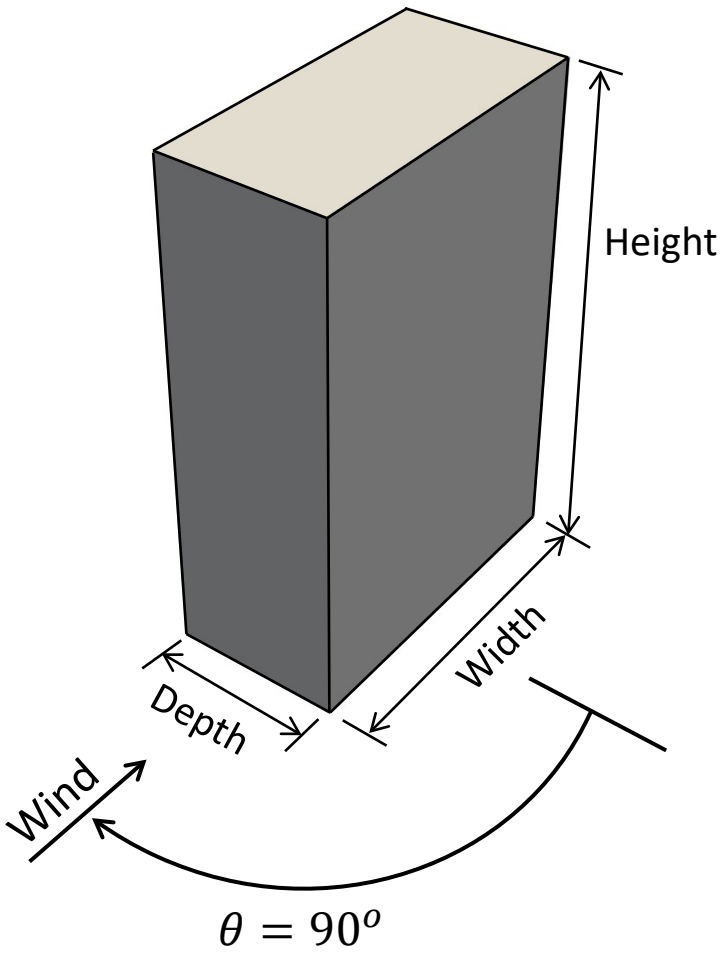


→ CSV file defining pressure sampling points



→ Vertical profiles of the target wind characteristics to be used as input for TInf

Tutorial-2: Target wind tunnel measurement



Taken from TPU database [1]

Parameters	Value	Unit
Building width (full-scale)	80	m
Building depth (full-scale)	40	m
Building height (full-scale)	120	m
Geometric scale of the model	1:400	
Velocity scale of the model	1:4	
Time scale of the model	1:100	
Roof-height mean wind speed	10.6924	m/s
Duration of the simulation	34	s
Wind direction	90	degrees
Aerodynamic roughness length in full scale (full-scale)	0.5	m
Reynolds Number	2.13×10^5	
Reference Height (full-scale)	120	m
Air Density	1.225	Kg/m^3

[1]Tokyo Polytechnic University: http://www.wind.arch.t-kougei.ac.jp/info_center/windpressure/highrise/Homepage/homepageHDF.htm

Tutorial-2: Create computational domain

Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | CFD-Results

WE-UQ

Start | Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | Results

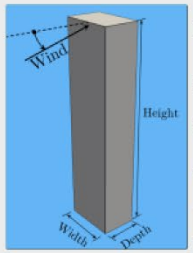
Dimentions and Scale

Input Dimension Normalization: Relative Geometric Scale: 400

Building Shape

Shape Type: Simple Geometry File: Import STL

Building Dimension and Orientation



Building Width: 80

Building Depth: 40

Building Height: 120

Wind Direction: 90

Generate STL Geometry

Domain Size

Domain Length (X-axis): 22.667

Domain Width (Y-axis): 7.333

Domain Height (Z-axis): 6

Fetch Length (X-axis): 7

COST Recommendation:

Normalization is done relative to the building height

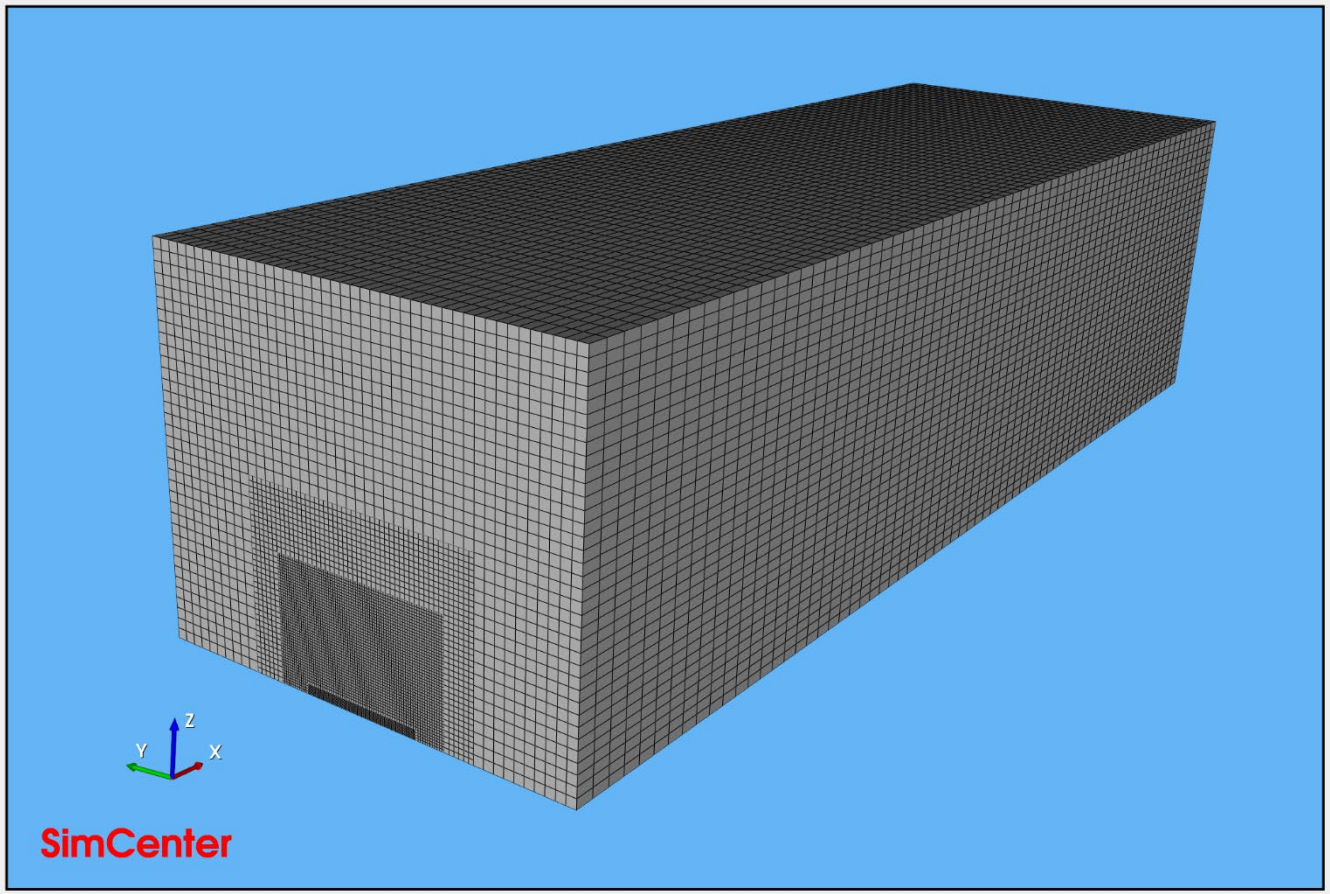
Coordinate System

Absolute Origin: Building Bottom Center

Coordinate: X_o: 0 Y_o: 0 Z_o: 0

Save Case Files

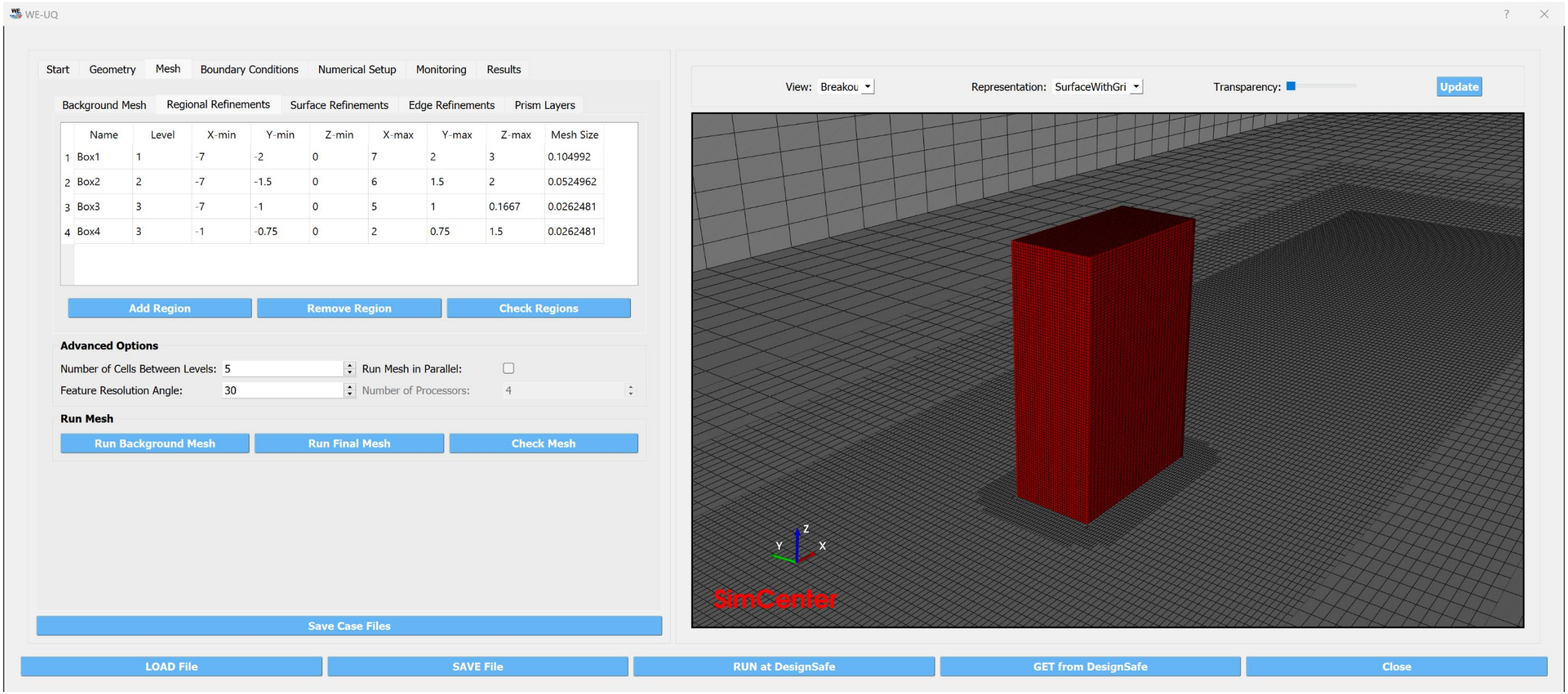
View: AllMesh Representation: SurfaceWithGri Transparency: Update



LOAD File | SAVE File | RUN at DesignSafe | GET from DesignSafe | Close

Tutorial-2: Generate mesh

Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | CFD-Results



Tutorial 2: Define boundary conditions

Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | CFD-Results

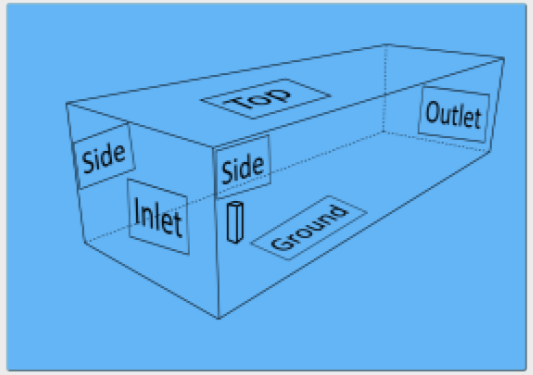
Start | Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | Results

Wind Characteristics

Velocity Scale:	4	Time Scale:	100
Reference Wind Speed:	10.69	Air Density:	1.225
Reference Height:	0.3	Kinematic Viscosity:	1.5e-05
Roughness Length:	0.5	Reynolds Number:	213800

Calculate

Boundary Conditions



Face Name	Boundary Condition
Inlet:	TInf
Outlet:	zeroPressureOutlet
Sides:	symmetry
Top:	slip
Ground:	roughWallFunction

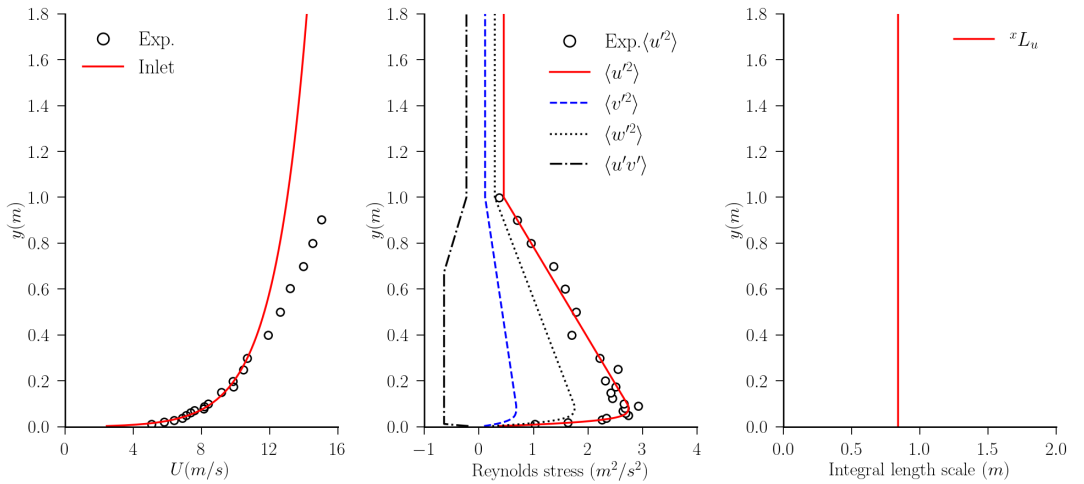
Inflow Generation

Generation Method: ○ DFSR ● DFM ○ SEM ○ DFSEM ○ TSM

Inflow Time Step: 0.005

Max. Frequency: 100

Wind Profile: Table | Import(*.csv) | Show Wind Profiles

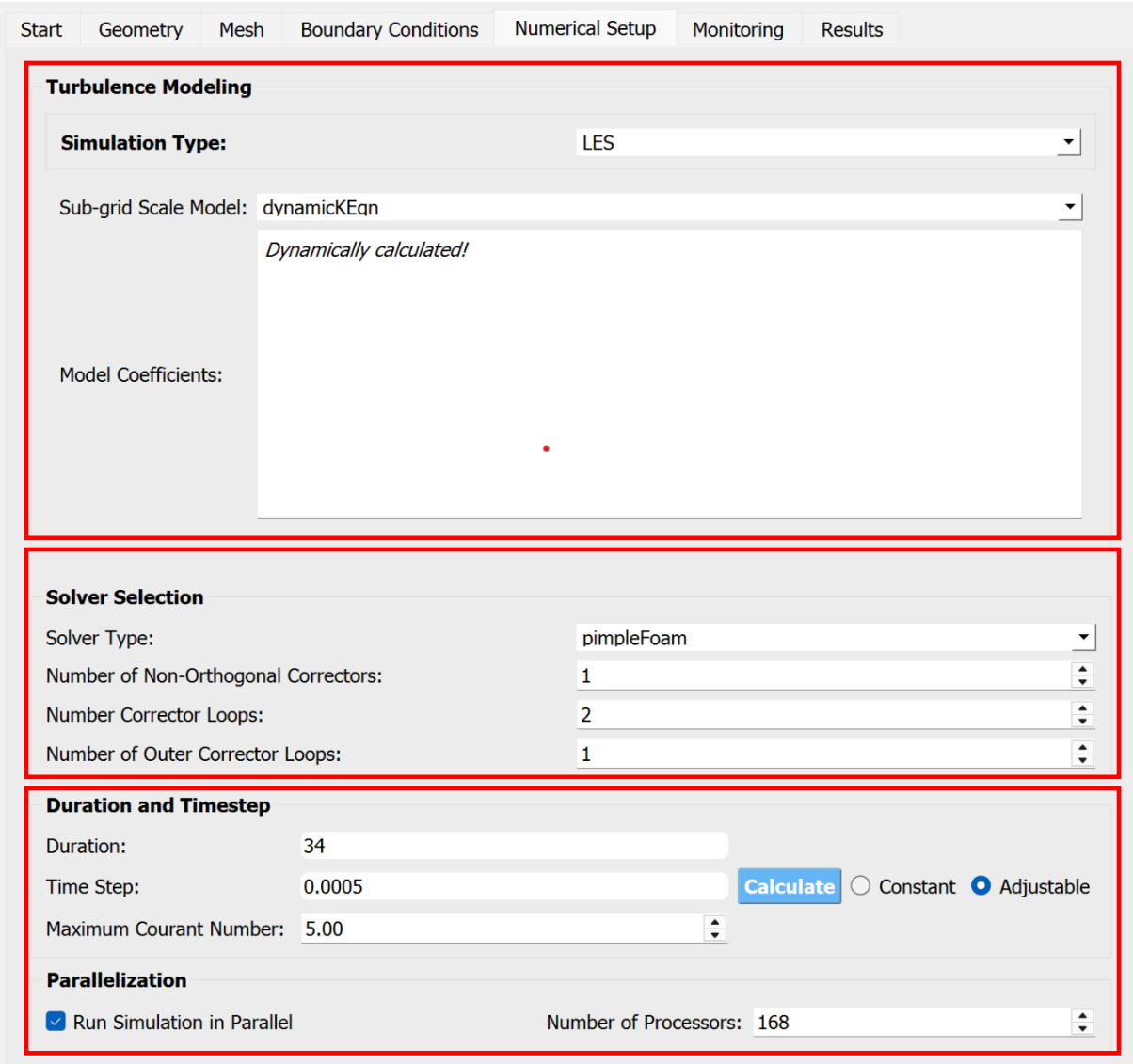


Wind Profiles

	z[m]	Uav[m/s]	R11[m2/s2]	R12[m2/s2]	R13[m2/s2]	R22[m2/s2]	R23[m2/s2]	R33[m2/s2]	xLu[m]	yLu[m]	zLu[m]	xLv[m]	yLv[m]	zLv[m]	xLw[m]	yLw[m]	zLw[m]
1	0.003125	2.44221	0.381923	0	-0.171865	0.244431	0	0.095481	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
2	0.00625	3.49297	0.72061	0	-0.324274	0.46119	0	0.180152	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
3	0.009375	4.17198	1.02055	0	-0.459248	0.653155	0	0.255139	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
4	0.0125	4.6746	1.28491	0	-0.5742	0.822345	0	0.321228	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
5	0.015625	5.07384	1.51671	0	-0.5742	0.970693	0	0.379177	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
6	0.01875	5.40505	1.71882	0	-0.5742	1.10004	0	0.429705	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
7	0.021875	5.68808	1.89399	0	-0.5742	1.21215	0	0.473497	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
8	0.025	5.93518	2.04482	0	-0.5742	1.30869	0	0.511206	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
9	0.028125	6.15445	2.17379	0	-0.5742	1.39123	0	0.543447	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
10	0.03125	6.35153	2.28322	0	-0.5742	1.46126	0	0.570805	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
11	0.034375	6.53051	2.3753	0	-0.5742	1.52019	0	0.593825	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
12	0.0375	6.69443	2.45209	0	-0.5742	1.56934	0	0.613022	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
13	0.040625	6.84562	2.5155	0	-0.5742	1.60992	0	0.628874	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
14	0.04375	6.98593	2.56731	0	-0.5742	1.64308	0	0.641827	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
15	0.046875	7.11682	2.60915	0	-0.5742	1.66986	0	0.652289	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
16	0.05	7.23947	2.64254	0	-0.5742	1.69123	0	0.660636	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
17	0.05625	7.46379	2.68926	0	-0.5742	1.72113	0	0.672315	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872
18	0.0625	7.66494	2.7167	0	-0.5742	1.73869	0	0.679176	0.8371	0.226017	0.234388	0.16742	0.050226	0.058597	0.385066	0.117194	0.267872

Tutorial-2: Specify numerical settings

Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | CFD-Results



Select Turbulence Model
e.g., LES, RANS, DES

Select Solver Type e.g., steady state (SIMPLE), transient (pisoFoam, pimpleFoam)

Set duration and time-step, Courant Number, number of processors

Tutorial-2: Monitor simulation data

Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | CFD-Results

Start | Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | Results

Integrated Loads

Base Loads

Monitor Base Loads: ☑

Write Interval: 2

Story Loads

Floor Height Specification: Uniform Floor Heigh

Number of Stories: 30

Floor to Floor Distance (CFD): 0.01

Write Interval: 2

Pressure Data

☑ Sample Pressure Data on the Building Surface

○ Create a Grid of Sampling Points

Number of Points Along Width: 5

Number of Points Along Depth: 10

Number of Points Along Height: 12

● Import Sampling Points (*.CSV)

Open Sampling Point File

Show Coordinates of Points

Write Interval: 2

VTK Planes

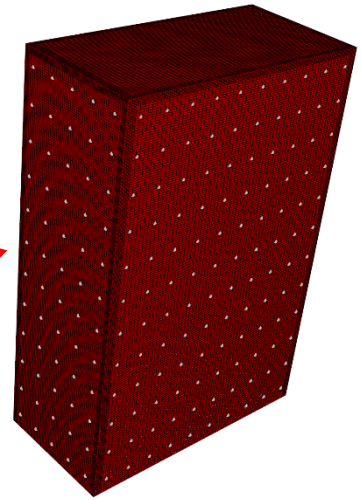
☑ Sample Flow Field

Add Plane | Remove Plane | Show Plane

	Name	Normal	point-X	point-Y	point-Z	Start Time	End Time	Field
1	Plane1	Y	0	0	0.2	1	3	Velocity
2	Plane2	Z	0	0	0.2	1	3	Velocity

Flow Write Interval: 40

Select results to be monitored (aerodynamic base and story loads)



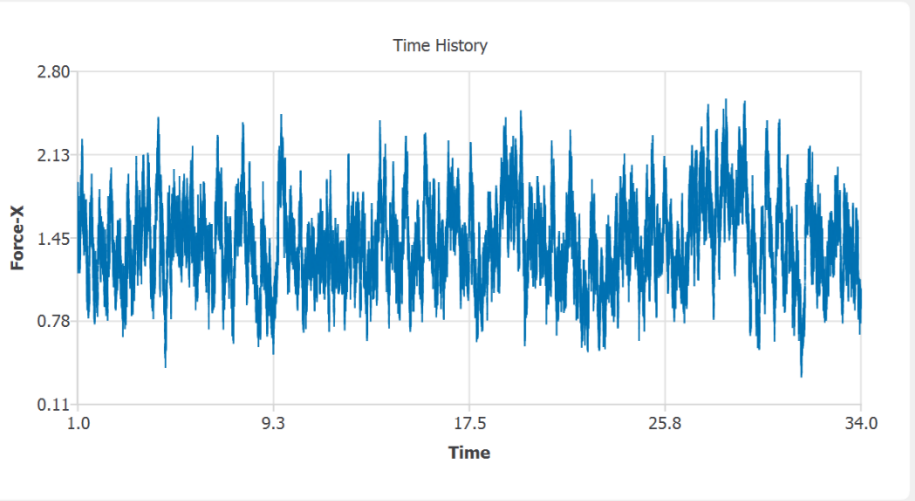
Monitor surface pressure fluctuations at selected sampling points

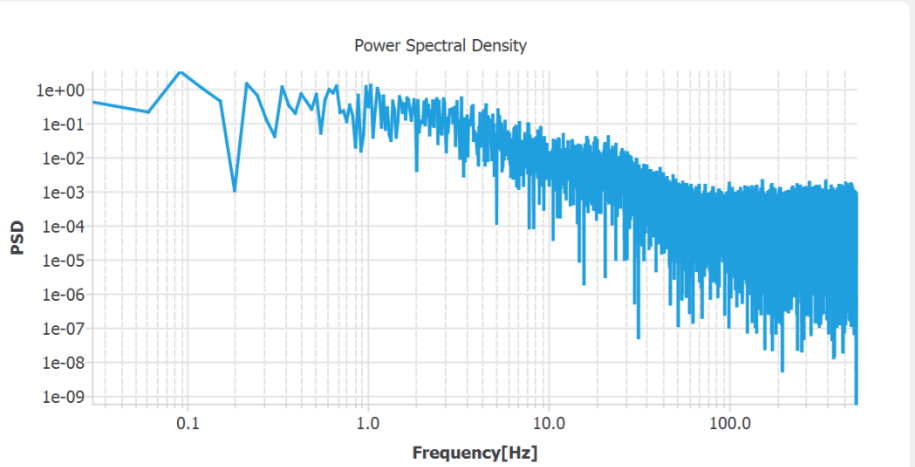
Record flow filed on selected planes for flow visualization

Tutorial-2: Check simulation results (integrated loads)

Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | CFD-Results

Summary | Time History



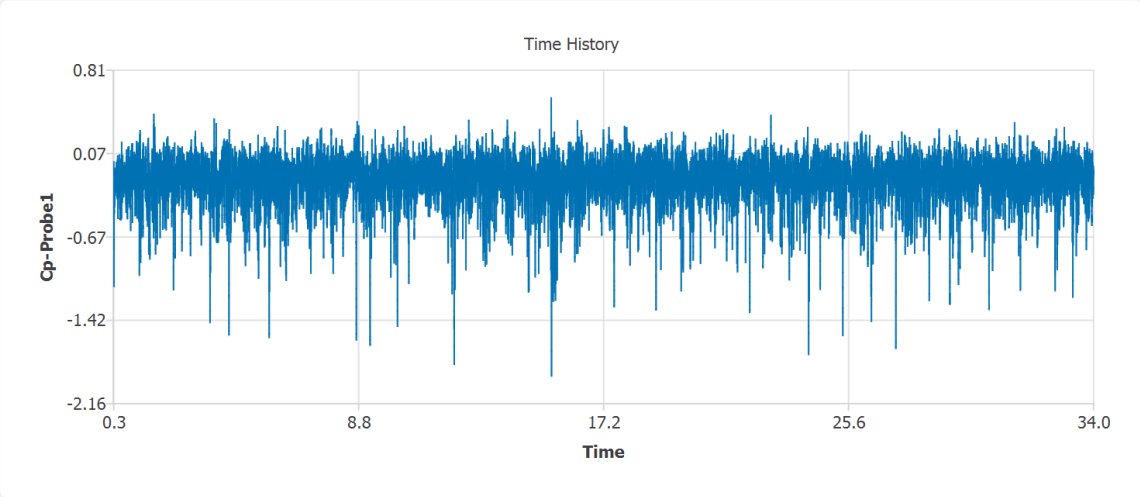


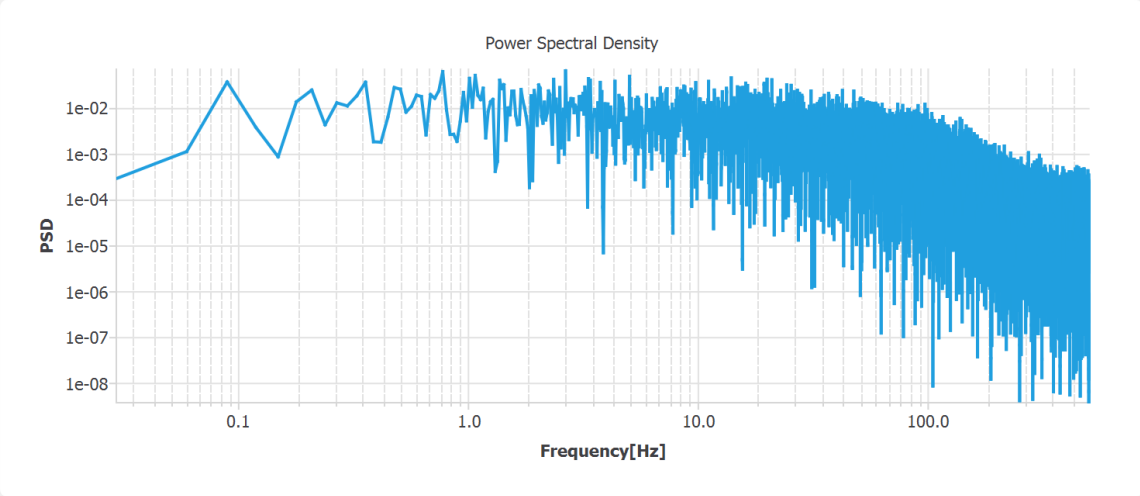
	Time	**Force-X**	Force-Y	Force-Z	Moment-X	Moment-Y	Moment-Z
1	1	1.81729	-0.180946	0.608582	2.69202e-05	-0.0007504...	8.71062e-05
2	1.001	1.62672	0.360165	0.820304	1.44791e-07	-0.0007011...	7.73577e-05
3	1.002	1.77406	0.336213	0.655714	-1.69766e-...	-0.0006660...	5.80223e-05
4	1.003	1.90093	0.350655	0.510113	-3.31506e-...	-0.00062024	4.47301e-05
5	1.004	1.72246	0.430454	0.694547	-7.07137e-...	-0.0005947...	4.00419e-05
6	1.005	1.82832	-0.529985	0.565048	-0.0001082...	-0.0005780...	3.7285e-05
7	1.006	1.78718	-0.419164	0.62255	-0.0001233	-0.0005548...	3.91354e-05
8	1.007	1.58549	0.247296	0.808898	-0.0001434...	-0.0005116...	4.17887e-05
9	1.008	1.76234	-0.535637	0.588653	-0.0001509...	-0.0004639...	4.35624e-05
10	1.009	1.75448	0.555203	0.567225	-0.0001431...	-0.0004143...	3.53201e-05
11	1.01	1.67419	0.14991	0.615514	-0.0001340...	-0.0003515...	3.40782e-05
12	1.011	1.61504	0.106895	0.647585	-0.0001430...	-0.0002858...	4.47066e-05
13	1.012	1.44604	0.141382	0.769369	-0.0001386...	-0.0002409...	5.28014e-05
14	1.013	1.54884	0.460106	0.599267	-0.0001043...	-0.0002301...	4.75281e-05
15	1.014	1.46816	0.422222	0.622436	-9.0454e-05	-0.00020179	4.00709e-05
16	1.015	1.33921	-0.181962	0.729443	-7.66322e-...	-0.0001773...	3.87599e-05
17	1.016	1.31627	0.229011	0.725983	-4.75411e-...	-0.0001666...	4.38797e-05
18	1.017	1.17612	0.487414	0.827535	-9.11773e-...	-0.0001535...	5.24051e-05
19	1.018	1.40766	0.511237	0.542806	1.84829e-05	-0.0001498...	6.30669e-05
20	1.019	1.32634	0.180376	0.606584	1.8649e-05	-0.0001321...	7.40019e-05
21	1.02	1.55123	0.684813	0.326973	-1.75401e-...	-9.42942e-...	8.2799e-05

Tutorial-2: Check simulation results (point pressure)

Geometry | Mesh | Boundary Conditions | Numerical Setup | Monitoring | CFD-Results

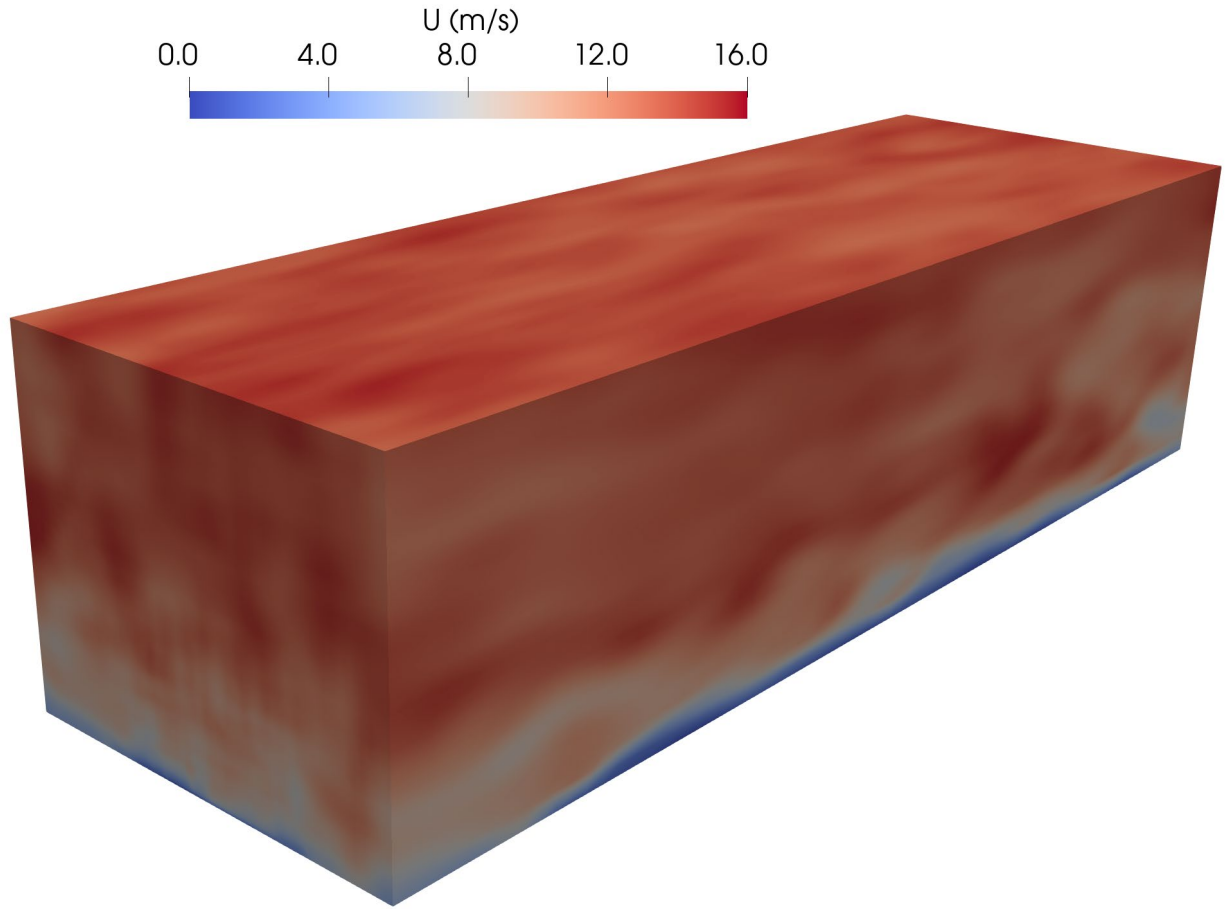
Summary | Time History





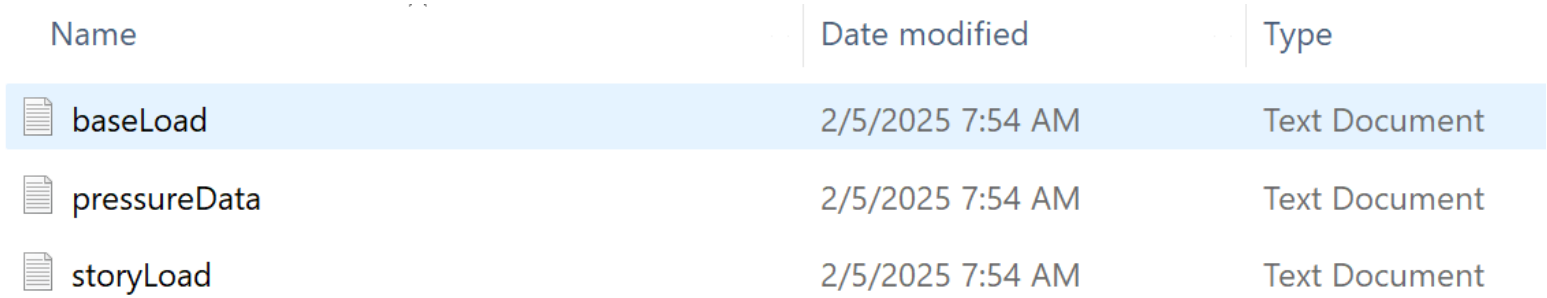
	Time	**Cp-Probe1**	Cp-Probe2	Cp-Probe3	Cp-Probe4	Cp-Probe5	Cp-Probe6
1	0.341	-0.125455	-0.268102	-0.50914	-0.292028	-0.626399	-0.925689
2	0.342	-0.0068934	-0.376468	-0.198158	-0.344267	-0.643436	-0.828693
3	0.343	-0.0911472	-0.59754	-0.193745	-0.48049	-0.864563	-0.777016
4	0.344	-0.199622	-0.492963	-0.2829	-0.632498	-0.969313	-0.671464
5	0.345	-0.358163	-0.299387	-0.406267	-0.889882	-0.925058	-0.684901
6	0.346	-0.588671	-0.343455	-0.643029	-1.09572	-0.78875	-0.898938
7	0.347	-0.78233	-0.759506	-1.10147	-1.24839	-0.850008	-1.34518
8	0.348	-0.313181	-0.706112	-1.08065	-0.819953	-0.636878	-1.10869
9	0.349	-0.38476	-1.01621	-1.14337	-0.934216	-0.8263	-1.1411
10	0.35	-0.644056	-1.13391	-0.947028	-1.01176	-0.965123	-1.04472
11	0.351	-0.888941	-1.04443	-0.813006	-0.978508	-0.901478	-1.07132
12	0.352	-1.07832	-0.978425	-0.977932	-1.1044	-0.927393	-1.40558
13	0.353	-1.11341	-0.920249	-1.05076	-1.07959	-1.23593	-1.68813
14	0.354	-0.691257	-0.62827	-0.749274	-0.696532	-1.36224	-1.04697
15	0.355	-0.513864	-0.645325	-0.720183	-0.689173	-1.63617	-0.744138
16	0.356	-0.40309	-0.62838	-0.679047	-0.822225	-1.39705	-0.725687
17	0.357	-0.439871	-0.637876	-0.669638	-1.14232	-0.956013	-0.674646
18	0.358	-0.451434	-0.595305	-0.693539	-1.28291	-0.732377	-0.613305
19	0.359	-0.459915	-0.554744	-0.826041	-1.10041	-0.639711	-0.639054
20	0.36	-0.34729	-0.426758	-0.887405	-0.660795	-0.439272	-0.559346
21	0.361	-0.160633	-0.337437	-0.672852	-0.352818	-0.298492	-0.49161

Tutorial-2: Check simulation results (flow field)



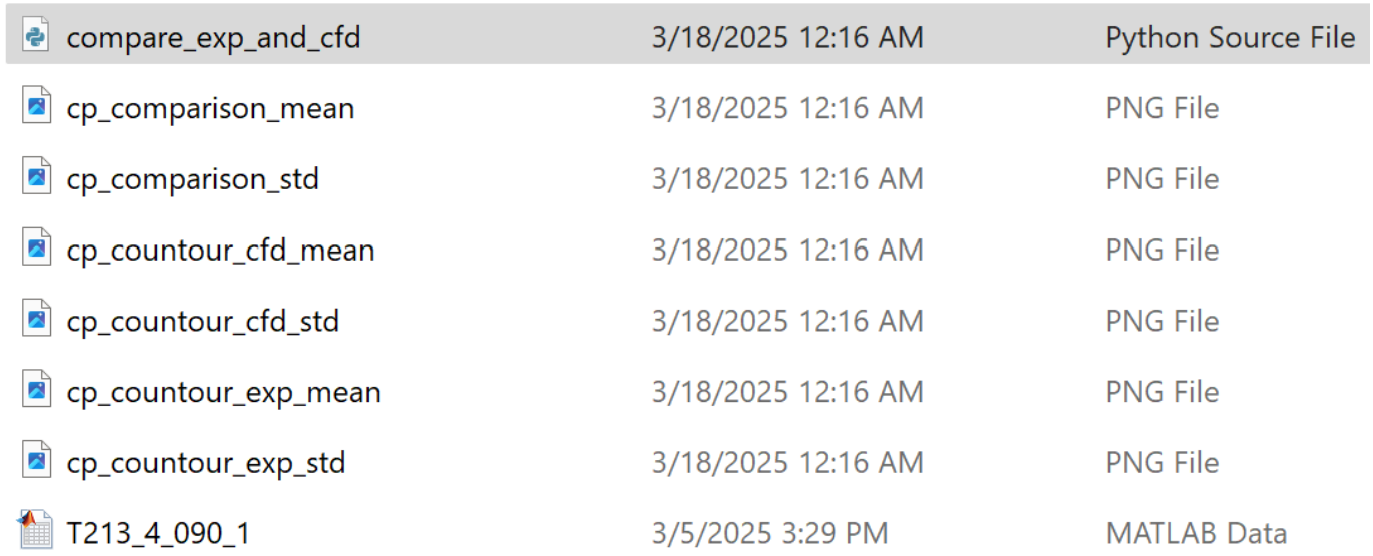
Tutorial-2: Simulation output and validation

- **Wind load output path:** `simFiles/constant/simCenter/output/windLoads`



Name	Date modified	Type
baseLoad	2/5/2025 7:54 AM	Text Document
pressureData	2/5/2025 7:54 AM	Text Document
storyLoad	2/5/2025 7:54 AM	Text Document

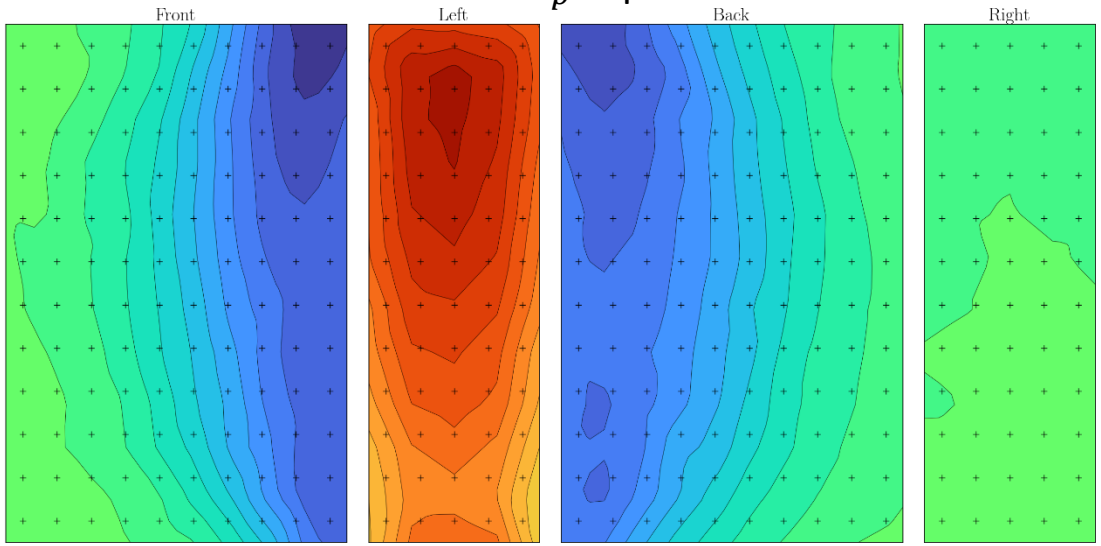
- **Data and Python script for Cp comparison plots:** `validation/`



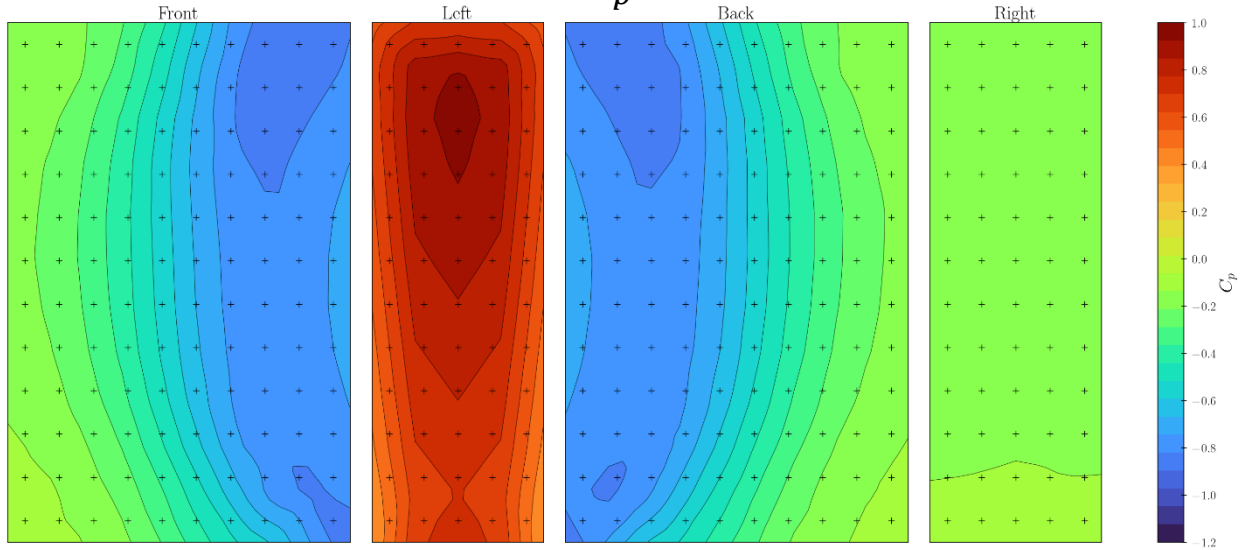
compare_exp_and_cfd	3/18/2025 12:16 AM	Python Source File
cp_comparison_mean	3/18/2025 12:16 AM	PNG File
cp_comparison_std	3/18/2025 12:16 AM	PNG File
cp_countour_cfd_mean	3/18/2025 12:16 AM	PNG File
cp_countour_cfd_std	3/18/2025 12:16 AM	PNG File
cp_countour_exp_mean	3/18/2025 12:16 AM	PNG File
cp_countour_exp_std	3/18/2025 12:16 AM	PNG File
T213_4_090_1	3/5/2025 3:29 PM	MATLAB Data

Tutorial-2: C_p plots and comparison with experiment

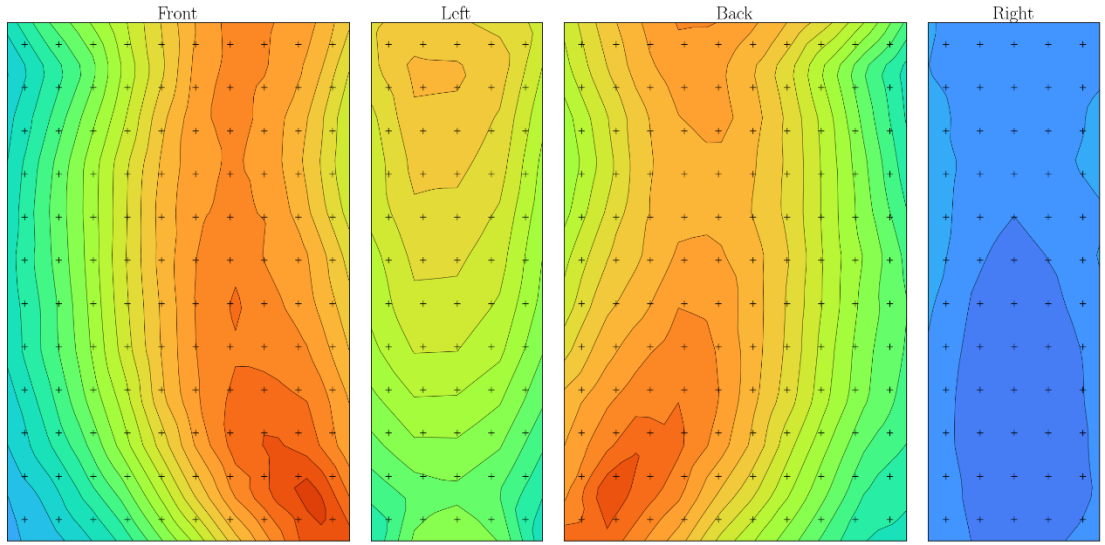
Mean C_p Experiment



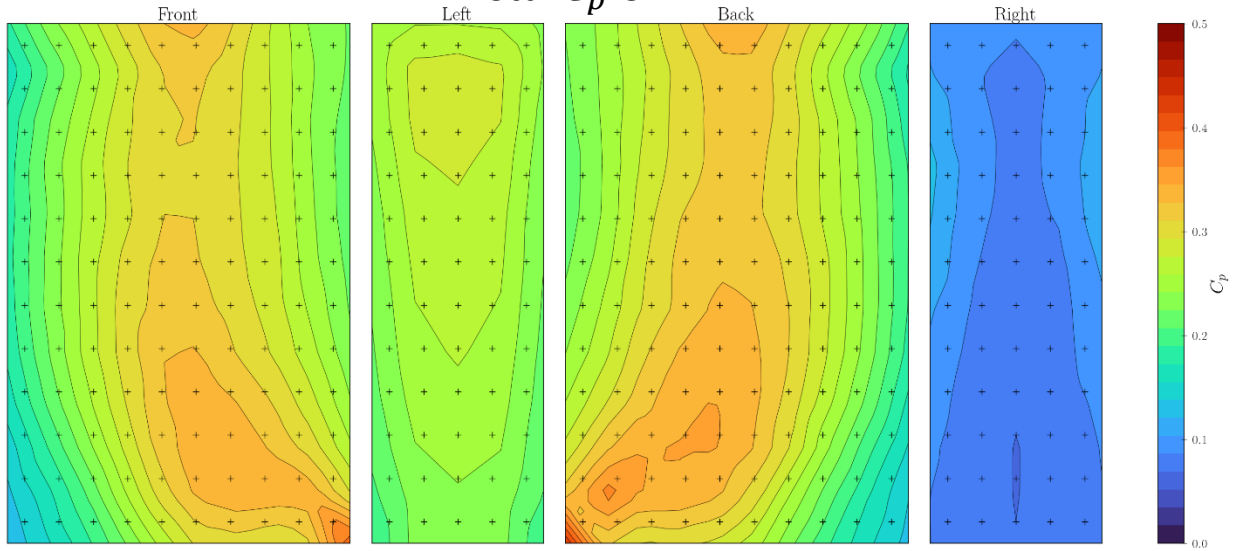
Mean C_p CFD



Std. C_p Experiment

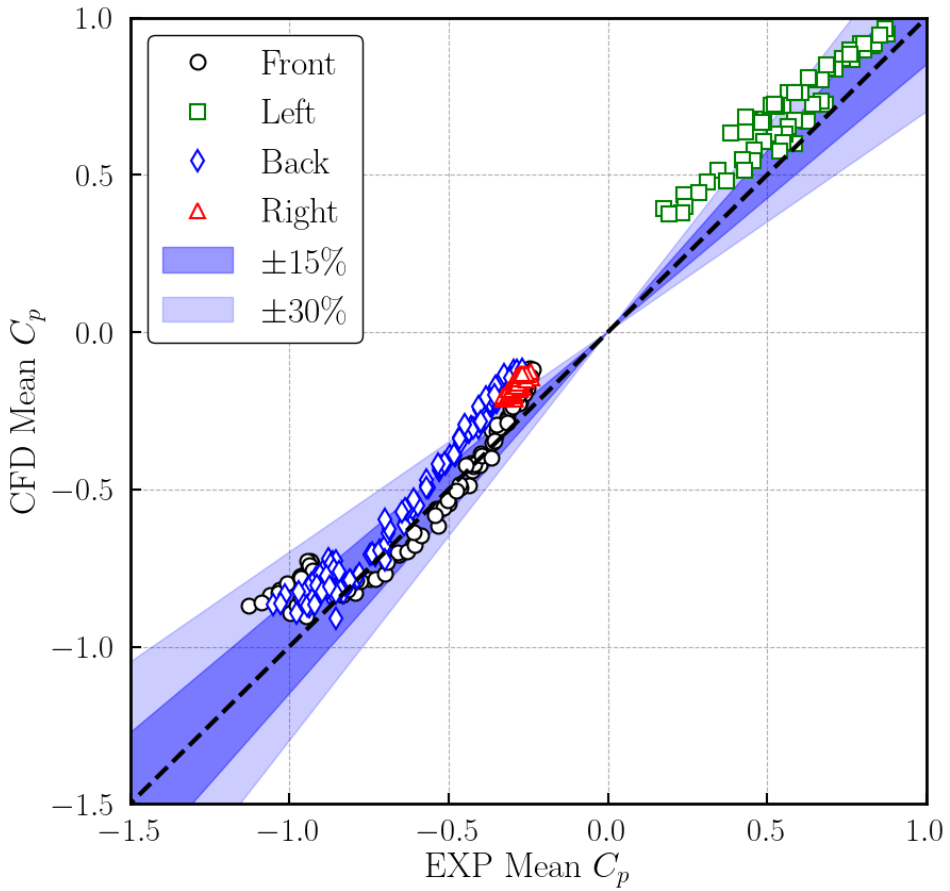


Std. C_p CFD



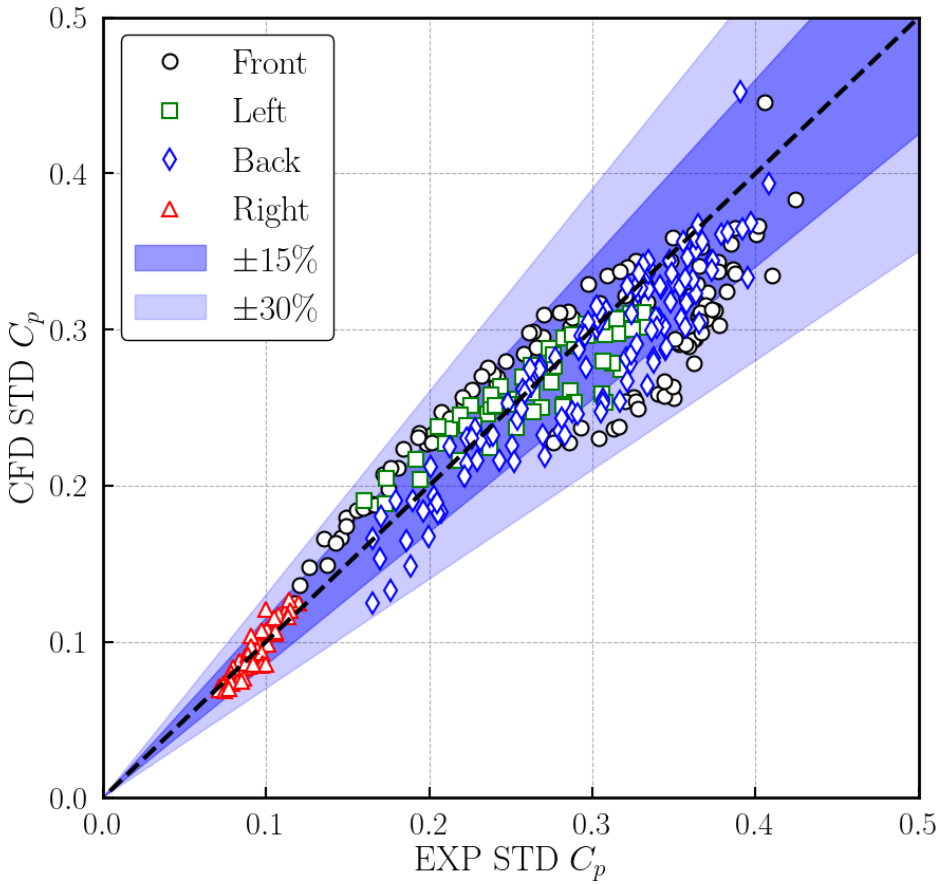
Tutorial-2: C_p plots and comparison with experiment

Mean C_p Comparison



Normalized average **error for mean Cp(%): 5.07**

Std. C_p Comparison



Normalized average **error for Std. Cp(%): 6.84**