

WE-UQ Tutorial

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

Abiy Melaku

Postdoctoral Researcher University of California, Berkeley

The SimCenter is supported by grants from the U.S. National Science Foundation (1612843 & 2131111).

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.





NSF award: CMMI 2131111

Outline

Introduction

- ✓ WE-UQ's CFD workflow
- \checkmark Target experimental data

CFD Setup in WE-UQ

- ✓ Geometry & domain setup
- \checkmark Mesh generation
- ✓ Boundary conditions
- ✓ Numerical setup
- ✓ Run simulation on DesignSafe

Results and post-processing

- ✓ Display results in WE-UQ
- \checkmark Flow visualization using Paraview
- \checkmark Compare with the experimental data



CFD workflow in WE-UQ: wind load simulation





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



ParaView



Tutorial-2: Simulation input and case files





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

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



Tutorial-2: Create computational domain



Tutorial-2: Generate mesh





Tutorial 2: Define boundary conditions





Tutorial-2: Specify numerical settings

Geometry		Mesh		Boundary Conditions	Numerical Setup	Monitoring		CFD-Results
Start Geometry Mesh	Boundary Conditions	Numerical Setup	Monitoring F	Results				
Turbulence Modeling								
Simulation Type:		LES		<u> </u>				
Sub-grid Scale Model: dvr Dy Model Coefficients:	namicKEqn namically calculated!			-	Select Turbulence Mod e.g., LES, RANS, DES	del		
Solver Selection Solver Type: Number of Non-Orthogonal Number Corrector Loops: Number of Outer Corrector L	Correctors: .oops:	pimpleFoam 1 2 1		• • •	Select Solver Type e.g. transient (pisoFoam, p	, steady state (impleFoam)	(SIMPL	E),
Duration and Timestep Duration: Time Step: Maximum Courant Number: Parallelization	34 0.0005 5.00		Calculate	🛛 🔿 Constant 💿 Adjustable	Set duration and time- number of processors	-step, Courant	Numb	er,



Tutorial-2: Monitor simulation data

Geometry		M	esh	\mathbf{i}	Boun Condi	idary itions	Numerical Setup		Monitoring		CFD-Results
Start Geometry Mesh Integrated Loads Base Loads Monitor Base Loads: Write Interval: Write Interval: Write Interval: Pressure Data Sample Pressure Data of Create a Grid of Samp Number of Points Along Number of Points Along Write Interval:	Boundary Condi 2 2 In the Building Sur ling Points Width: 5 Depth: 10 Height: 12 2	itions Numeri	ical Setup	Monitoring R Specification: Stories: In Distance (CFE al: Interpretent of the second s	Results Uniform Flor 30 0.01 2 Poort Sampling Po been Sampling Po	or Heigh	Select resul (aerodynam)	lts to nic b	o be monitored base and story l Monitor surfac at selected sar	oads) ce pre npling	ssure fluctuations points
Sample Flow Field Image: Sample Flow Field Image: Plane1 Y Image: Plane2 Z Flow Write Interval:	Add al point-X • 0 • 0	Plane point-Y 0 0	Remov point-Z 0.2 0.2	Ye Plane Start Time 1 1	End Time 3 V 3 V	Plane Field relocity • relocity •	Record flow fi planes for flow	iled o w vis	on selected sualization		



Tutorial-2: Check simulation results (integrated loads)

Geometry Mesh	Bound Condit	dary tions		Numeri	cal Setu	up Mo	nitoring	CFD-Results
Summary Time History								
Time History	1	Time 1	Force-X 1.81729	Force-Y -0.180946	Force-Z 0.608582	Moment-X Moment-Y 2.69202e-05 -0.0007504.	Moment-Z 8.71062e-05	
	2 3	1.001 1.002	1.62672 1.77406	0.360165	0.820304	1.44791e-07 -0.0007011. -1.69766e -0.0006660.	7.73577e-05 5.80223e-05	
2.45-1.45-1.45-1.45-1.45-1.45-1.45-1.45-1	4	1.003	1.90093	0.350655	0.510113	-3.31506e0.00062022 -7.07137e0.0005947.	4 4.47301e-05	
0.78	6 7	1.005 1.006	1.82832 1.78718	-0.529985 -0.419164	0.565048	-0.00010820.0005780. -0.0001233 -0.0005548.	3./285e-05 3.91354e-05	
0.11 1.0 9.3 17.5 25.8 34.0 Time	8 9 10	1.007 1.008 1.009	1.76234 1.75448	-0.535637 0.555203	0.588653	-0.00014340.0005116. -0.00015090.0004639. -0.00014310.0004143.	4.35624e-05 3.53201e-05	
Power Spectral Density	11 12	1.01 1.011	1.67419 1.61504	0.14991 0.106895	0.615514 0.647585	-0.00013400.00035150.00014300.0002858.	3.40782e-05 4.47066e-05	
le+00 le-01	13 14	1.012 1.013	1.44604 1.54884	0.141382 0.460106	0.769369 0.599267	-0.00013860.0002409. -0.00010430.0002301.	5.28014e-05 4.75281e-05	
1e-02 1e-03 g 1e-04	15 16	1.014 1.015	1.46816 1.33921	0.422222 -0.181962	0.622436 0.729443	-9.0454e-05 -0.00020179 -7.66322e -0.0001773.	9 4.00709e-05 3.87599e-05	
1e-05 1e-06 1e-07	17 18	1.016 1.017	1.31627 1.17612	0.229011 0.487414	0.725983 0.827535	-4.75411e -0.0001666. -9.11773e -0.0001535.	4.38797e-05 5.24051e-05	
1e-08 1e-09 0.1 1.0 10.0 100.0	19 20	1.018 1.019	1.40766 1.32634	0.511237	0.542806	1.84829e-05 -0.0001498. 1.8649e-05 -0.0001321. 1.75101 2.10015	6.30669e-05 7.40019e-05	
Frequency[Hz]	21	1.02	1.55123	0.684813	0.326973	-1.75401e9.42942e	8.2799e-05	

SimCenter WER

Tutorial-2: Check simulation results (point pressure)

	Results	CFD-	g	Monitorin	n <	al Setup	Numeric		Boundary Conditions		Mesh	try	Geome
Time History Time Cp-Probe													Summary Time History
0.31 0.324 0.125455 0.268102 0.50914 0.229208 0.626399 0.42 0.0068934 0.376468 0.19158 0.34267 0.642450 0.42 0.00911472 0.59754 0.193745 0.48049 0.993153 0.42 0.00911472 0.59754 0.28927 0.480697 0.99315 0.48049 0.993153 0.42 0.44 0.19922 0.49327 0.480697 0.89882 0.993153 0.480697 0.480697 0.480697 0.480892 0.993153 0.480697 0.89882 0.993159 0.480697 0.480697 0.4809567 0.489953 0.680678 0.34 0.31311 0.70122 1.10147 1.2439 0.89587 0.4809 0.38476 1.0121 1.1437 0.995123 0.34 0.31311 0.70112 1.0805 0.81953 0.636878 0.34 0.31311 0.70227 1.01476 0.995123 0.34 0.31311 0.70212 1.0147 1.2439 0.638671 0.35 0.544056 1.1391 0.947228 1.0176 0.995123<	Cp-Probe6	Cp-Probe5	Cp-Probe4	Cp-Probe3	Cp-Probe2	Cp-Probe1	Time				Time History		
 2 3.42 0.006934 0.37648 0.91818 0.34267 0.64348 0.991472 0.99754 0.99754 0.99754 0.99754 0.89882 0.963313 0.34267 0.64643 0.96313 0.991472 0.99754 0.406267 0.89882 0.92508 0.34 0.34145 0.406267 0.89882 0.92508 0.344 0.34345 0.406267 0.89882 0.92508 0.344 0.31181 0.706112 0.10065 0.81993 0.868678 0.346 0.313181 0.706112 0.10147 0.40258 0.80869 0.31181 0.947028 0.947028 0.947028 0.94714 0.947028 0.947028 0.9174 0.92144 0.92144 0.92144 0.92144 0.92144 0.92144 0.92144 0.92144 0.92144 0.92142 0.92142 0.92142 0.92142 0.92142 0.92142 0.92142 0.92142 0.92144 0.921424 0.92142 0.92142 0	-0.925689	-0.626399	-0.292028	-0.50914	-0.268102	-0.125455	0.341	1			Time History		0.81
0.07 0.043 0.0911472 0.09754 0.193754 0.04804 0.08463 0.07 0.05754 0.02875 0.0287 0.0176 0.0287	-0.828693	-0.643436	-0.344267	-0.198158	-0.376468	-0.0068934	0.342	2					
4 0.344 0.199622 0.49293 0.2829 0.632498 0.99931 4 0.345 0.358163 0.299387 0.406667 0.808982 0.92508 4 0.34 0.358163 0.299387 0.406667 0.808928 0.92508 4 0.34 0.358163 0.299387 0.40667 0.40929 0.40667 0.808928 0.92508 4 0.34 0.358163 0.299387 0.40667 0.408982 0.92508 5 0.34 0.358163 0.299387 0.40667 0.408982 0.92508 5 0.347 0.34515 0.538671 0.343455 0.64029 1.0147 1.2489 0.80801 5 0.347 0.313181 0.70512 1.0147 1.2489 0.8081 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.81951 0.82251 1.3219 0.82251 1.3219 0.82251 1.3219 0.32191 1.3219 0.3212	-0.777016	-0.864563	-0.48049	-0.193745	-0.59754	-0.0911472	0.343	3	and a subscription to with a subscription of	ومستركبهم والملجي الألمس أم التقص	والمتالية العروانة إوم الاسالة التار	haadiinda ahaada ahaada ahaanka	0.07-14-14-14-14-14-14-14-14-14-14-14-14-14-
5 0.345 -0.358163 -0.29387 0.406267 -0.89882 0.92508 -1.42 -2.16 0.3 8.8 17.2 25.6 34.0 Time	-0.671464	-0.969313	-0.632498	-0.2829	-0.492963	-0.199622	0.344	4	An de la de la constante de la	All card to bin Attend the rest of	indi di Milandi Angela	al a na dhe dhi ta' ka a bhfaith	
0 0.346 0.588671 0.343455 0.643029 1.09572 0.78875 1.102 0.3 8.8 17.2 25.6 340 0.348 0.706112 1.0405 0.819953 0.636878 0.34 0.347 0.3476 1.01621 1.1437 0.934216 0.8263 0.34 0.35 0.64056 1.13391 0.947028 1.01176 0.96123 0.35 0.64056 1.13391 0.947028 1.01176 0.95123 0.35 0.64056 1.13391 0.947028 1.01176 0.95123 10 0.35 0.64056 1.13391 0.947028 1.01176 0.95123 11 0.35 1.0584 0.978328 0.978328 0.978328 0.978508 0.91478 12 0.35 1.0131 0.904028 1.0144 0.927393 1.1044 0.927393 16.04 0.978328 1.0144 0.920249 1.0506 1.07959 1.3251 16.05 1.606 0.691257 0.62827 0.702183 0.669137 1.66617 16.06 <td>-0.684901</td> <td>-0.925058</td> <td>-0.889882</td> <td>-0.406267</td> <td>-0.299387</td> <td>-0.358163</td> <td>0.345</td> <td>5</td> <td></td> <td></td> <td></td> <td></td> <td>-0.67</td>	-0.684901	-0.925058	-0.889882	-0.406267	-0.299387	-0.358163	0.345	5					-0.67
-1.42 -1.42 <td< td=""><td>-0.898938</td><td>-0.78875</td><td>-1.09572</td><td>-0.643029</td><td>-0.343455</td><td>-0.588671</td><td>0.346</td><td>6</td><td rowspan="3"></td><td>8 </td></td<>	-0.898938	-0.78875	-1.09572	-0.643029	-0.343455	-0.588671	0.346	6		8			
1 0.3 8.8 17.2 25.6 34.0 1 0.34 0.3476 1.01621 1.14337 0.94216 0.8263 1 0.35 0.644056 1.1331 0.947028 1.01671 0.917932 0.90178 1 0.05 0.548091 1.01621 1.04433 0.917028 1.01671 0.917932 0.901783 1 0.05 0.51384 0.901782 0.977932 1.01641 0.901783 0.901783 1 0.05 0.513864 0.901825 0.977932 1.01641 0.901783 1 0.05 0.513864 0.640552 0.70183 0.69173 1.02225 1.3293 1 0.05 0.513864 0.645325 0.720183 0.689173 1.63617 1 0.979 0.513864 0.637376 0.669638 1.14232 0.95013 1 0.979 0.513864 0.637365 0.69339 1.28291 0.53201 1 0.979 0.59158 0.554744 0.86913 1.1041 0.90712	-1.34518	-0.850008	-1.24839	-1.10147	-0.759506	-0.78233	0.347	7			-1.42		
2.16 0.3 8.8 17.2 25.6 30.4 Time 0.3476 0.10121 0.1437 0.94216 0.6263 10 0.5 0.64056 1.13310 0.94708 0.10170 0.94216 0.96123 11 0.51 0.64056 1.13310 0.94208 0.901783 0.901783 12 0.352 0.70820 0.97920 0.10160 0.907930 1.1040 0.92793 13 0.640 0.91257 0.6287 0.97924 0.969523 0.3520 1.1031 0.90178 1.2598 14 0.354 0.61257 0.62874 0.699153 0.62814 0.699153 0.629134 0.629134 1.4232 0.3520 1.3121 15 0.351 0.439915 0.62825 0.70183 0.699153 0.691384 0.69131 1.4222 1.3910 16 0.561 0.439915 0.63914 0.69139 1.4220 0.59131 0.69139 1.4220 0.59131 16 0.5914 0.59144 0.59140 0.59141 0.502011 1.0011 0.59171 <td>-1.10869</td> <td>-0.636878</td> <td>-0.819953</td> <td>-1.08065</td> <td>-0.706112</td> <td>-0.313181</td> <td>0.348</td> <td>8</td> <td></td> <td></td> <td></td>	-1.10869	-0.636878	-0.819953	-1.08065	-0.706112	-0.313181	0.348	8					
100 0.55 0.644056 1.1331 0.947028 1.0176 0.965123 11 0.511 0.588941 1.0443 0.813006 0.978508 0.901478 12 0.522 1.07832 0.978425 0.979323 1.0140 0.927393 12 0.521 0.51364 0.61257 0.62827 0.709274 0.666523 1.3291 14 0.551 0.513864 0.64325 0.720183 0.689173 1.62817 15 0.551 0.63091 0.65234 0.669125 0.720183 0.689173 1.63617 16 0.551 0.61307 0.62838 0.679047 0.82225 1.39705 17 0.551 0.439871 0.63787 0.669383 1.1422 0.55017 18 0.551 0.45915 0.651344 0.651340 0.65	-1.1411	-0.8263	-0.934216	-1.14337	-1.01621	-0.38476	0.349	9	.5.6 34.0	25	17.2	8.8	-2.16
11 0.51 0.88891 -1.0443 0.81300 0.97850 0.90147 12 0.52 -1.07832 0.97825 0.97932 1.0140 0.927393 14 0.51 0.51864 0.61257 0.62827 0.70182 0.669137 0.639137 0.669137 0.62827 0.70183 0.69173 0.62817 0.62827 0.70183 0.68917 1.6261 150 6.05 0.63014 0.61037 0.62828 0.67047 0.62827 0.690383 0.69173 0.62828 0.67047 0.62827 0.690383 0.69173 0.69174 0.6017	-1.04472	-0.965123	-1.01176	-0.947028	-1.13391	-0.644056	0.35	10			Time		
1000 10100 10100	-1.07132	-0.901478	-0.978508	-0.813006	-1.04443	-0.888941	0.351	11					
1-02 0.353 -1.11341 -0.920249 -1.05076 -1.07959 -1.23593 1-03 1-04 0.351 -0.691257 -0.62827 -0.749274 -0.696532 -1.36224 1-04 0.355 -0.513864 -0.645325 -0.720183 -0.69173 -1.63617 1-05 1-05 0.356 -0.439871 -0.62827 -0.696538 -1.14232 -0.956013 1-04 0.357 -0.439871 -0.637876 -0.690538 -1.14232 -0.956013 1-07 0.359 -0.451344 -0.595305 -0.693539 -1.28291 -0.732377 1-08 0.359 -0.459915 -0.554744 -0.826041 -1.10041 -0.699711	-1.40558	-0.927393	-1.1044	-0.977932	-0.978425	-1.07832	0.352	12		sity	Power Spectral Deps		
1e-02 -0.691257 -0.62827 -0.749274 -0.696532 -1.36224 1e-03 -0.64 -0.61257 -0.62827 -0.749274 -0.696532 -1.3627 1e-04 -0.64 -0.61257 -0.62827 -0.749274 -0.696532 -1.3627 1e-05 -0.66 -0.61257 -0.61257 -0.62837 -0.720183 -0.698173 -1.63617 1e-05 -0.66 -0.60391 -0.62838 -0.679047 -0.82225 -1.39705 1e-05 -0.66 -0.63876 -0.695391 -0.696384 -1.14232 -0.956013 1e-05 -0.67 -0.439871 -0.637876 -0.695399 -1.28291 -0.732377 1e-05 -0.69 -0.59154 -0.554744 -0.826041 -1.10041 -0.639711 1e-05 -0.69 -0.554744 -0.826041 -1.10041 -0.639711	-1.68813	-1.23593	-1.07959	-1.05076	-0.920249	-1.11341	0.353	13		international design and the second second	l M. B. Jadd als I f		
1e-03 1c-04 0.355 0.513864 0.645325 0.720183 0.689173 1.63617 1e-04 0.356 0.40309 0.62838 0.679047 0.82225 1.39705 1e-06 0.356 0.45325 0.669638 0.14232 0.956013 1e-07 0.357 0.45915 0.557744 0.62834 0.62834 1.10210 0.639711	-1.04697	-1.36224	-0.696532	-0.749274	-0.62827	-0.691257	0.354	14	A Providence in the second sec	ana kanganan menangkana. Malawa		\times	1e-02
1e-04 1e-05 1e-06 1e-06 <td< td=""><td>-0.744138</td><td>-1.63617</td><td>-0.689173</td><td>-0.720183</td><td>-0.645325</td><td>-0.513864</td><td>0.355</td><td>15</td><td>The second second</td><td>Alexandra (Malinia) da sera da se</td><td></td><td>V 4</td><td>1e-03</td></td<>	-0.744138	-1.63617	-0.689173	-0.720183	-0.645325	-0.513864	0.355	15	The second second	Alexandra (Malinia) da sera da se		V 4	1e-03
2 1e-05 1e-06 1e-07 1e-07 1e-08 1e-08	-0.725687	-1.39705	-0.822225	-0.679047	-0.62838	-0.40309	0.356	16	linte to				1e-04
1e-06 1e-07 1e-08 0.358 0.451434 0.595305 0.693539 1.28291 0.732377 1e-08 1e-08 <td>-0.674646</td> <td>-0.956013</td> <td>-1.14232</td> <td>-0.669638</td> <td>-0.637876</td> <td>-0.439871</td> <td>0.357</td> <td>17</td> <td></td> <td></td> <td></td> <td></td> <td>2 1e-05</td>	-0.674646	-0.956013	-1.14232	-0.669638	-0.637876	-0.439871	0.357	17					2 1e-05
1e-07 1e-08	-0.613305	-0.732377	-1.28291	-0.693539	-0.595305	-0.451434	0.358	18				1e-06	
16.08	-0.639054	-0.639711	-1.10041	-0.826041	-0.554744	-0.459915	0.359	19					1e-07
20 0.36 -0.34729 -0.426758 -0.887405 -0.660795 -0.439272	-0.559346	-0.439272	-0.660795	-0.887405	-0.426758	-0.34729	0.36	20					1e-08
0.1 1.0 10.0 100.0 21 0.361 -0.160633 -0.337437 -0.672852 -0.352818 -0.298492	-0.49161	-0.298492	-0.352818	-0.672852	-0.337437	-0.160633	0.361	21	100.0	10.0 Hzl	1.0	0.1	



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	Туре
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
<pre>cp_countour_cfd_std</pre>	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
1 T213_4_090_1	3/5/2025 3:29 PM	MATLAB Data



Tutorial-2: C_p plots and comparison with experiment







Tutorial-2: C_p plots and comparison with experiment

Mean C_p Comparison

Std. C_p Comparison



Normalized average error for mean Cp(%): 5.07

SimCenter WERI



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