INTRO OV3 WIND

Ir. Huib Plomp
Assistant Professor Urban physics
Chair of Building Physics

Architectural and Urban Design
&
Wind

Architectural Aerodynamics

Architectural Aerodynamics

Klimaat van Nederland 2

J. Wieringa en P. J. Rijkoort

Windklimaat van Nederland

met medewerking van:
R. Agterberg
A. Denkema
J. M. Koopstra
B. Oemraw
G. J. Yperlaan
B. Zwart

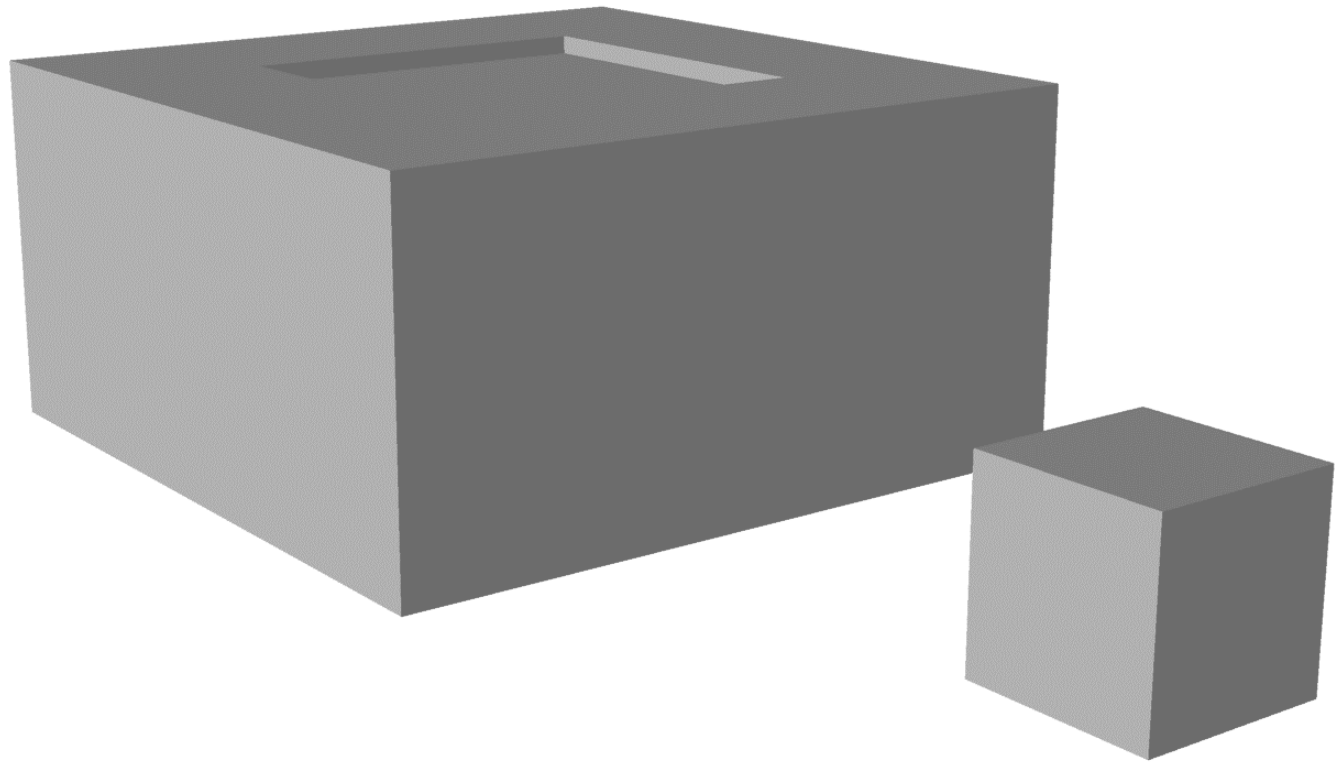
Staatsuitgeverij, Den Haag 1983

RESEARCH QUESTION(s)
SIMULATION MODELING
WIND ENGINEERING
METEOROLOGY
ARCHITECTURAL AERODYNAMICS Modelling
RESULTS
REFERENCES

RESEARCH QUESTION

Architectural Aerodynamics

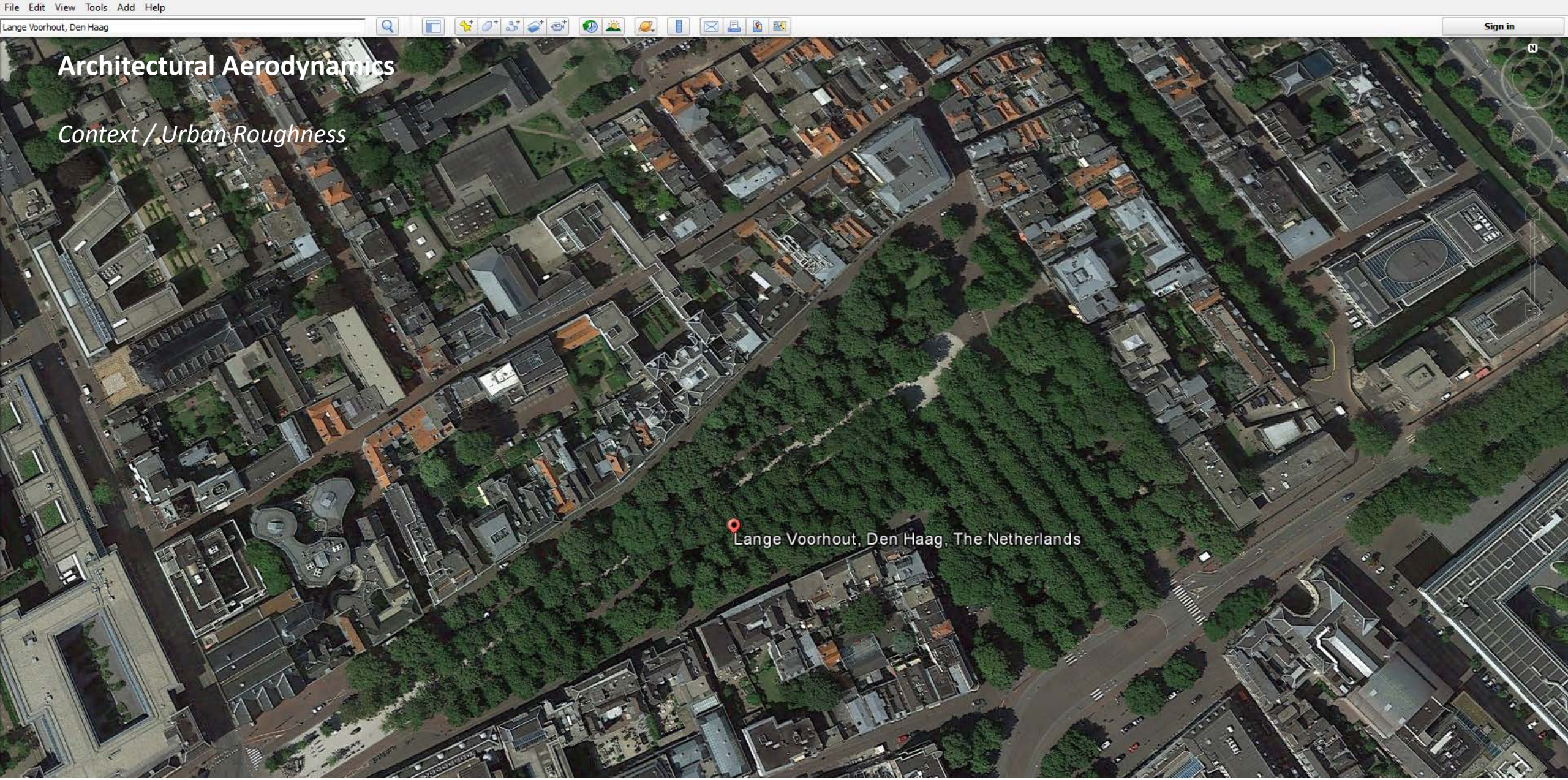
Wind flow and Geometries



TWO VOLUMES. Large volume 40x40x20 m **(Escher Museum)** ***and small volume 10x10x10 m*** **(Entrance building)**

Architectural Aerodynamics

Context / Urban Roughness



THE HAGUE / Lange Voorhout

Architectural Aerodynamics / Design

Design development / Design process

Volume model 10 x 10 x 10

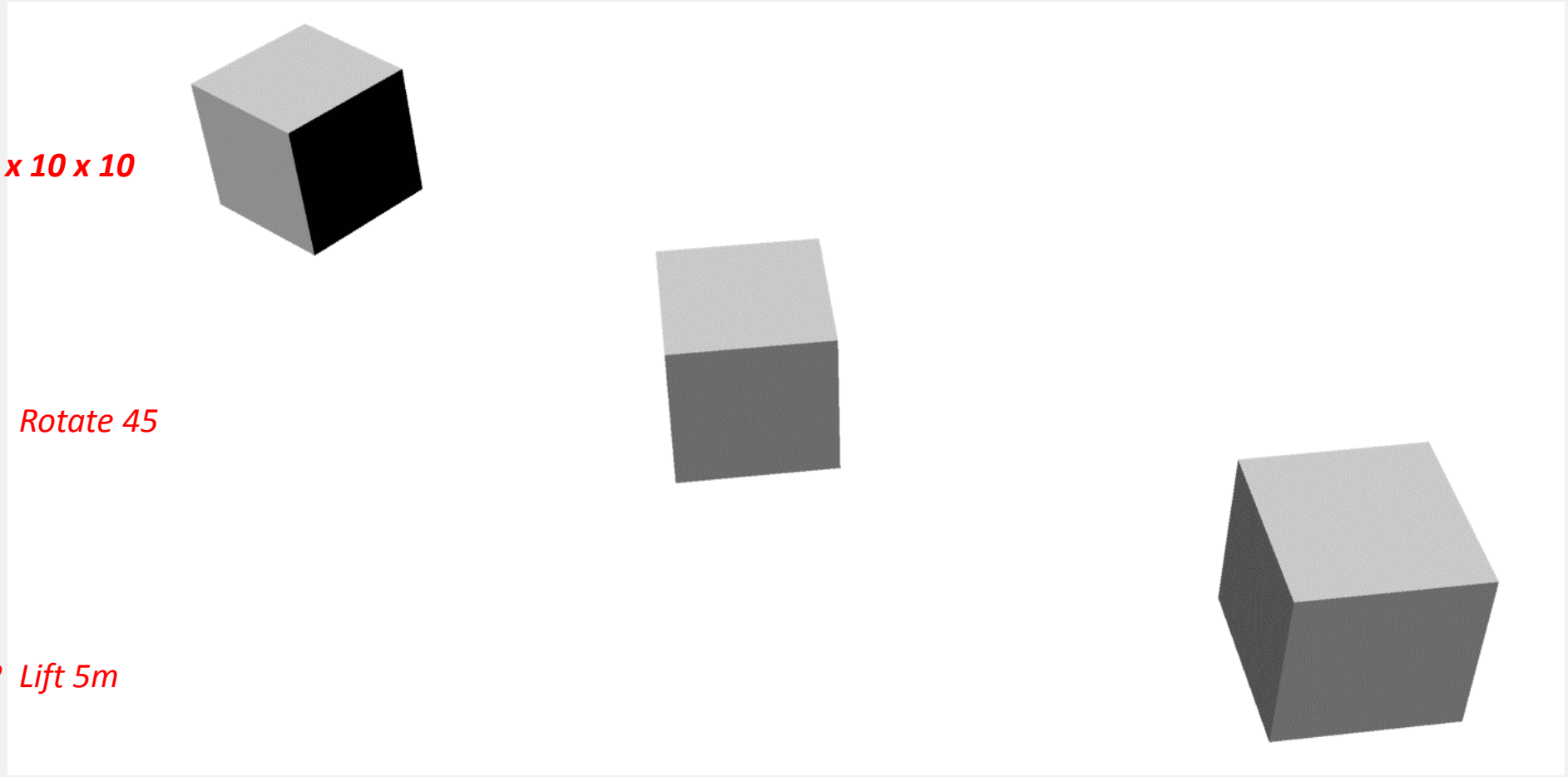
+

> *Transformatie 1 Rotate 45*

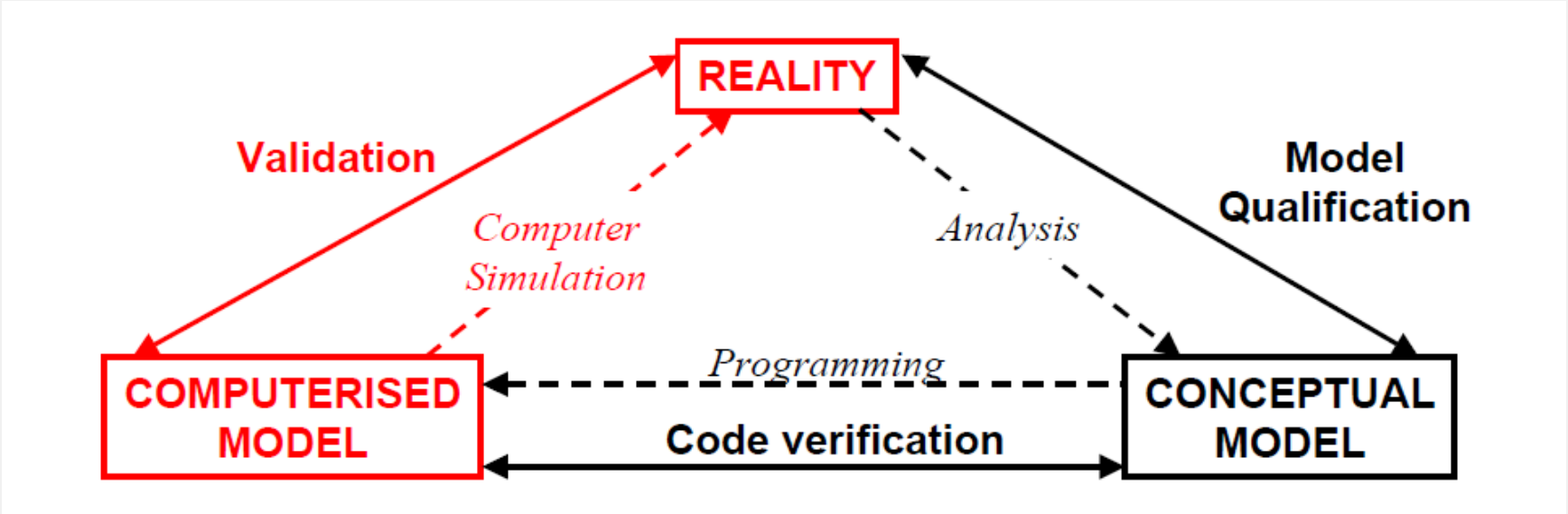
+

> *Transformatie 2 Lift 5m*

+



Simulation modeling / Quality assurance



COST action 732 Best Practice Guideline for the CFD simulation of flows in the urban environment

Simulation modeling

Simulation modeling has become an essential tool for analyzing anticipated performance, validating designs, demonstrating and visualizing operations, testing hypotheses, and performing many other analyses. It is the preferred tool in a variety of industries and in some industries, it is even required prior to all major capital investments.

The underlying assumption is that simulation modeling is the correct tool for the problem that you are trying to solve.

Banks J , Gibson R. (1997) Ten Rules! Do not simulate when..

SIMULATION MODELING

Do not simulate when ..

TEN RULES!

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (1) The problem can be solved using "common sense analysis"

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (2) The problem can be solved analytically (using a closed form)

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (3) It's easier to change or perform direct experiments on the real system

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (4): There aren't proper resources available for the project

Although almost every simulation project has many "qualitative" benefits, the expense of the model, data collection and analysis is usually justified by the expected quantitative stake.

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (5): There aren't proper resources available for the project

Primary resources required to complete a successful simulation project include people, software/computers, and money.

The most critical component in any successful simulation project is people–experienced analysts who understand the problem, select the proper level of detail, translate it into a simulation model requirement, program the model, etc.

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (6): There isn't enough time for the model results to be useful

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (7): There is no data not even estimates

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (8): The model can't be verified or validated

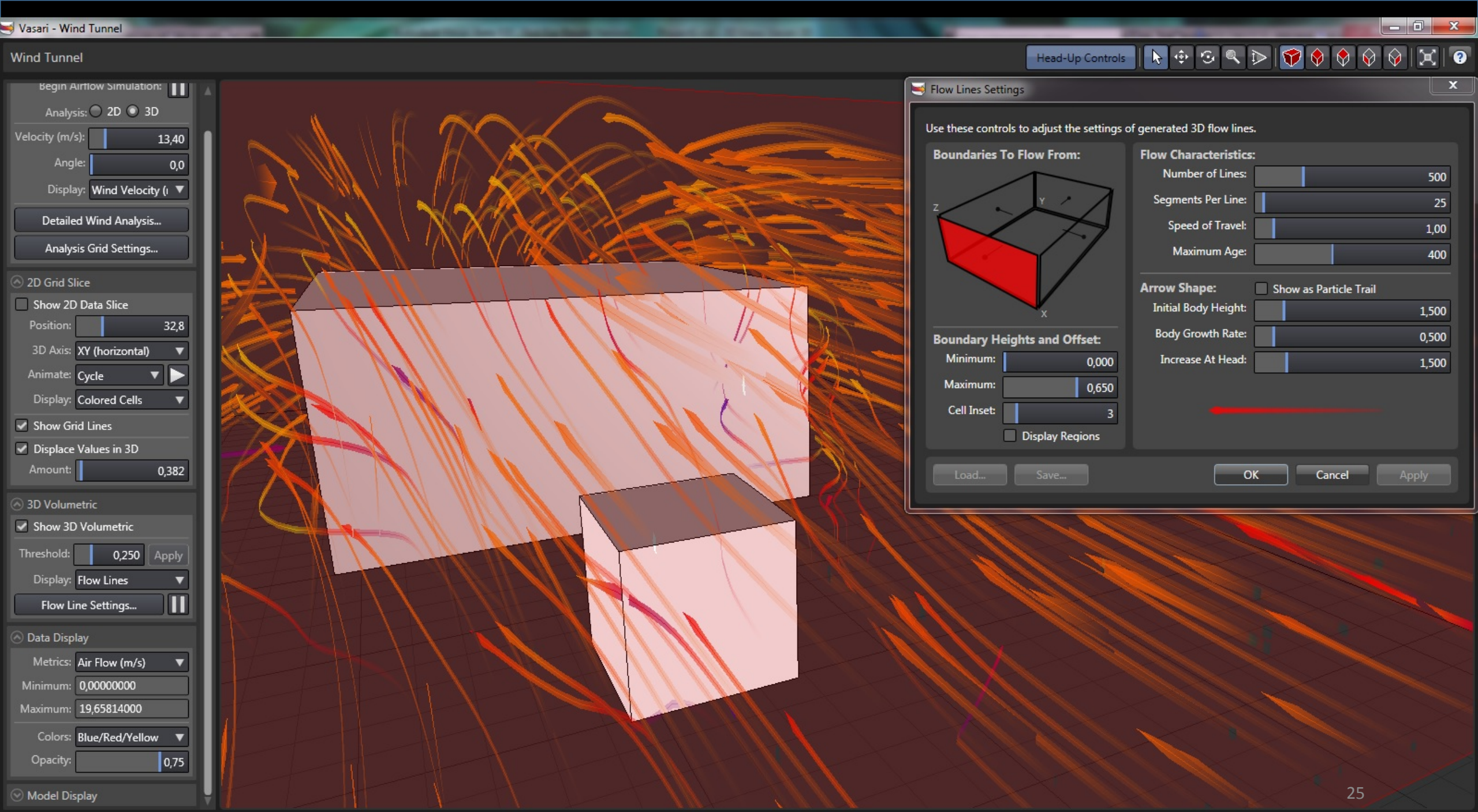
Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

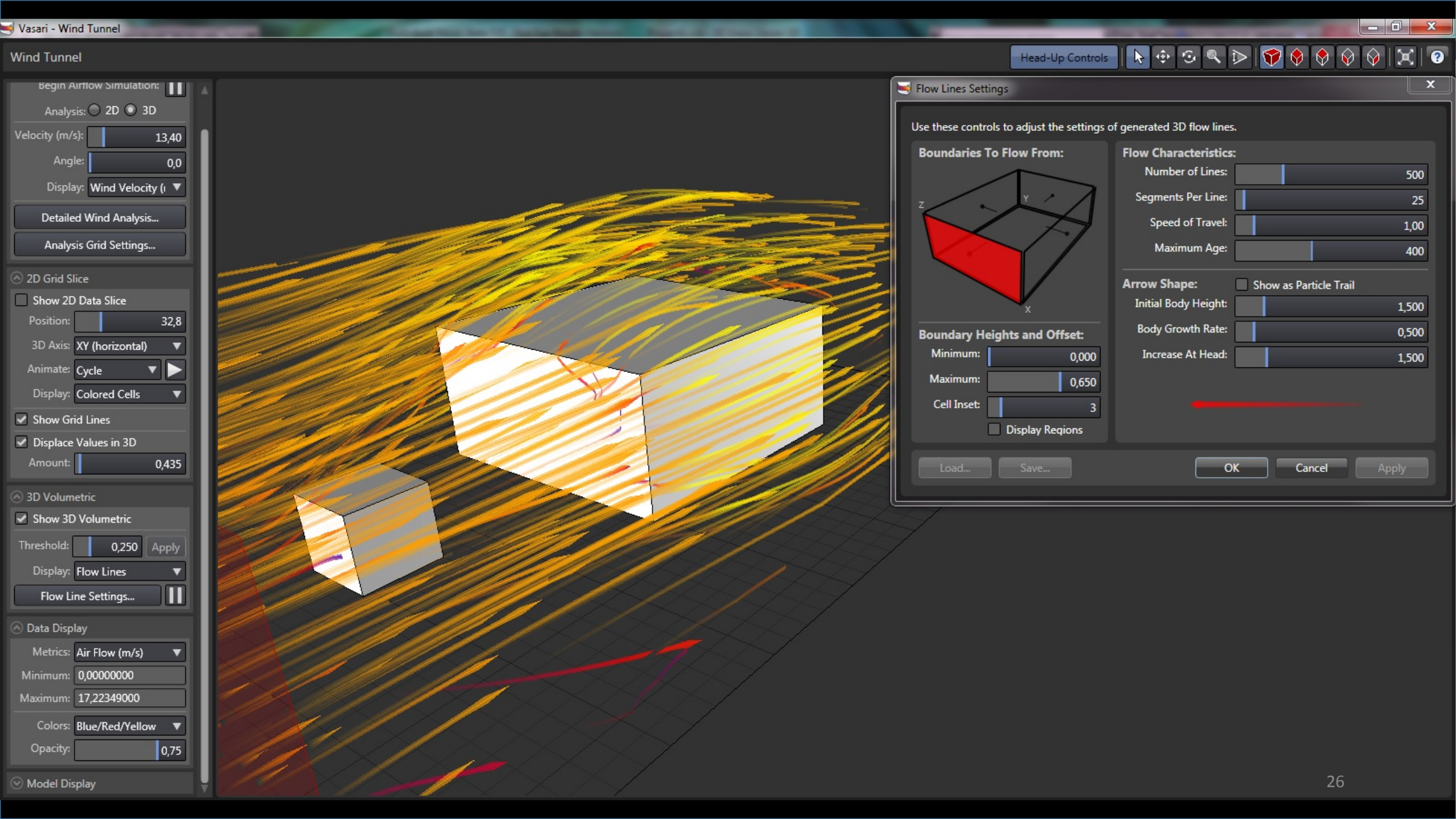
Rule (9): Project expectations can't be met

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!

Rule (10): If system behavior is too complex, or can't be defined

Banks J , Gibson R. (1997) Do not simulate when .. TEN RULES!!


Vasari - Wind Tunnel
Wind Tunnel
Head-Up Controls
Begin Airflow Simulation:
Analysis: 2D 3D
Velocity (m/s): 13,40
Angle: 0,0
Display: Wind Velocity (
Detailed Wind Analysis...
Analysis Grid Settings...
2D Grid Slice
Show 2D Data Slice
Position: 32,8
3D Axis: XY (horizontal)
Animate: Cycle
Display: Colored Cells
Show Grid Lines
Displace Values in 3D
Amount: 0,382
3D Volumetric
Show 3D Volumetric
Threshold: 0,250
Apply
Display: Flow Lines
Flow Line Settings...
Data Display
Metrics: Air Flow (m/s)
Minimum: 0,00000000
Maximum: 19,65814000
Colors: Blue/Red/Yellow
Opacity: 0,75
Model Display
Flow Lines Settings
Use these controls to adjust the settings of generated 3D flow lines.
Boundaries To Flow From:
Z
Y
X
Boundary Heights and Offset:
Minimum: 0,000
Maximum: 0,650
Cell Inset: 3
Display Regions
Flow Characteristics:
Number of Lines: 500
Segments Per Line: 25
Speed of Travel: 1,00
Maximum Age: 400
Arrow Shape:
Show as Particle Trail
Initial Body Height: 1,500
Body Growth Rate: 0,500
Increase At Head: 1,500
Load...
Save...
OK
Cancel
Apply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Display: Colored Cells
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Displace Values in 3D
Amount: 0,435
3D Volumetric
Show 3D Volumetric
Threshold: 0,250
Apply
Display: Flow Lines
Flow Line Settings...
Data Display
Metrics: Air Flow (m/s)
Minimum: 0,00000000
Maximum: 17,22349000
Colors: Blue/Red/Yellow
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Use these controls to adjust the settings of generated 3D flow lines.
Boundaries To Flow From:
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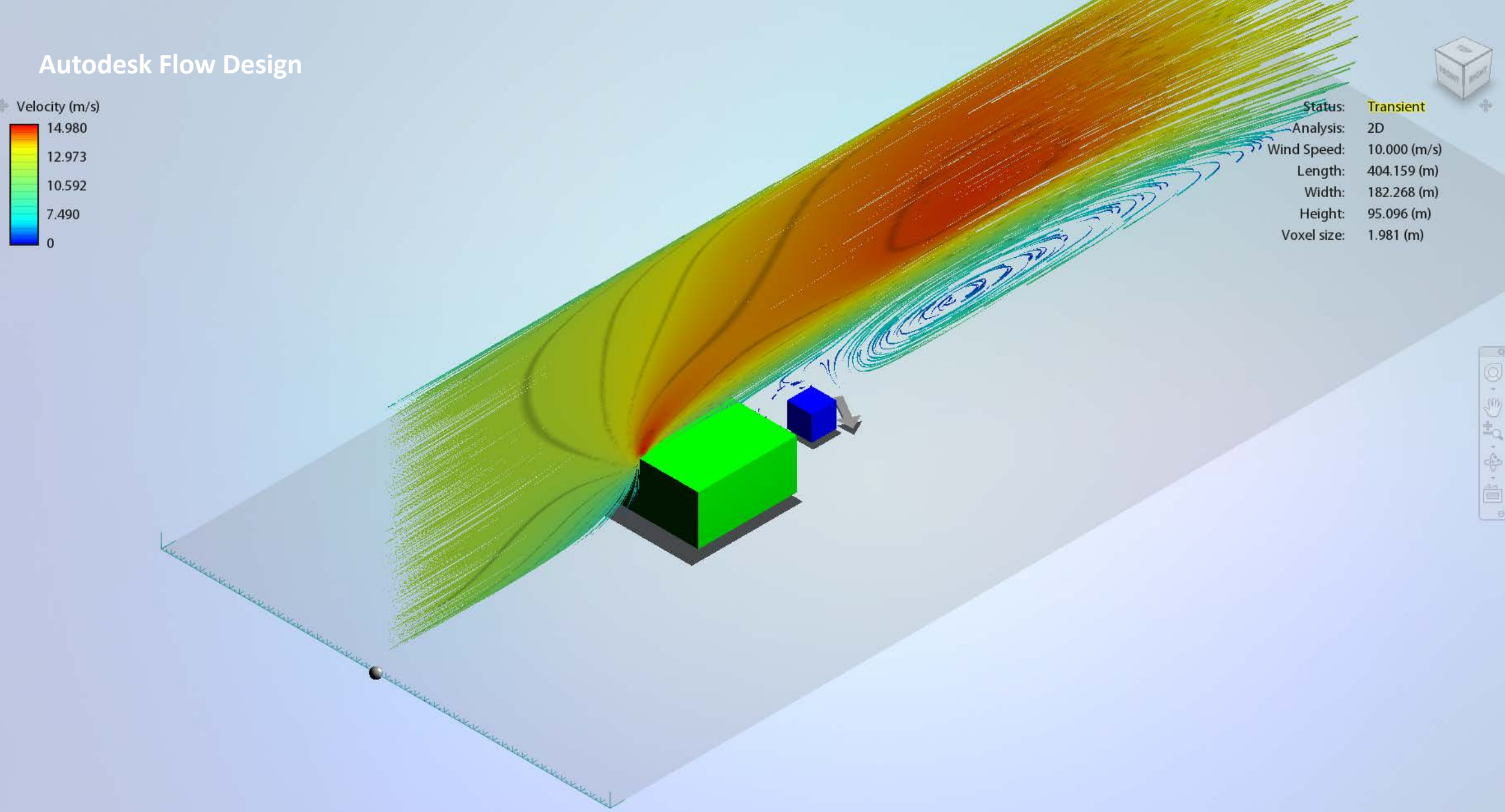
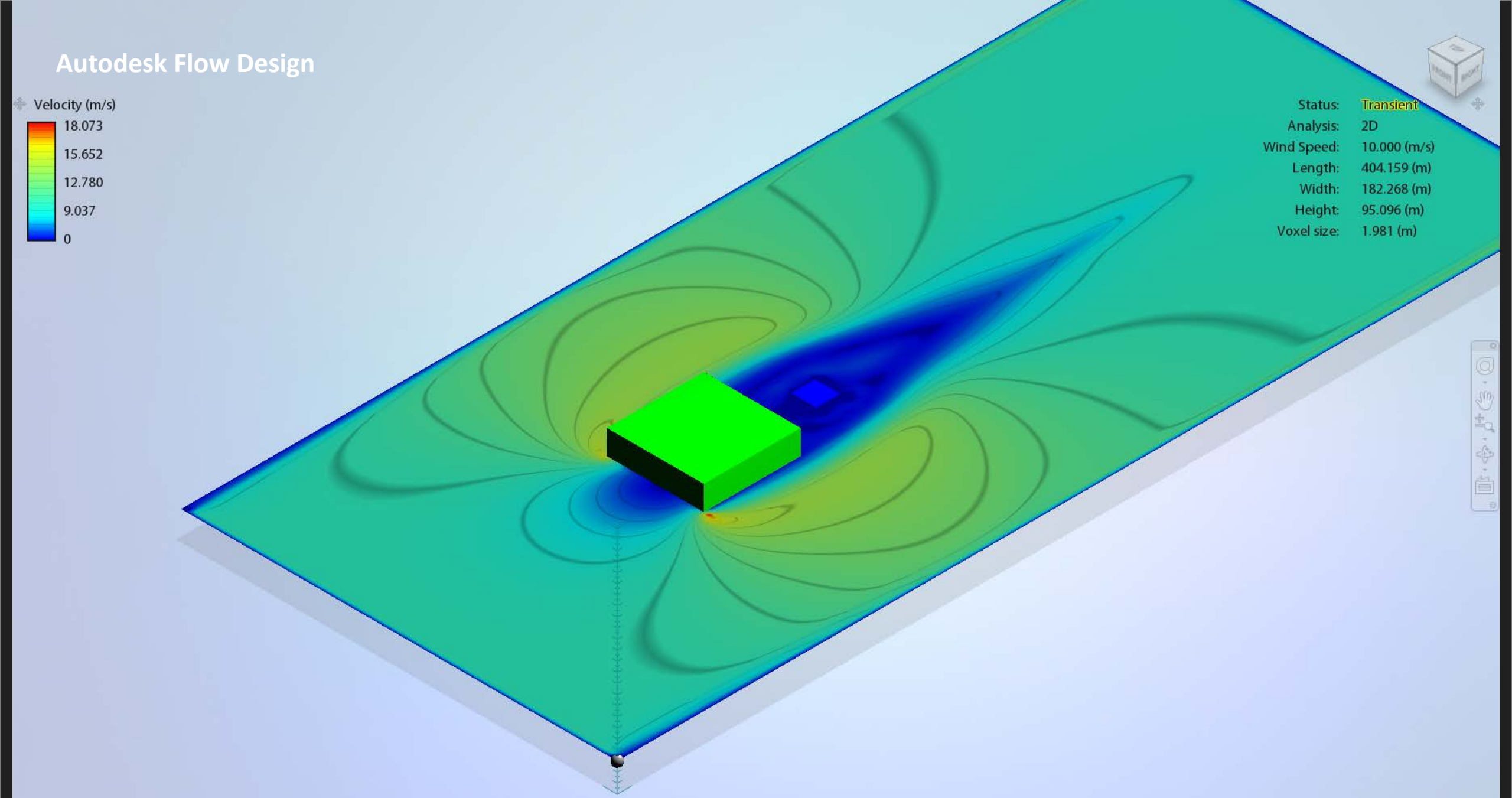
Boundary Heights and Offset:
Minimum: 0,000
Maximum: 0,650
Cell Inset: 3
Display Regions
Flow Characteristics:
Number of Lines: 500
Segments Per Line: 25
Speed of Travel: 1,00
Maximum Age: 400
Arrow Shape:
Show as Particle Trail
Initial Body Height: 1,500
Body Growth Rate: 0,500
Increase At Head: 1,500
Load...
Save...
OK
Cancel
Apply

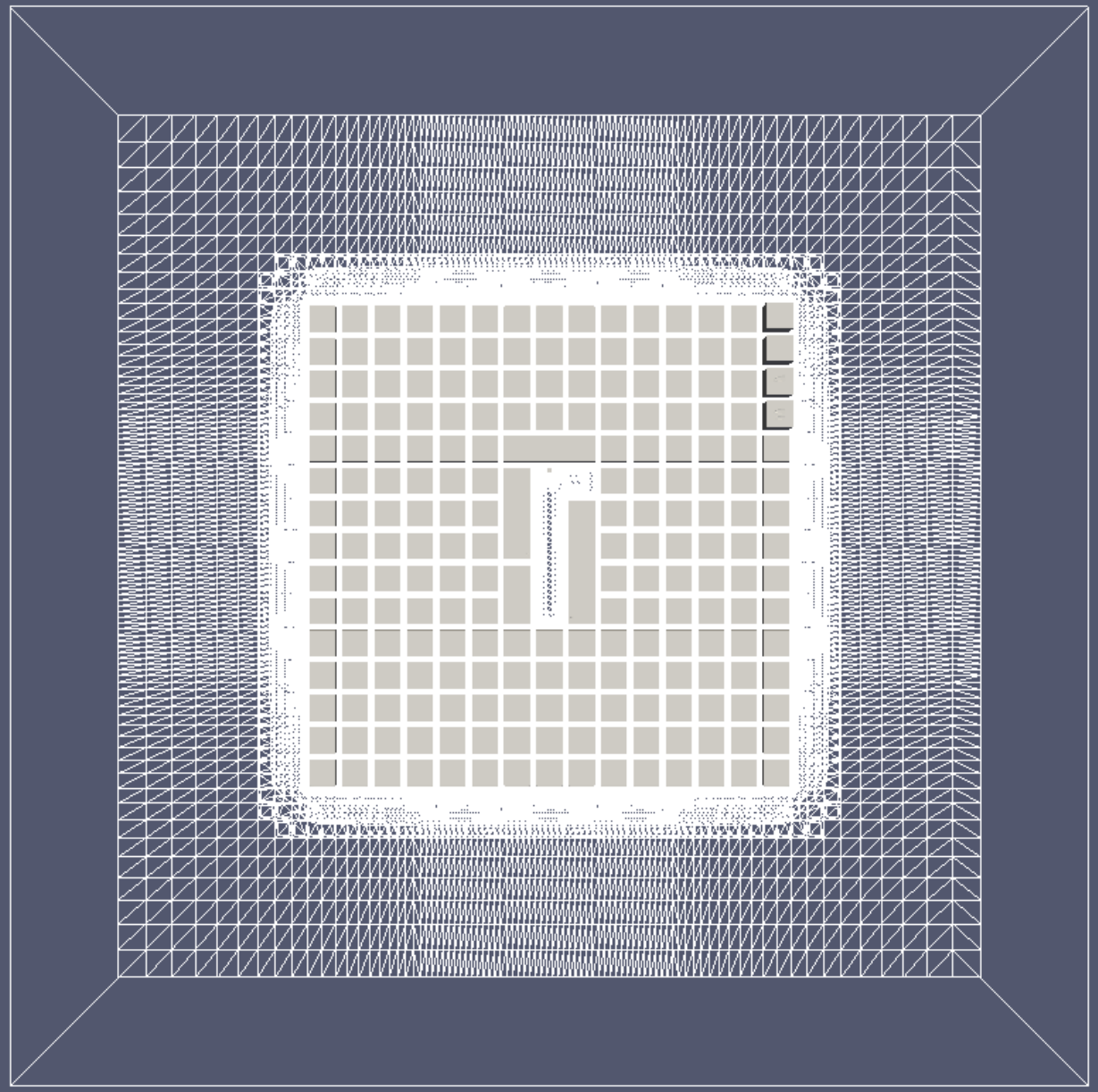
Autodesk Flow Design

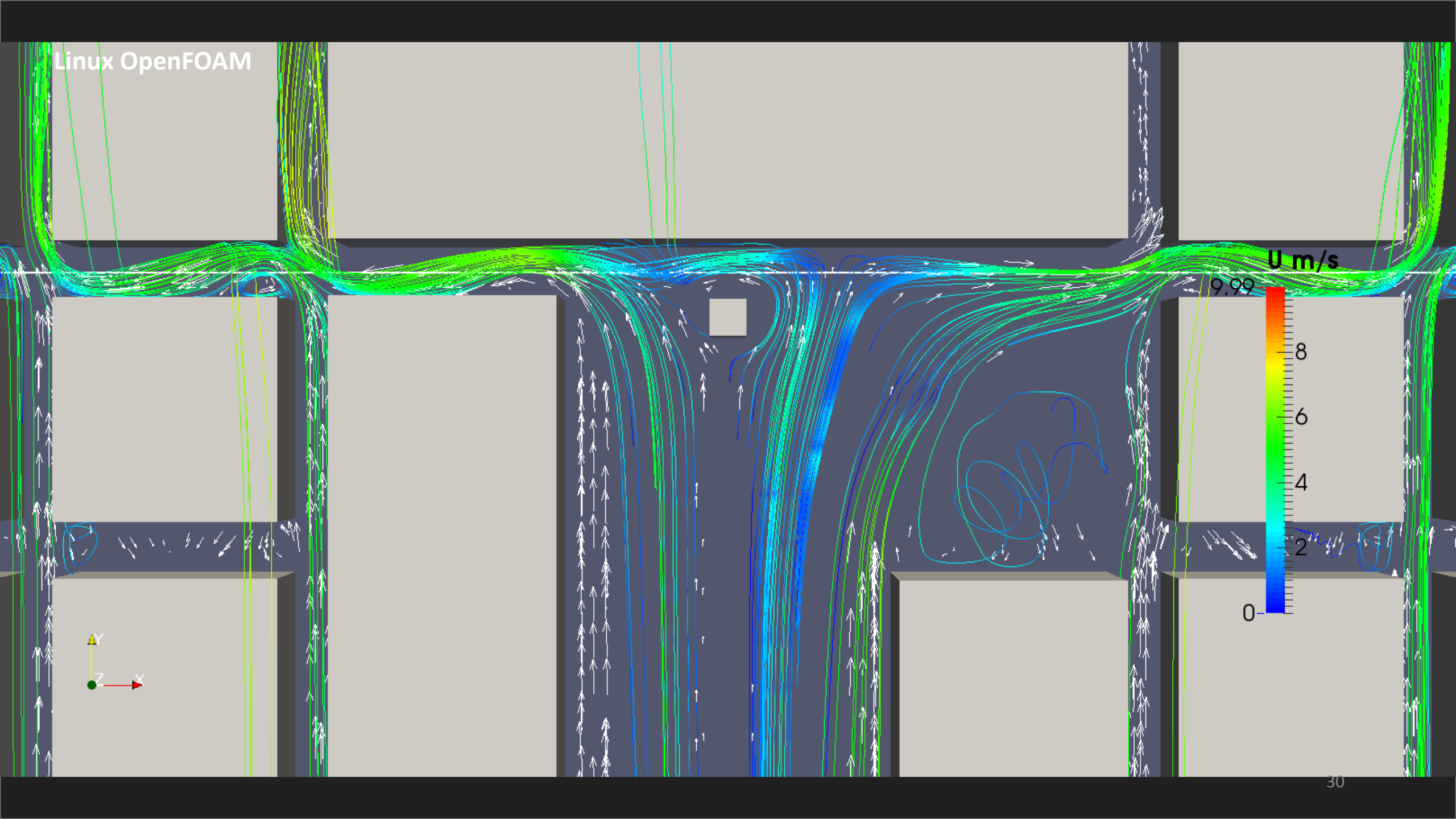


Autodesk Flow Design



Linux OpenFOAM




Linux OpenFOAM
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WIND ENGINEERING

Wind ENGINEERING

Definition
Full scale measurements
Wind Tunnel experiments
Nummerical experiments

According to the definition given by Jack E. Cermak (1975),

"Wind engineering is best defined as the rational treatment of the interactions between wind in the atmospheric boundary layer and man and his works on the surface of earth".

It is a multi-disciplinary matter concerning multifold topics.

from the website (www.iawe.org) of the IAWE International Association of Wind Engineering 2013

Wind ENGINEERING

Dynamic Effects

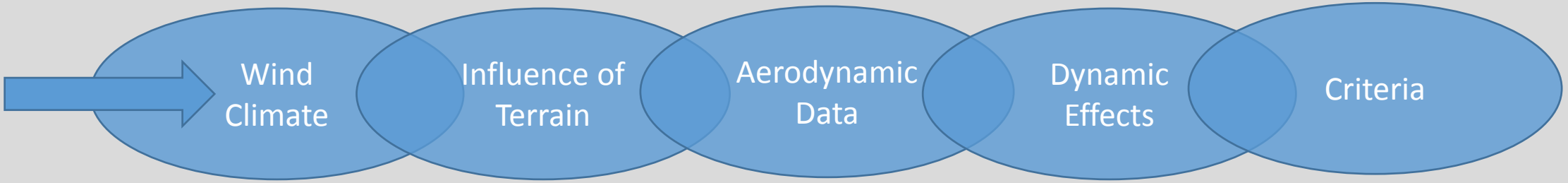
Wind Climate

Criteria

Aerodynamic Data

Influence of Terrain

WIND LOADS & EFFECTS

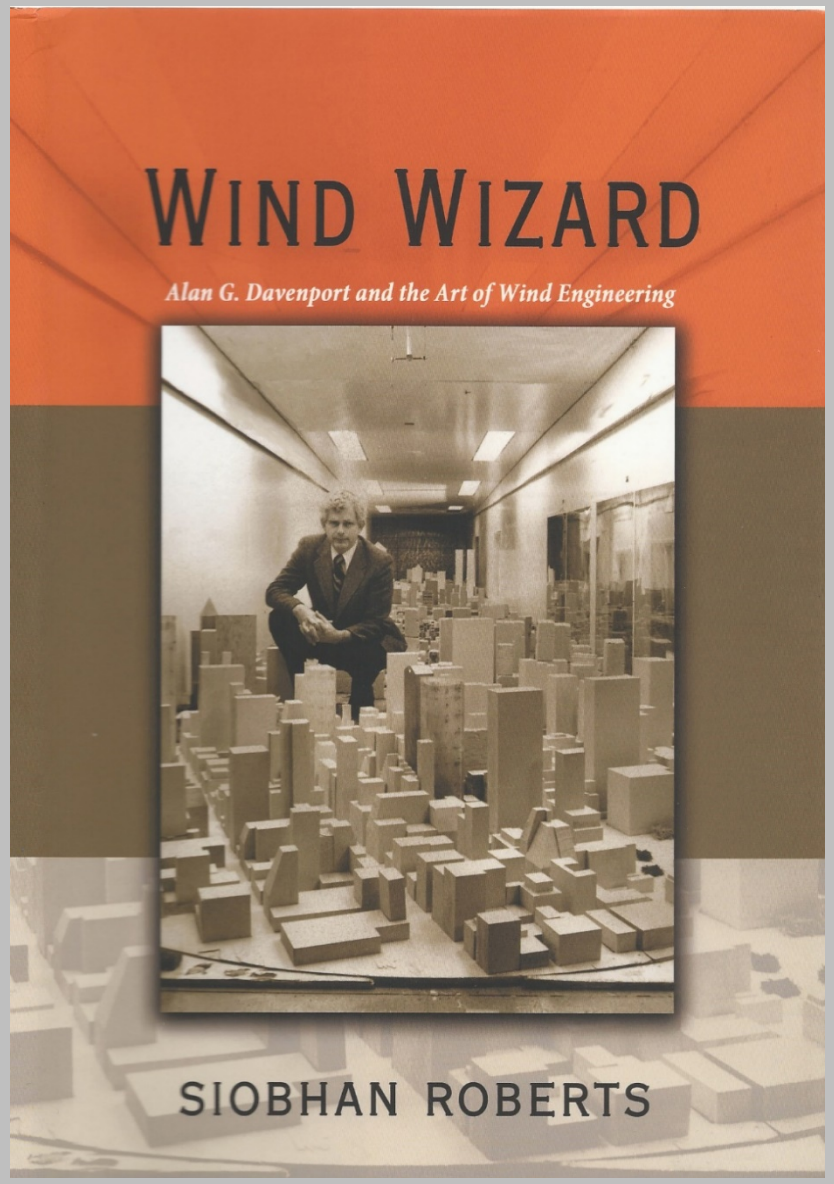


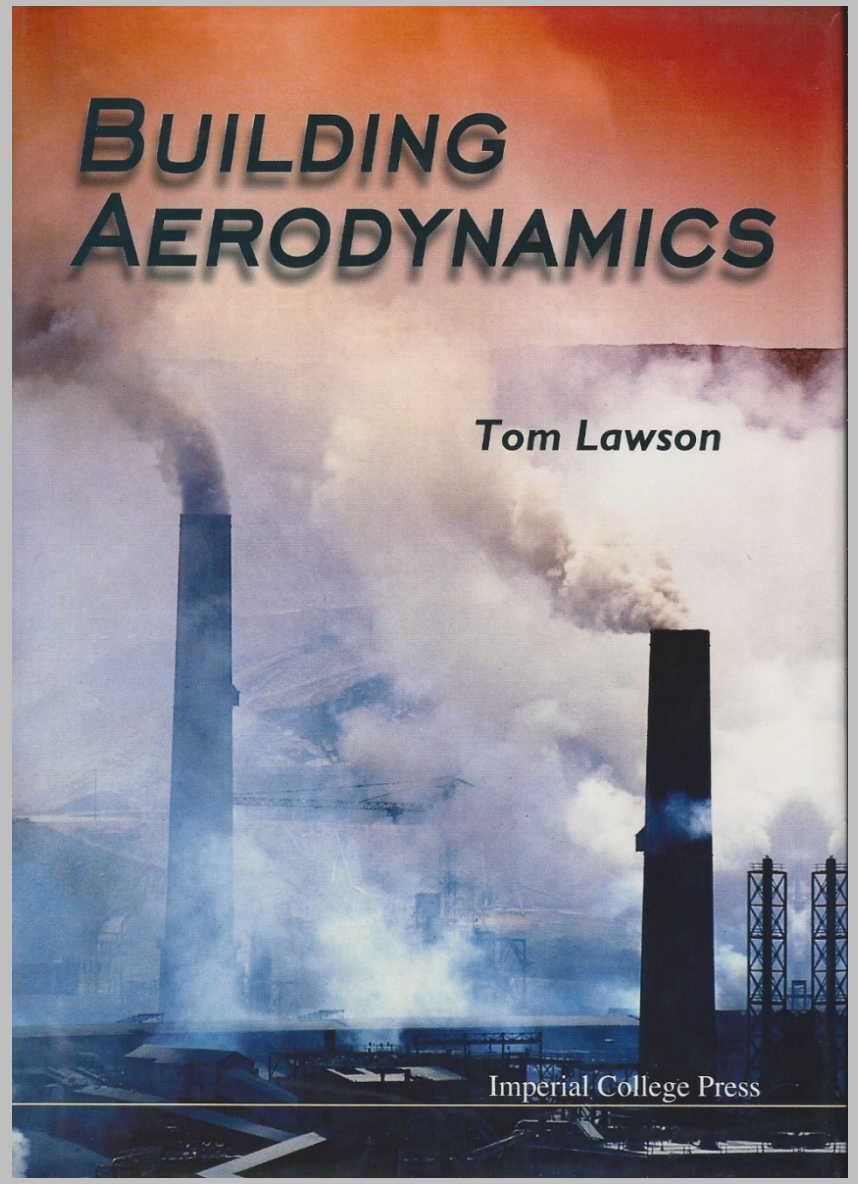
Alan Davenport's Wind Loading Chain

Wind ENGINEERING

Alan Davenport
Wind Wizard
2013

Tom Lawson
Building Aerodynamics
2001

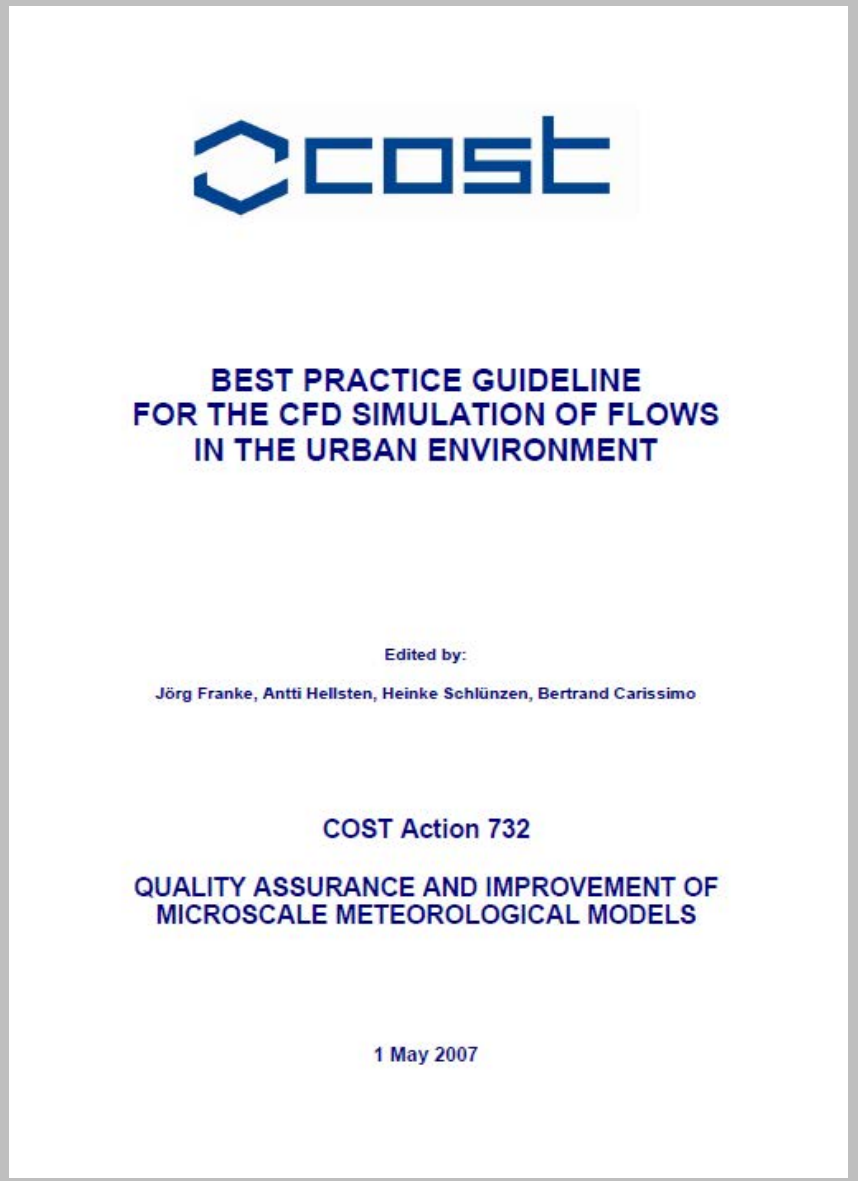




Wind ENGINEERING / Rules

Quality Assurance 2005

Best Practice Guideline 2007



cost

BEST PRACTICE GUIDELINE
FOR THE CFD SIMULATION OF FLOWS
IN THE URBAN ENVIRONMENT

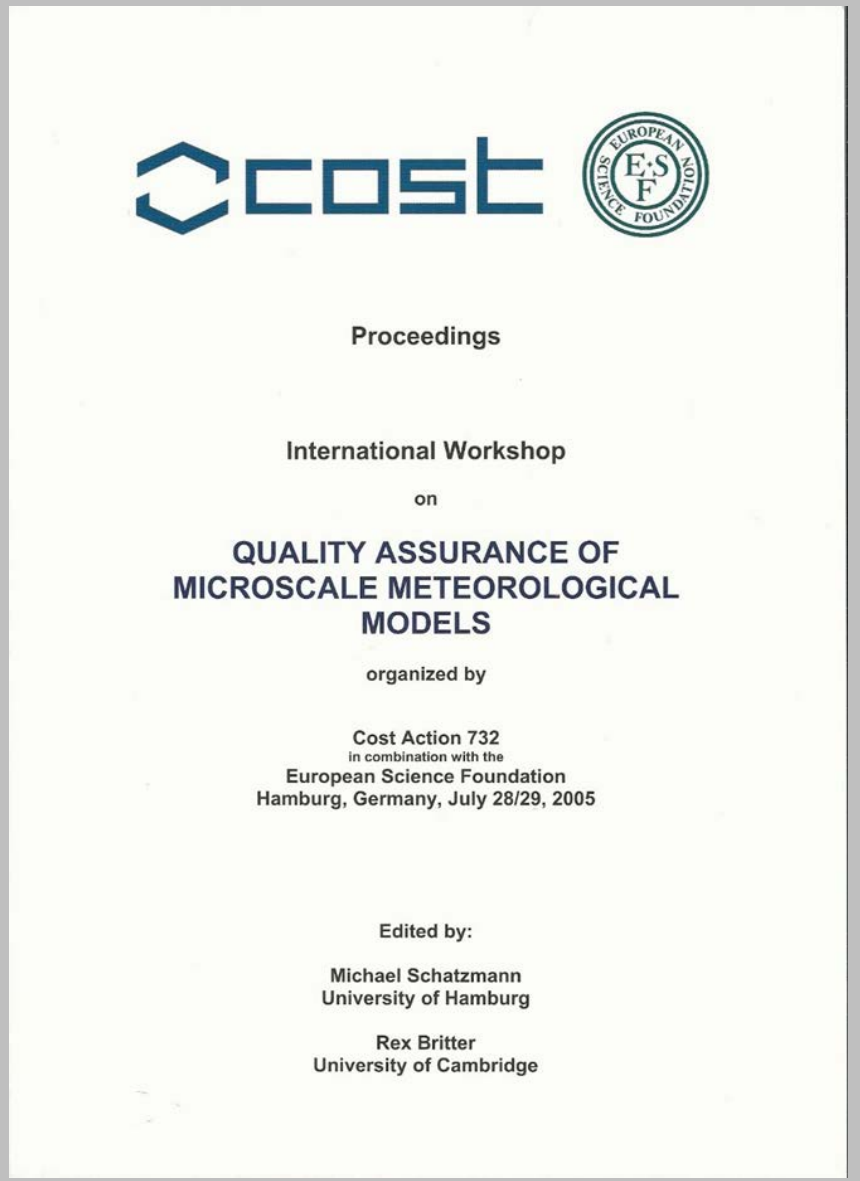
Edited by:

Jörg Franke, Antti Hellsten, Heinke Schlünzen, Bertrand Carissimo

COST Action 732

QUALITY ASSURANCE AND IMPROVEMENT OF
MICROSCALE METEOROLOGICAL MODELS

1 May 2007



cost

Proceedings

International Workshop

on

QUALITY ASSURANCE OF
MICROSCALE METEOROLOGICAL
MODELS

organized by

Cost Action 732
in combination with the
European Science Foundation
Hamburg, Germany, July 28/29, 2005

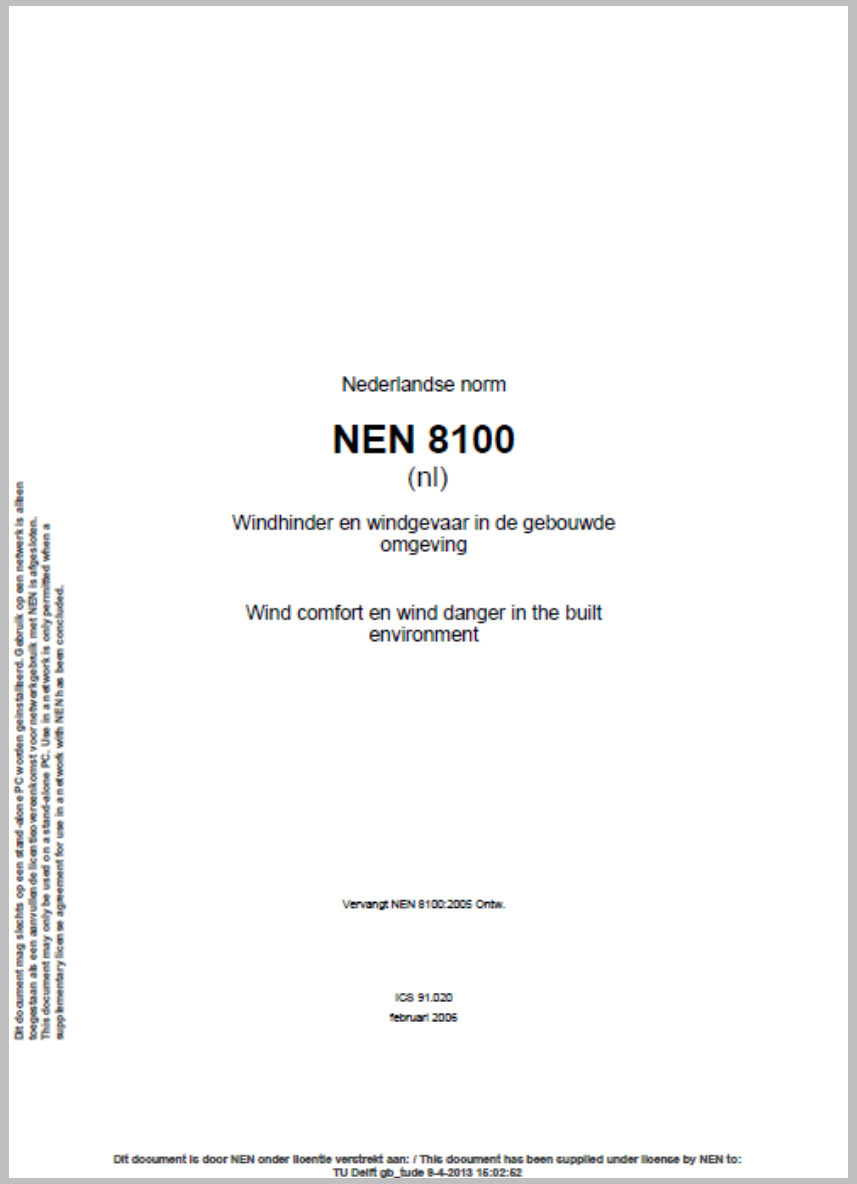
Edited by:

Michael Schatzmann
University of Hamburg

Rex Britter
University of Cambridge

Normen 2006

Richtlijnen 2006



Nederlandse norm

NEN 8100

(nl)

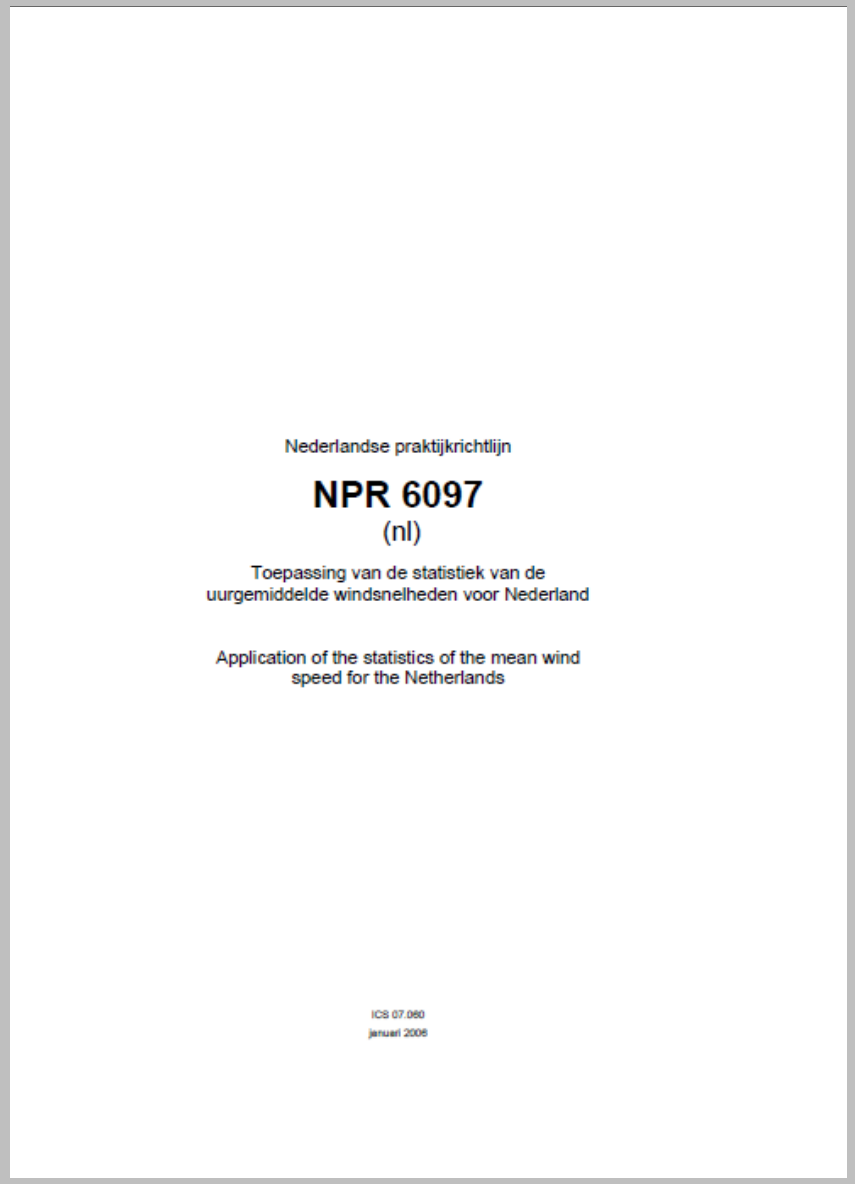
Windhinder en windgevaar in de gebouwde omgeving

Wind comfort en wind danger in the built environment

Vervangt NEN 8100:2005 Ontw.

ICS 91.020

februari 2006



Nederlandse praktijkrichtlijn

NPR 6097

(nl)

Toepassing van de statistiek van de uurgemiddelde windsnelheden voor Nederland

Application of the statistics of the mean wind speed for the Netherlands

ICS 07.060

januari 2006

Criteria NL / Wind hinder en windgevaar

Tabel 1 — Eisen voor de beoordeling van het lokale windklimaat voor windhinder

Overschrijdingskans $p(v_{LOK} > v_{DR,H})$ in procenten van het aantal uren per jaar	Kwaliteitsklasse	Activiteiten		
		I. Doorlopen	II. Slenteren	III. Langdurig zitten
< 2,5	A	Goed	Goed	Goed
2,5 – 5	B	Goed	Goed	Matig
5 – 10	C	Goed	Matig	Slecht
10 – 20	D	Matig	Slecht	Slecht
> 20	E	Slecht	Slecht	Slecht

Nederlandse norm: NEN 8100 Windhinder en windgevaar in de gebouwde omgeving

NEN 8100:2005
TOELICHTING

3.6
windhinder
Een individu kan hinder ondervinden door wind. Te denken is aan wapperende kleding, verwaaide haren, gehinderd worden bij het lezen van een krant, gehinderd worden bij het lopen enz. Het is persoonlijk of een individu wel of niet windhinder ondervindt. Een kind en een bejaarde reageren anders op de wind dan een gezonde volwassene.

Het ervaren van windhinder is afhankelijk van de activiteit die men op dat moment onderneemt. De kans dat bij een willekeurige windsnelheid hinder wordt ondervonden is bij stilzitten groter dan bij stevig doorlopen.

Dat windhinder soms optreedt is acceptabel; zo stormt het nu eenmaal af en toe. Bij een “goed” windklimaat zal men daarom wel af en toe windhinder ervaren, maar geen *overmatige* windhinder. In een situatie zonder *overmatige* windhinder heeft het merendeel van het publiek geen last van windhinder.

Nederlandse norm: NEN 8100 Windhinder en windgevaar in de gebouwde omgeving

6.2 Windhinder

De eis bij de beoordeling van het lokale windklimaat voor windhinder is gebaseerd op de volgende twee onderdelen:

— een drempelsnelheid ter beoordeling van windhinder $v_{DR;H}$ voor de lokale windsnelheid op loop- of verblijfsniveau v_{LOK};

— een overschrijdingskans $p(v_{LOK} > v_{DR;H})$.

Als grenswaarde voor de drempelsnelheid ter beoordeling van het lokale windklimaat voor windhinder ($v_{DR;H}$) wordt een uurgemiddelde windsnelheid van 5,0 m/s aangehouden. De overschrijdingskans $p(v_{LOK} > v_{DR;H})$ wordt bepaald volgens hoofdstuk 7. De grootte van de overschrijdingskans bepaalt in welke kwaliteitsklasse het lokale windklimaat valt.

Nederlandse norm: NEN 8100 Windhinder en windgevaar in de gebouwde omgeving

6.3 Windgevaar

Naar analogie van de beoordeling van het lokale windklimaat voor windhinder is de eis ter beoordeling van windgevaar gebaseerd op:

— een drempelsnelheid ter beoordeling van windgevaar $v_{DR;G}$ voor de lokale snelheid op loop- of verblijfsniveau v_{LOK};

— een overschrijdingskans $p(v_{LOK} > v_{DR;G})$.

Als grenswaarde voor de drempelsnelheid ter beoordeling van windgevaar ($v_{DR;G}$) wordt een uurgemiddelde windsnelheid van 15 m/s aangehouden. De overschrijdingskans $p(v_{LOK} > v_{DR;G})$ wordt bepaald volgens hoofdstuk 7.

Nederlandse norm: NEN 8100 Windhinder en windgevaar in de gebouwde omgeving

RESEARCH METHODS:

Full scale measurements
Windtunnel
CFD (Computational Fluid Dynamics) simulations

Full scale measurements

KNMI network
Weather stations

NPR 6097:2006 Application of the statistics of the mean wind speed for the Netherlands

Full scale measurements

Cabauw observatorium
213 meter hoog
1972

CESAR

Full scale measurements

Cabauw observatorium
213 meter hoog
1972

CESAR

Full scale measurements

Cabauw observatorium
213 meter hoog
1972

CESAR

Full scale measurements

Cabauw observatorium
213 meter hoog
1972

CESAR

Peutz
Molenhoek

Wind tunnel research

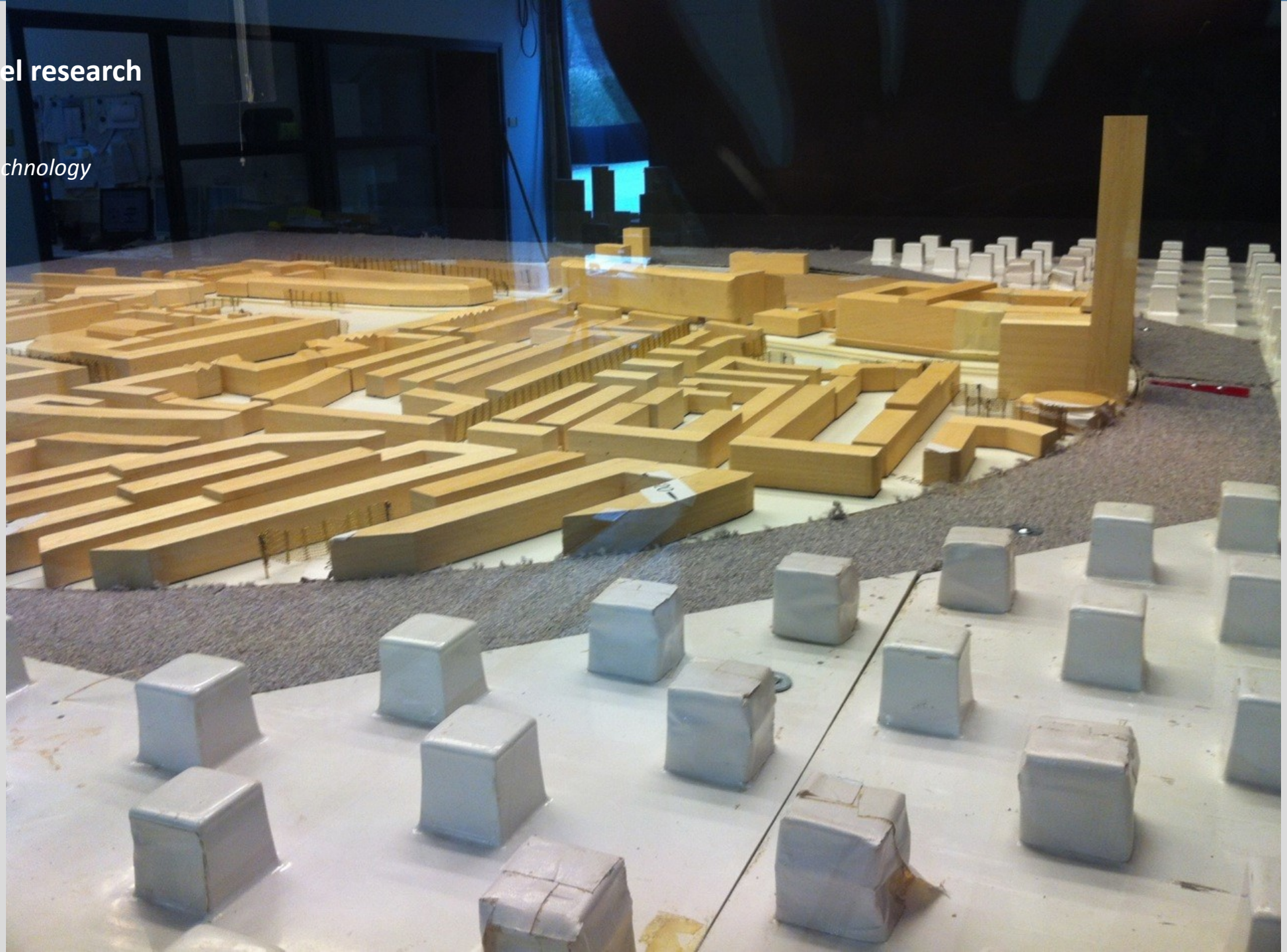
Peutz Wind Technology

Wind tunnel research

Peutz Wind Technology

Wind tunnel research

Peutz Wind Technology



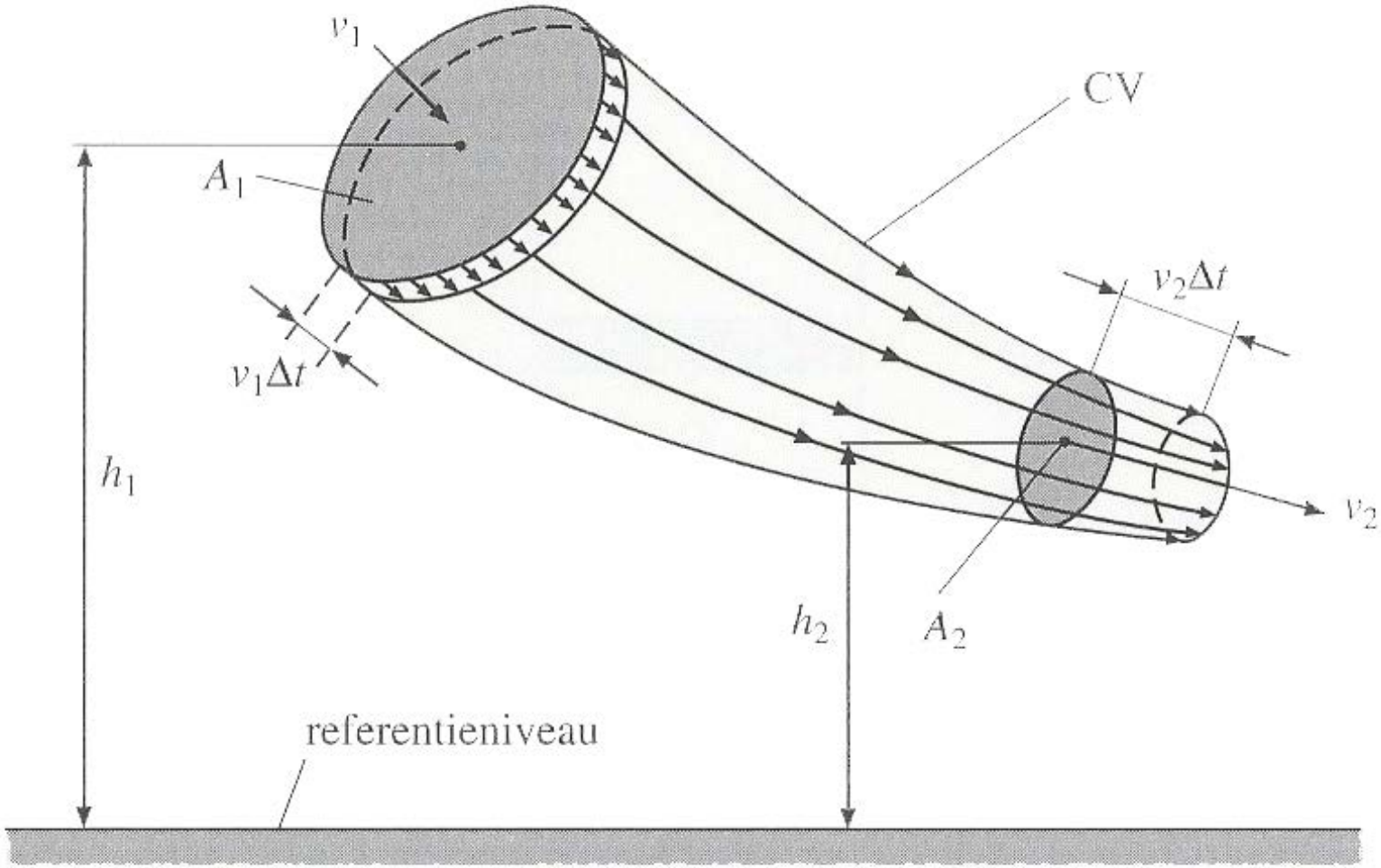
RESEARCH (COMPUTATIONAL) FLUID DYNAMICS based on:

Mathematics
Mechanics
Physics

Wind ENGINEERING (Computational) Fluid Dynamics

Models of the flow
Substantial derivative
Divergence of velocity

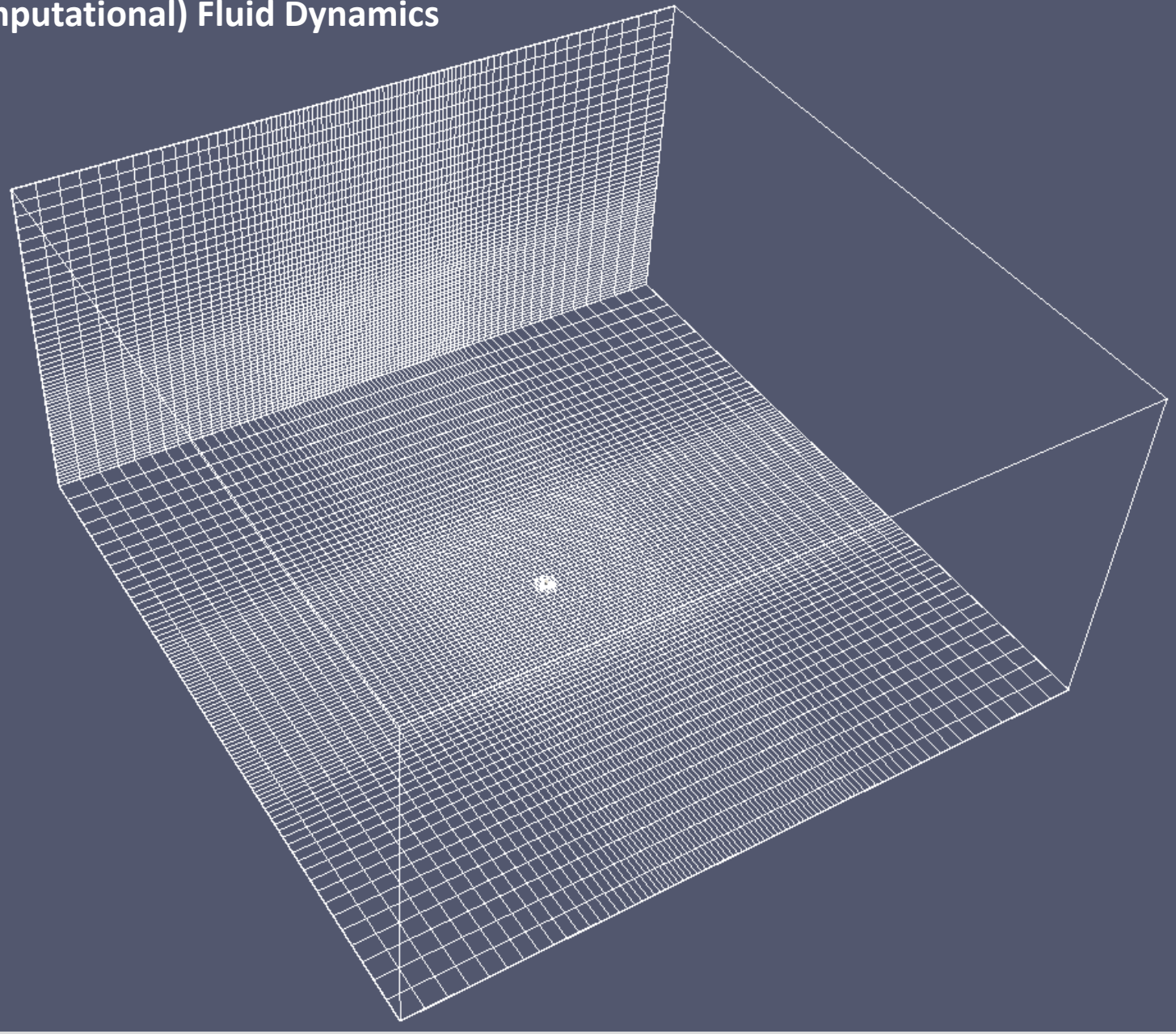
Continuity equation
Momentum equation
Energy equation

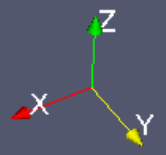


N. Dekkers J Wijnen : Eenvoudige stromingsleer 1 Grondbegrippen Modelregels

Wind ENGINEERING (Computational) Fluid Dynamics

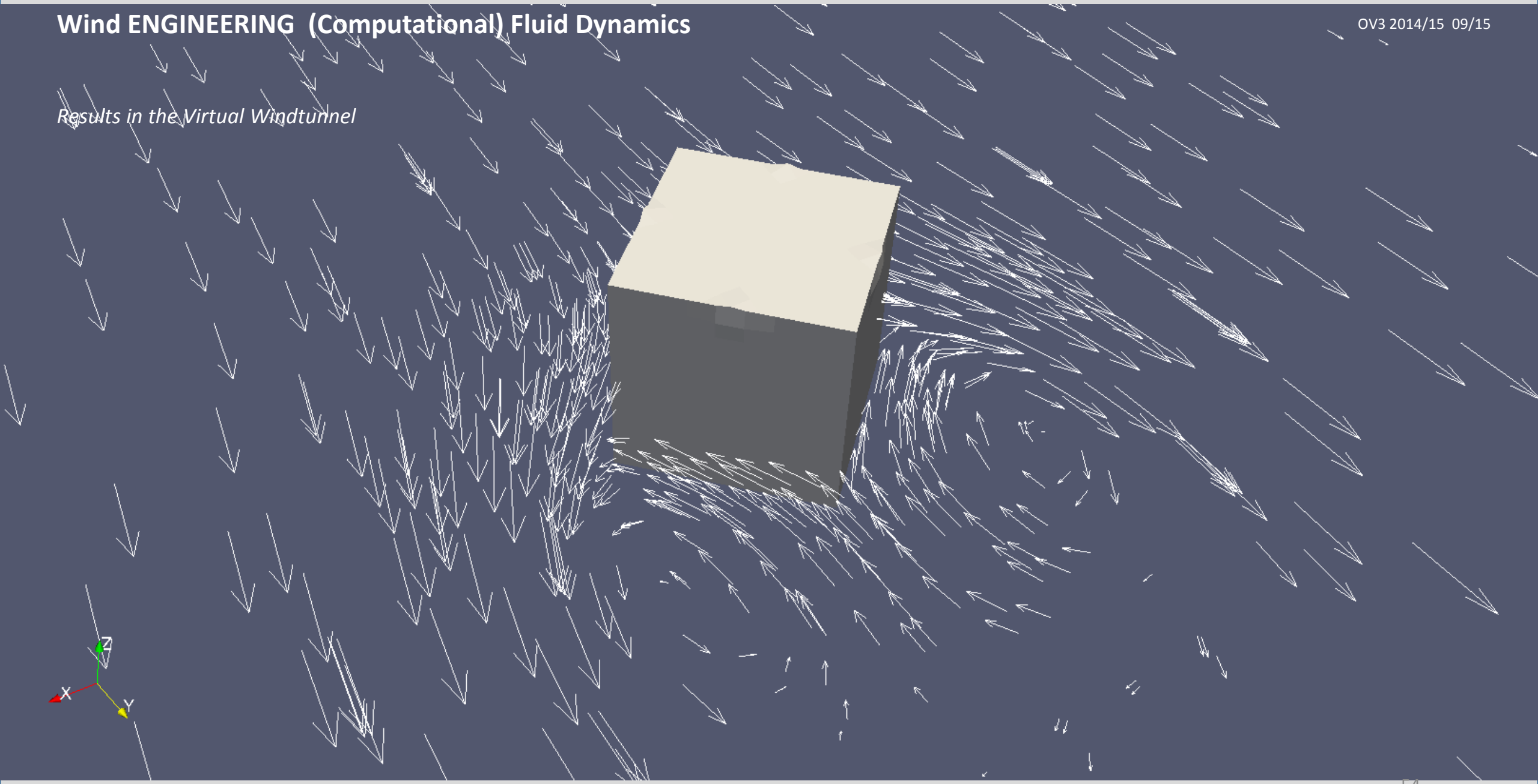
Model of the Virtual Windtunnel



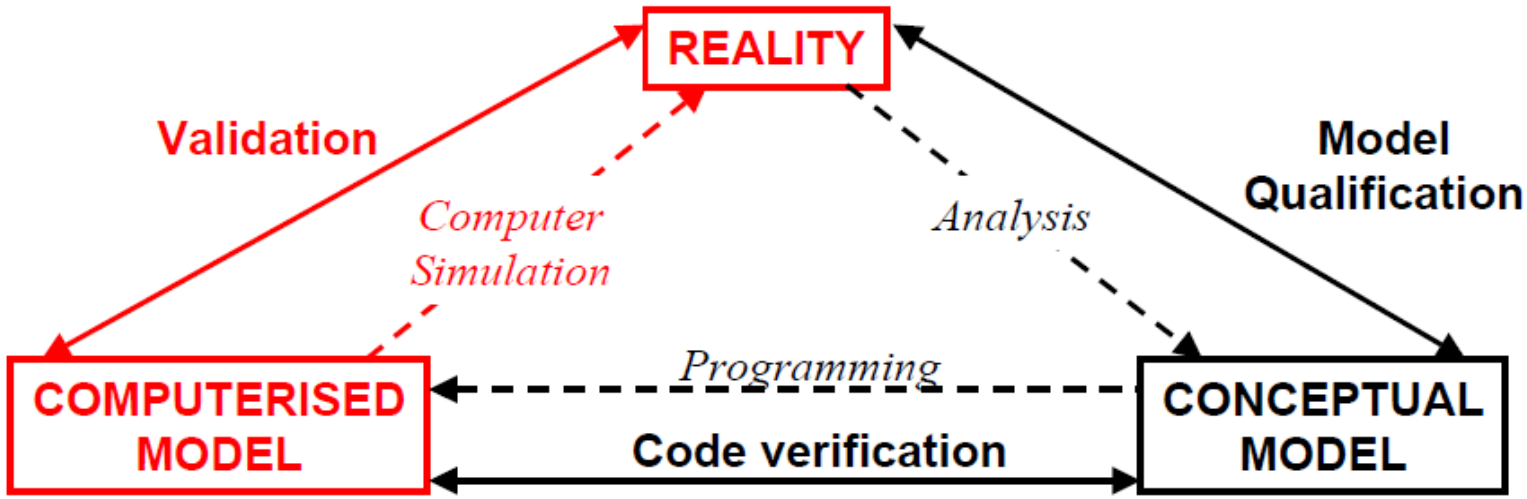


Wind ENGINEERING (Computational) Fluid Dynamics

Results in the Virtual Windtunnel



Simulation modeling / Quality assurance

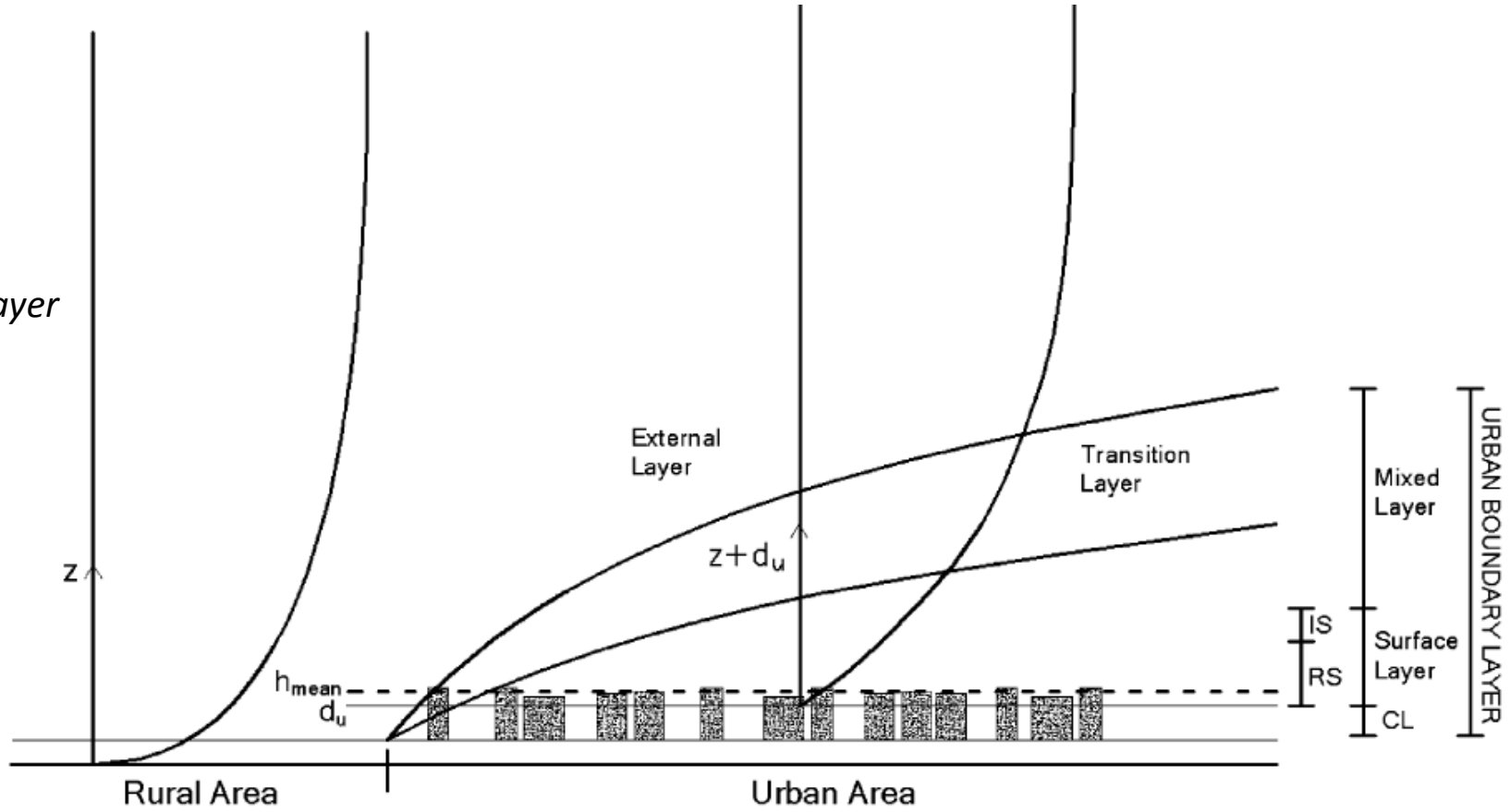


COST action 732 Best Practice Guideline for the CFD simulation of flows in the urban environment

METEOROLOGY

Meteorology – Urban Boundary Layer

CL Canopy Layer
RS Roughness Sublayer
IS Inertial Sublayer



Journal of Wind Engineering and Industrial Aerodynamics 94 (2006) Ricciardelli Some characteristics of the wind flow in the lower Urban Boundary Layer

Windspeed

Postadres: Postbus 201, 3730 AE De Bilt

Klimaatdata- en advies - Telefoon 030-220 68 50 - telefax 030-220 46 14 - Internet: http://www.knmi.nl/klimatologie

KNMI

Beaufortschaal (geldend voor **gemiddelde** windsnelheden)

Schaalcijfer Beaufort	Windsnelheidsequivalenten op 10 meter Hoogte boven vlak terrein			Benaming					Beschrijving van de zichtbare uitwerking van de windkracht op objecten in het binnenland
	m/s	km/h	zeemijlen/uur (knopen)	Nederlands boven zee	boven land	English Engels	Français Frans	Deutch Duits	
0	0 – 0,2	<1	<1	Stilte	Windstil	Calm	Calme	Stille	Rook stijgt recht of bijna recht omhoog.
1	0,3 – 1,5	1 - 5	1 - 3	Flauw en stil	Zwakke wind	Light air	Très lègere brise	Leiser Zug	Windrichting goed herkenbaar aan rookpluimen.
2	1,6 – 3,3	6 - 11	4 - 6	Flauwe koelte		Light breeze	Lègere brise	Leichte Brise	Bladeren beginnen te ritselen en windvanen kunnen gaan bewegen. Wind begint merkbaar te worden in het gelaat.
3	3,4 – 5,4	12 - 19	7 - 10	Lichte koelte	Matige wind	Gentle breeze	Petite brise	Schwache Brise	Bladeren en twijgen zijn voortdurend in beweging.
4	5,5 – 7,9	20 - 28	11 - 16	Matige koelte		Moderate breeze	Jolie brise	Mässige Brise	Kleine takken beginnen te bewegen. Stof en papier beginnen van de grond op te dwarrelen.
5	8,0 – 10,7	29 - 38	17 - 21	Frisse bries	Vrij krachtige wind	Fresh breeze	Bonne brise	Frische Brise	Kleine bebladerde takken makken zwaaiende bewegingen. Er vormen zich gekuifde golven op meren en kanalen.
6	10,8 – 13,8	39 - 49	22 - 27	Stijve bries	Krachtige wind	Strong breeze	Vent frais	Starker Wind	Grote takken bewegen. Parapluies kunnen slechts met moeite worden vastgehouden.
7	13,9 – 17,1	50 - 61	28 - 33	Harde wind	Harde wind	Near gale	Grand frais	Steifer Wind	Gehele bomen bewegen. De wind is hinderlijk wanneer men er tegen in loopt.
8	17,2 – 20,7	62 - 74	34 - 40	Stormachtig	Stormachtige wind	Gale	Coup de vent	Stürmischer Wind	Twijgen breken af. Fietsen en lopen wordt bemoeilijkt.
9	20,8 – 24,4	75 - 88	41 - 47	Storm	Storm	Strong gale	Fort coup de vent	Sturm	Lichte schade aan gebouwen. Schoorsteenkappen en dakpannen worden afgerukt.
10	24,5 – 28,4	89 - 102	48 - 55	Zware storm	Zware storm	Storm	Tempête	Schwerer Sturm	Ontwortelde bomen. Aanzienlijke schade aan gebouwen enz. Komt boven land zelden voor.
11	28,5 – 32,6	103 - 117	56 - 63	Zeer zware storm	Zeer zware storm	Violent Storm	Violente tempête	Orkanartiger sturm	Uitgebreide schade
12	> 32,6	> 117	> 63	Orkaan	Orkaan	Hurricane	Ouragan	Orkan	Komt boven land zeer zelden voor.

KNMI, Ministerie van Verkeer en Waterstaat

Windspeed

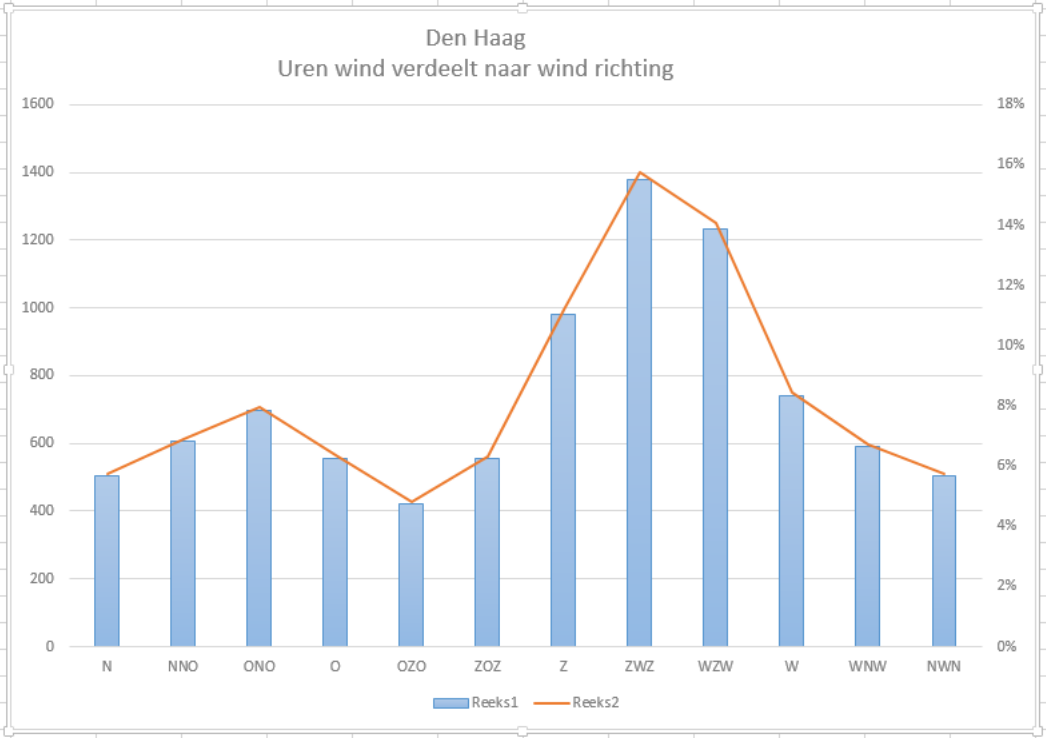
DH Windsnelheden H60m2 - Excel

BESTAND | FORMULES | GEGEVENS | CONTROLEREN | BEELD | ACROBAT | HULPMIDDELEN VOOR GRAFIEKEN: ONTWERPEN | INDELING

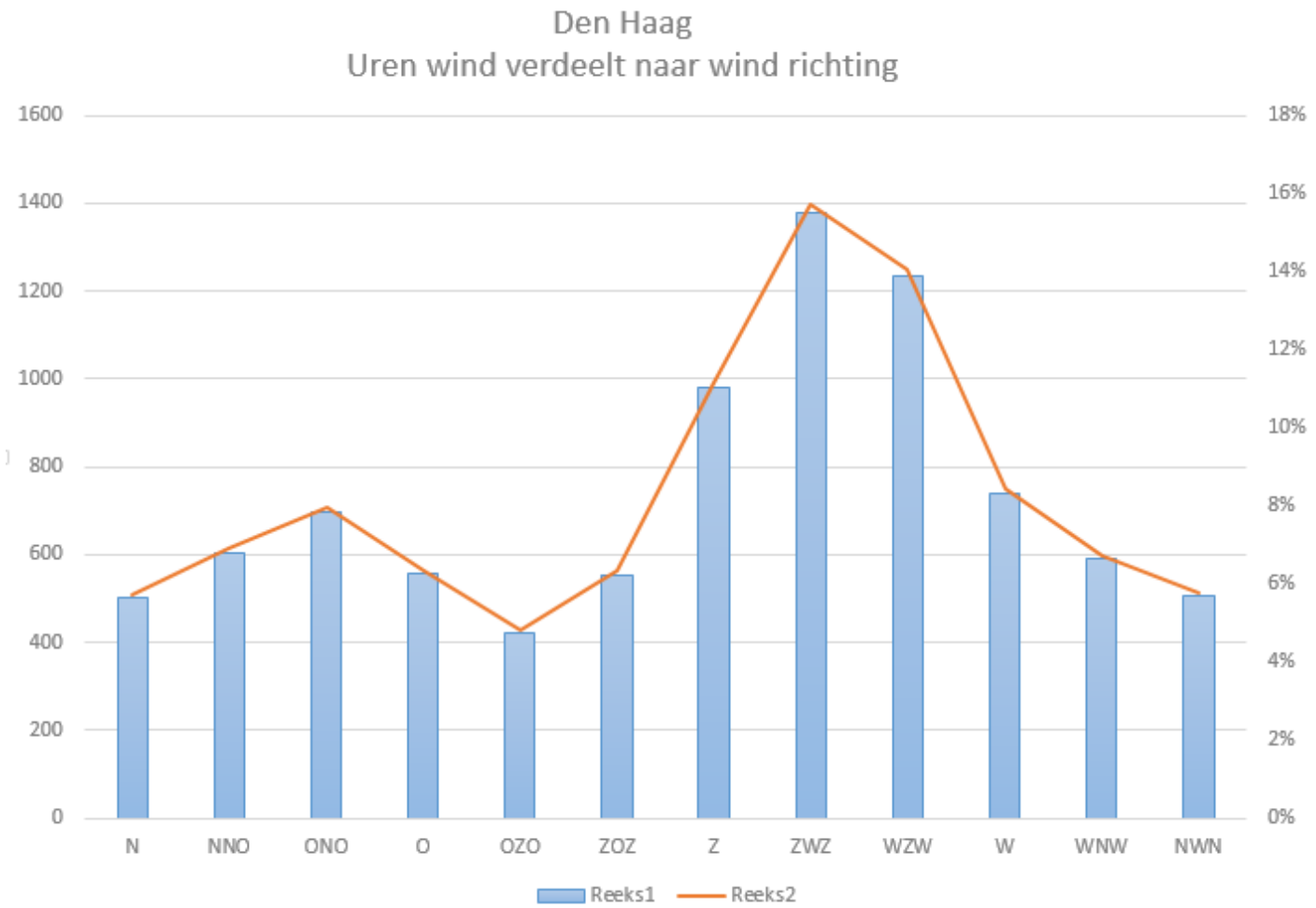
Huib Plomp

Grafiek 3

	A	B	D	E	F	G	H	I	J	K	L	M	N	O	P	R
1			35-01	02-04	05-07	08-10	11-13	14-16	17-19	20-22	23-25	26-28	29-31	32-34	cum	snelheden
2		richting	0	30	60	90	120	150	180	210	240	270	300	330		
3			N	NNO	ONO	O	OZO	ZOZ	Z	ZWZ	WZW	W	WNW	NWN		
4		uren	503	606	698	557	420	555	979	1380	1234	740	590	505	8765.2	
5		%	6%	7%	8%	6%	5%	6%	11%	16%	14%	8%	7%	6%	100%	100%
6																
7	windsnelheden															
8	m/s															
9	0.0	0.9	16.4	16.4	15.9	18.2	15.5	17.6	18.7	21.5	22.8	18.1	16.6	15.6	213.3	2%
10	1.0	1.9	54.7	57.2	54.2	51.8	46.8	55.7	68.0	70.3	67.9	58.6	57.9	51.5	694.6	8%
11	2.0	2.9	78.7	82.2	88.7	73.7	69.5	85.7	110.8	114.4	113.2	80.9	77.3	70.6	1045.7	12%
12	3.0	3.9	85.8	102.0	99.7	93.9	77.2	95.8	131.9	157.7	137.6	103.4	87.2	81.6	1253.8	14%
13	4.0	4.9	81.4	96.8	106.7	98.4	71.3	95.9	140.4	185.2	161.1	106.7	86.3	82.2	1312.4	15%
14	5.0	5.9	72.6	88.1	102.0	80.6	56.2	76.3	130.8	177.5	166.8	93.6	75.7	66.8	1187.0	14%
15	6.0	6.9	49.8	67.6	78.5	54.3	39.3	49.4	110.5	169.2	150.6	82.1	62.0	51.6	964.9	11%
16	7.0	7.9	31.6	41.1	54.2	38.2	25.4	34.8	90.8	140.6	127.8	62.0	47.3	36.0	729.8	8%
17	8.0	8.9	15.7	26.6	40.8	23.5	11.7	20.8	65.2	117.3	98.4	44.3	32.8	22.2	519.3	6%
18	9.0	9.9	7.8	14.2	26.7	11.9	4.6	13.0	47.9	84.5	70.3	32.8	21.9	12.8	348.4	4%
19	10.0	10.9	4.4	7.9	15.3	6.9	1.8	5.6	29.5	58.6	51.7	21.7	12.3	6.4	222.1	3%
20	11.0	11.9	1.9	3.0	9.3	3.2	0.4	2.8	16.7	38.8	28.3	15.7	8.1	3.8	132.0	2%
21	12.0	12.9	1.3	2.0	4.2	1.3	0.3	0.6	9.9	21.9	18.3	9.8	3.0	1.8	74.4	1%
22	13.0	13.9	0.4	0.4	1.6	0.5	0.1	0.4	4.8	11.5	9.7	4.9	0.9	0.9	36.1	0%
23	14.0	14.9	0.1	0.2	0.3	0.1		0.2	1.7	5.5	4.4	2.9	0.3	0.5	16.2	0%
24	15.0	15.9			0.1				0.9	2.8	2.3	1.5	0.2	0.2	8.0	0%
25	16.0	16.9			0.1				0.7	1.4	1.4	0.9	0.1		4.6	0%
26	17.0	17.9							0.2	0.6	0.5	0.2			1.5	0%
27	18.0	18.9								0.2	0.2	0.1			0.5	0%
28	19.0	19.9								0.1	0.2	0.1			0.4	0%
29	20.0	20.9									0.1	0.1			0.2	0%
30	21.0	21.9														
31	22.0	22.9														
32	23.0	23.9														
33	24.0	24.9														
34	25.0	25.9														
35	26.0	26.9														
36	27.0	27.9														
37	28.0	28.9														
38	29.0	29.9														
39	30.0	30.9														
40	31.0	31.9														
41	32.0	32.9														
42	33.0	33.9														
43	34.0	34.9														



Windspeed height 60m



Windspeed

DH Windsnelheden H60m2 - Excel

BESTAND FORMULES GEGEVENS CONTROLEREN BEELD ACROBAT

Huib Plomp

A7 windsnelheden

	A	B	D	E	F	G	H	I	J	K	L	M	N	O	P	R
1			35-01	02-04	05-07	08-10	11-13	14-16	17-19	20-22	23-25	26-28	29-31	32-34	cum	snelheden
2		richting	0	30	60	90	120	150	180	210	240	270	300	330		
3			N	NNO	ONO	O	OZO	ZOZ	Z	ZWZ	WZW	W	WNW	NWN		
4		uren	503	606	698	557	420	555	979	1380	1234	740	590	505	8765.2	
5		%	6%	7%	8%	6%	5%	6%	11%	16%	14%	8%	7%	6%	100%	100%
6																
7	windsnelheden															
8	m/s															
9	0.0	0.9	16.4	16.4	15.9	18.2	15.5	17.6	18.7	21.5	22.8	18.1	16.6	15.6	213.3	2%
10	1.0	1.9	54.7	57.2	54.2	51.8	46.8	55.7	68.0	70.3	67.9	58.6	57.9	51.5	694.6	8%
11	2.0	2.9	78.7	82.2	88.7	73.7	69.5	85.7	110.8	114.4	113.2	80.9	77.3	70.6	1045.7	12%
12	3.0	3.9	85.8	102.0	99.7	93.9	77.2	95.8	131.9	157.7	137.6	103.4	87.2	81.6	1253.8	14%
13	4.0	4.9	81.4	96.8	106.7	98.4	71.3	95.9	140.4	185.2	161.1	106.7	86.3	82.2	1312.4	15%
14	5.0	5.9	72.6	88.1	102.0	80.6	56.2	76.3	130.8	177.5	166.8	93.6	75.7	66.8	1187.0	14%
15	6.0	6.9	49.8	67.6	78.5	54.3	39.3	49.4	110.5	169.2	150.6	82.1	62.0	51.6	964.9	11%
16	7.0	7.9	31.6	41.1	54.2	38.2	25.4	34.8	90.8	140.6	127.8	62.0	47.3	36.0	729.8	8%
17	8.0	8.9	15.7	26.6	40.8	23.5	11.7	20.8	65.2	117.3	98.4	44.3	32.8	22.2	519.3	6%
18	9.0	9.9	7.8	14.2	26.7	11.9	4.6	13.0	47.9	84.5	70.3	32.8	21.9	12.8	348.4	4%
19	10.0	10.9	4.4	7.9	15.3	6.9	1.8	5.6	29.5	58.6	51.7	21.7	12.3	6.4	222.1	3%
20	11.0	11.9	1.9	3.0	9.3	3.2	0.4	2.8	16.7	38.8	28.3	15.7	8.1	3.8	132.0	2%
21	12.0	12.9	1.3	2.0	4.2	1.3	0.3	0.6	9.9	21.9	18.3	9.8	3.0	1.8	74.4	1%
22	13.0	13.9	0.4	0.4	1.6	0.5	0.1	0.4	4.8	11.5	9.7	4.9	0.9	0.9	36.1	0%
23	14.0	14.9	0.1	0.2	0.3	0.1		0.2	1.7	5.5	4.4	2.9	0.3	0.5	16.2	0%
24	15.0	15.9			0.1				0.9	2.8	2.3	1.5	0.2	0.2	8.0	0%
25	16.0	16.9			0.1				0.7	1.4	1.4	0.9	0.1		4.6	0%
26	17.0	17.9							0.2	0.6	0.5	0.2			1.5	0%
27	18.0	18.9								0.2	0.2	0.1			0.5	0%
28	19.0	19.9								0.1	0.2	0.1			0.4	0%
29	20.0	20.9									0.1	0.1			0.2	0%
30	21.0	21.9														
31	22.0	22.9														
32	23.0	23.9														
33	24.0	24.9														
34	25.0	25.9														
35	26.0	26.9														
36	27.0	27.9														
37	28.0	28.9														
38	29.0	29.9														
39	30.0	30.9														
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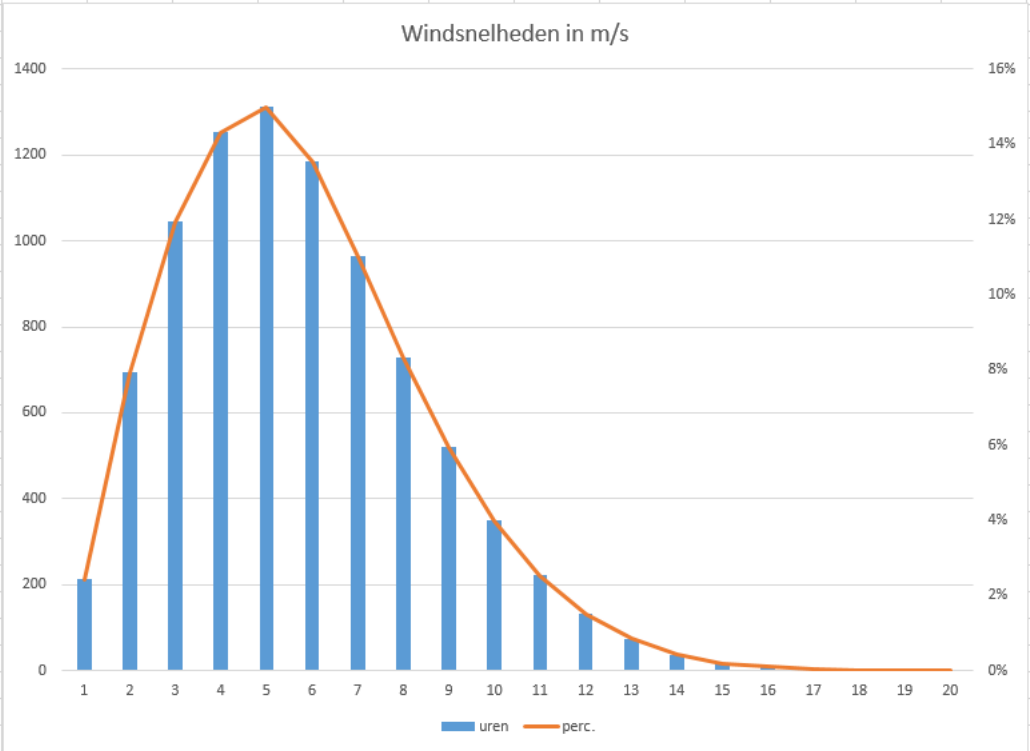
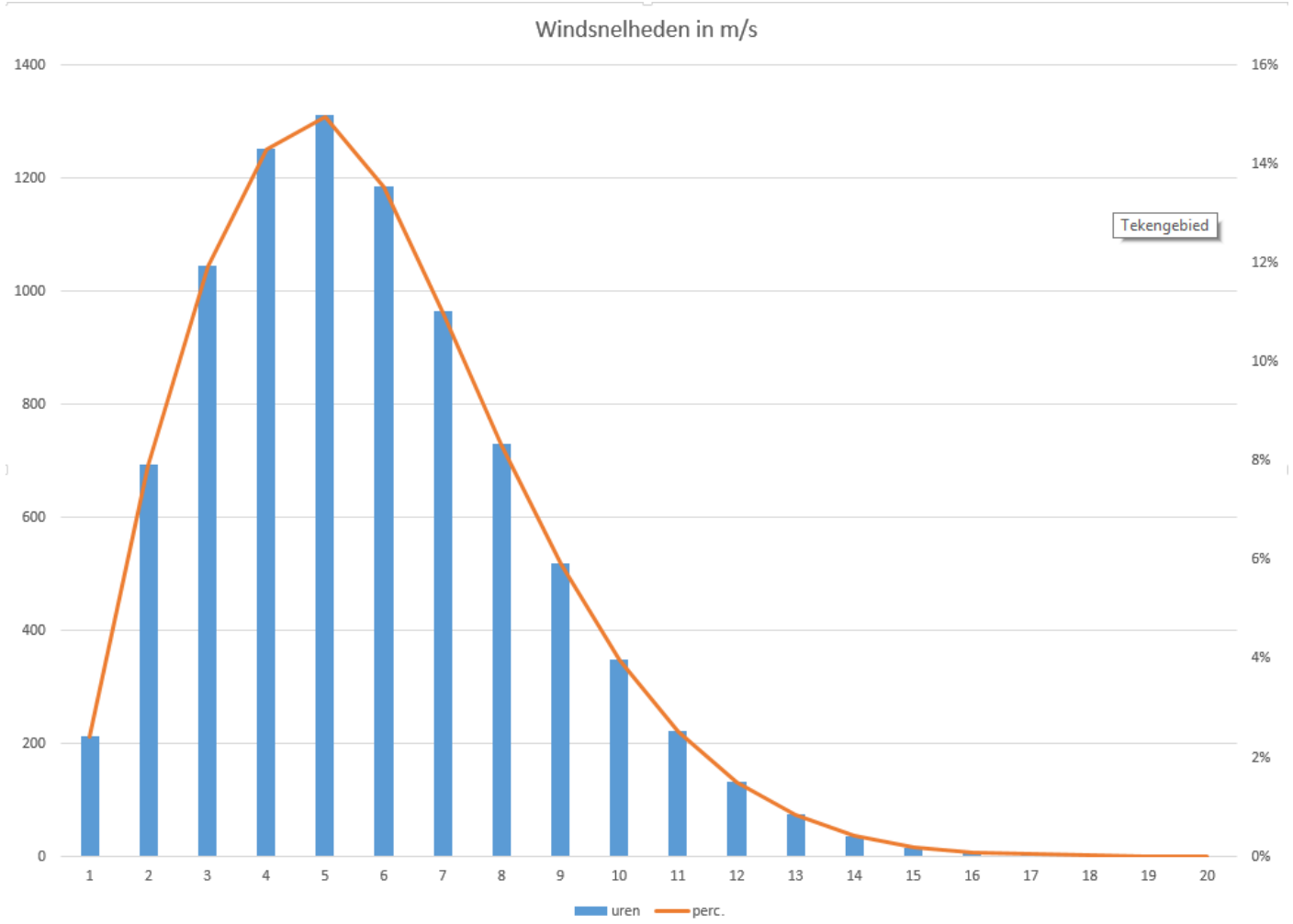
41	32.0	32.9														
42	33.0	33.9														
43	34.0	34.9														



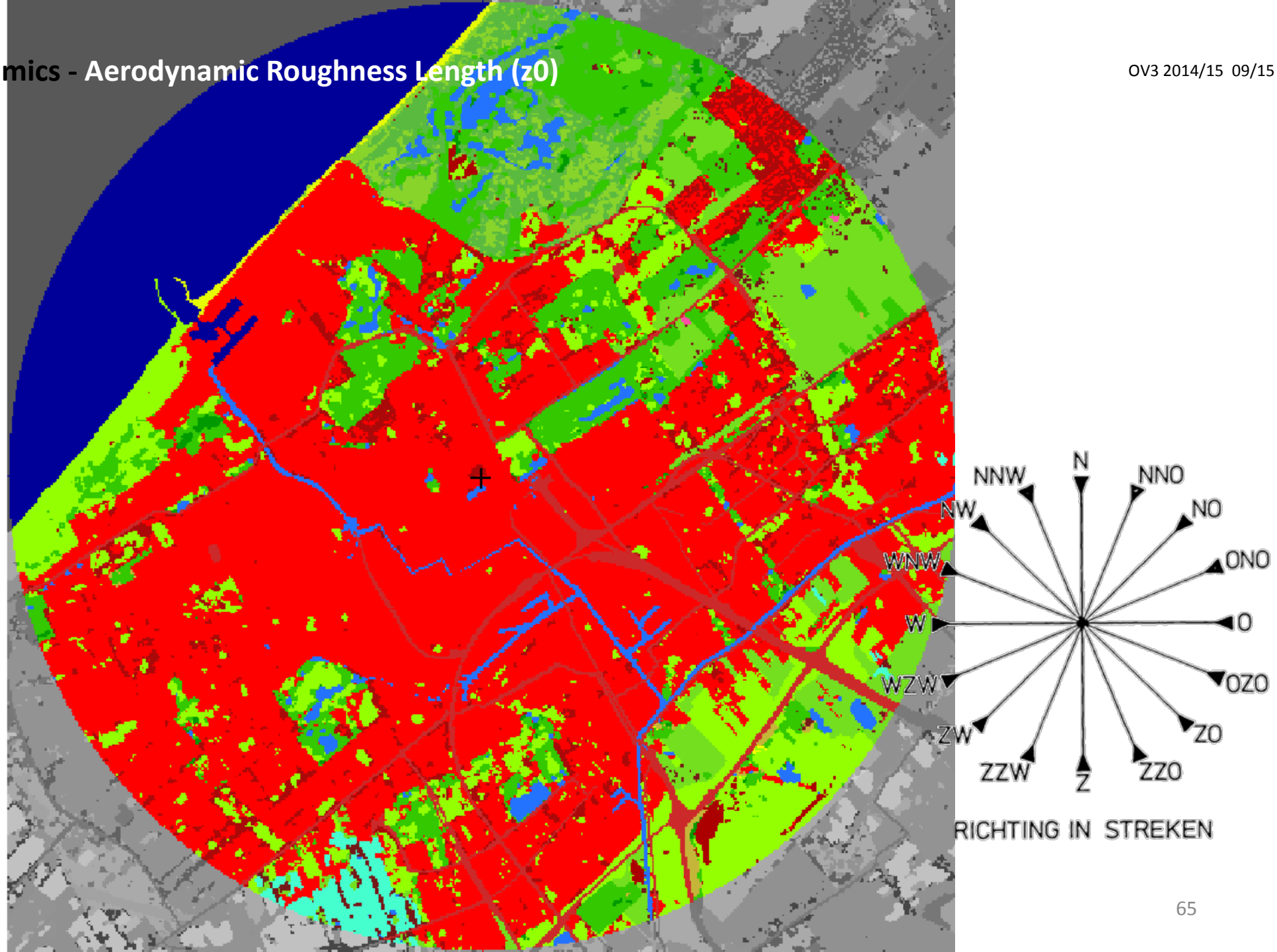
Windspeed height 60m



ARCHITECTURAL AERODYNAMICS
Modelling

CFD resultaten zijn fout, totdat het tegendeel bewezen is !!

Prof. dr. ir. Bert Blocken, TuE, Chair of Building and Urban Physics, Actiflow seminar Duurzaam simuleren (2013)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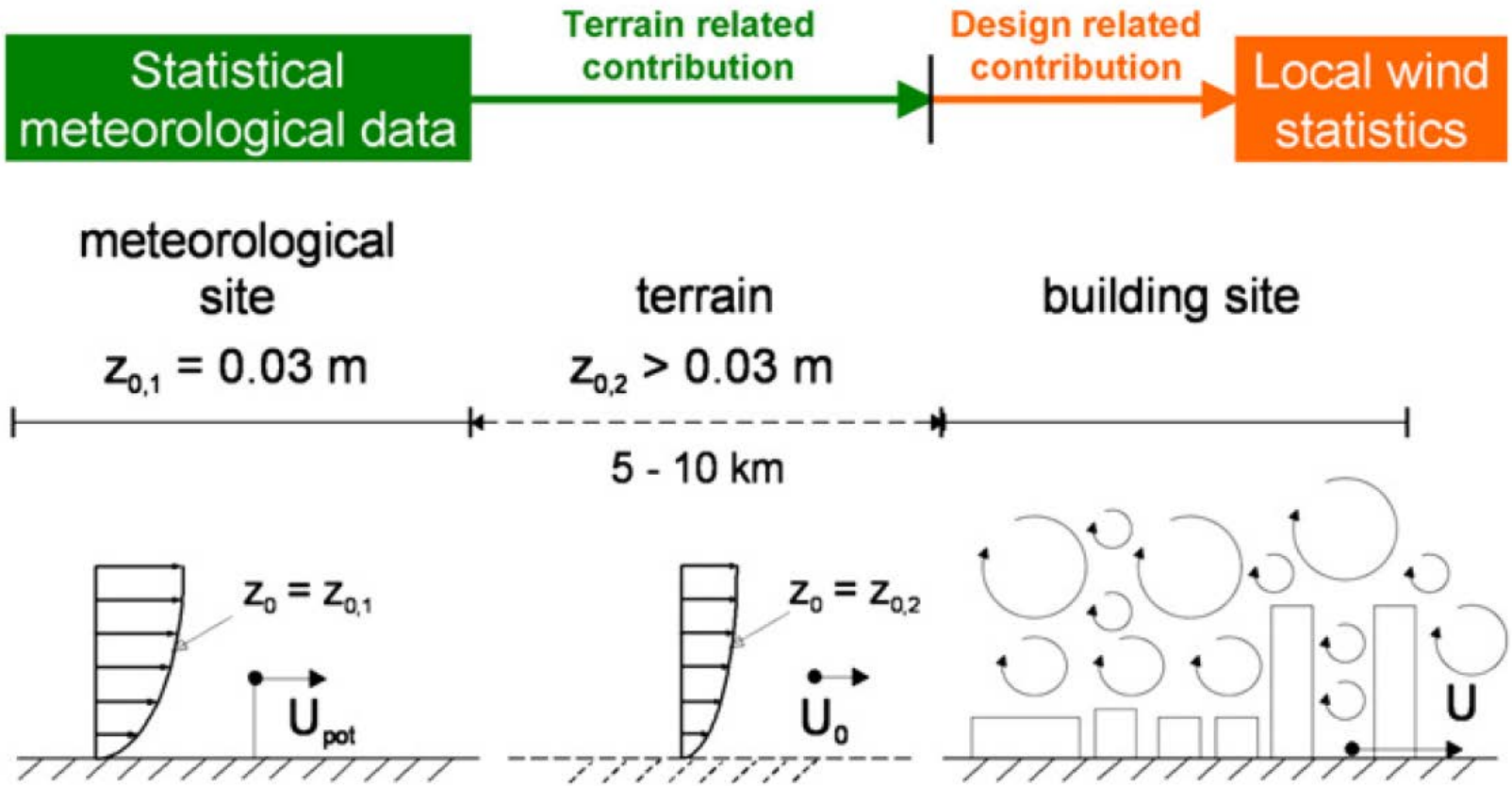
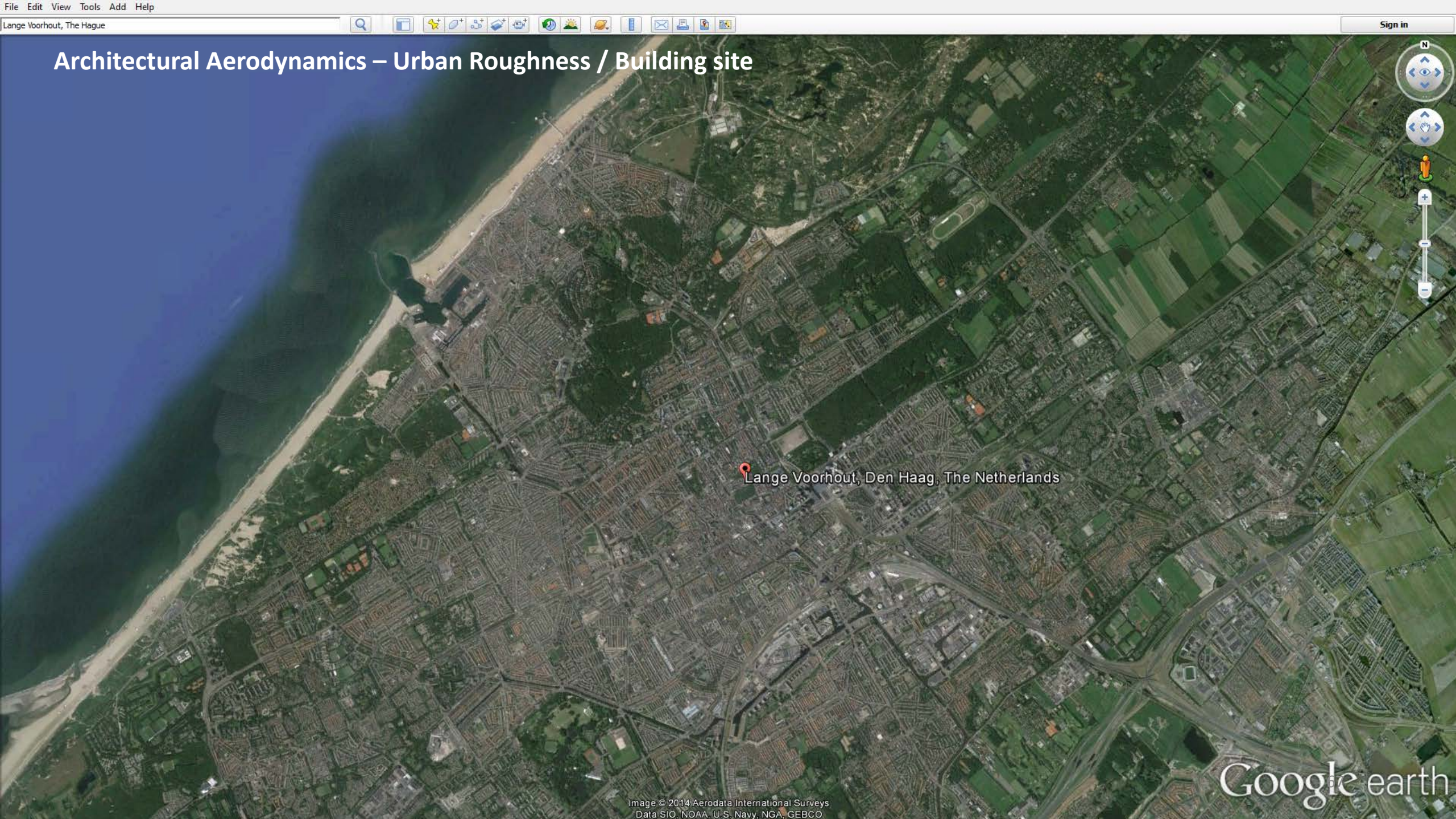
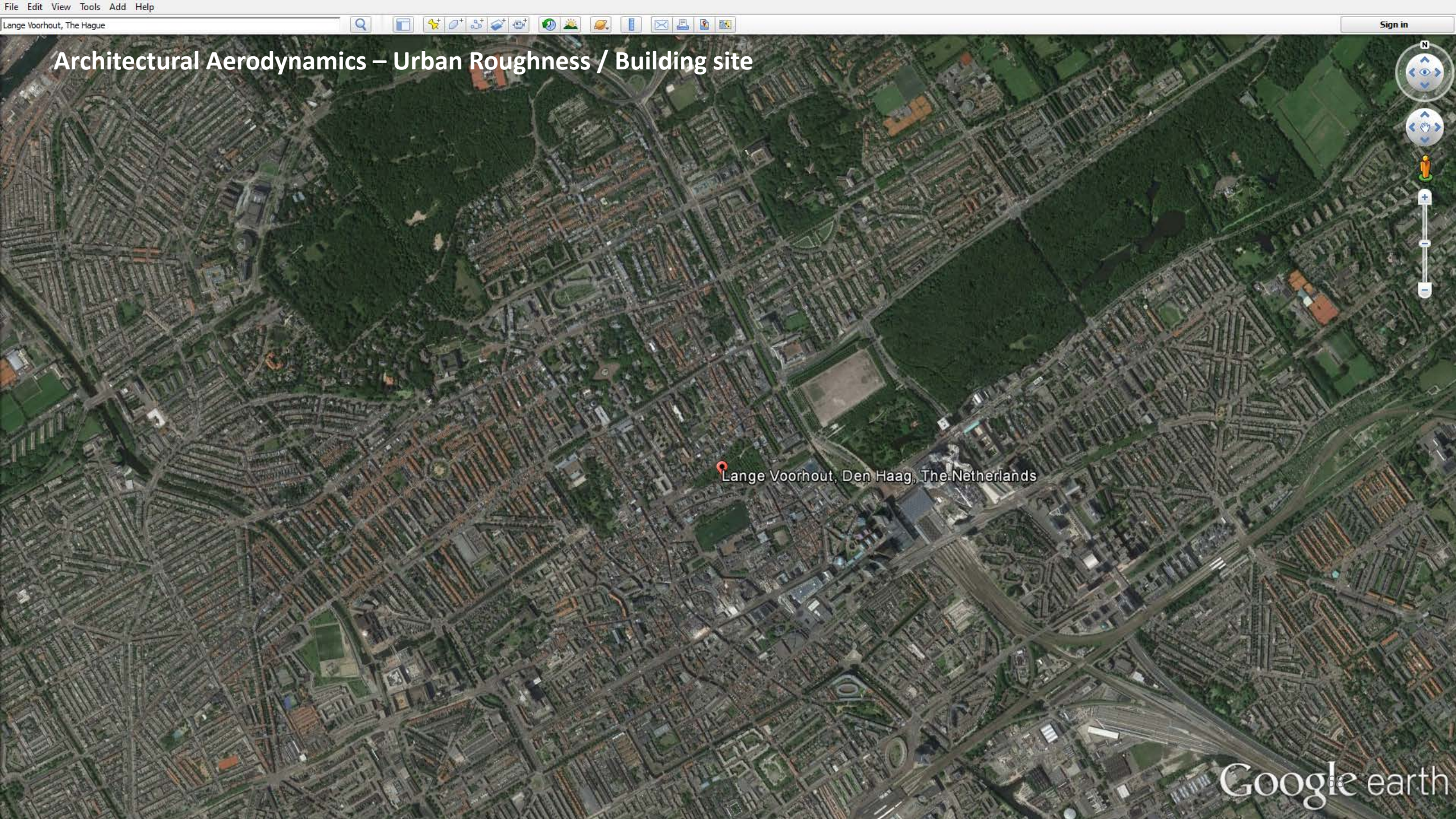
RICHTING IN STREKEN

Architectural Aerodynamics - Aerodynamic Roughness Length (z0)



B. Blocken / Environmental Modelling and Software 30 (2012)


File Edit View Tools Add Help
Lange Voorhout, The Hague
Sign in
Architectural Aerodynamics – Urban Roughness / Building site
Lange Voorhout, Den Haag, The Netherlands
Image © 2014 Aerodata International Surveys
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth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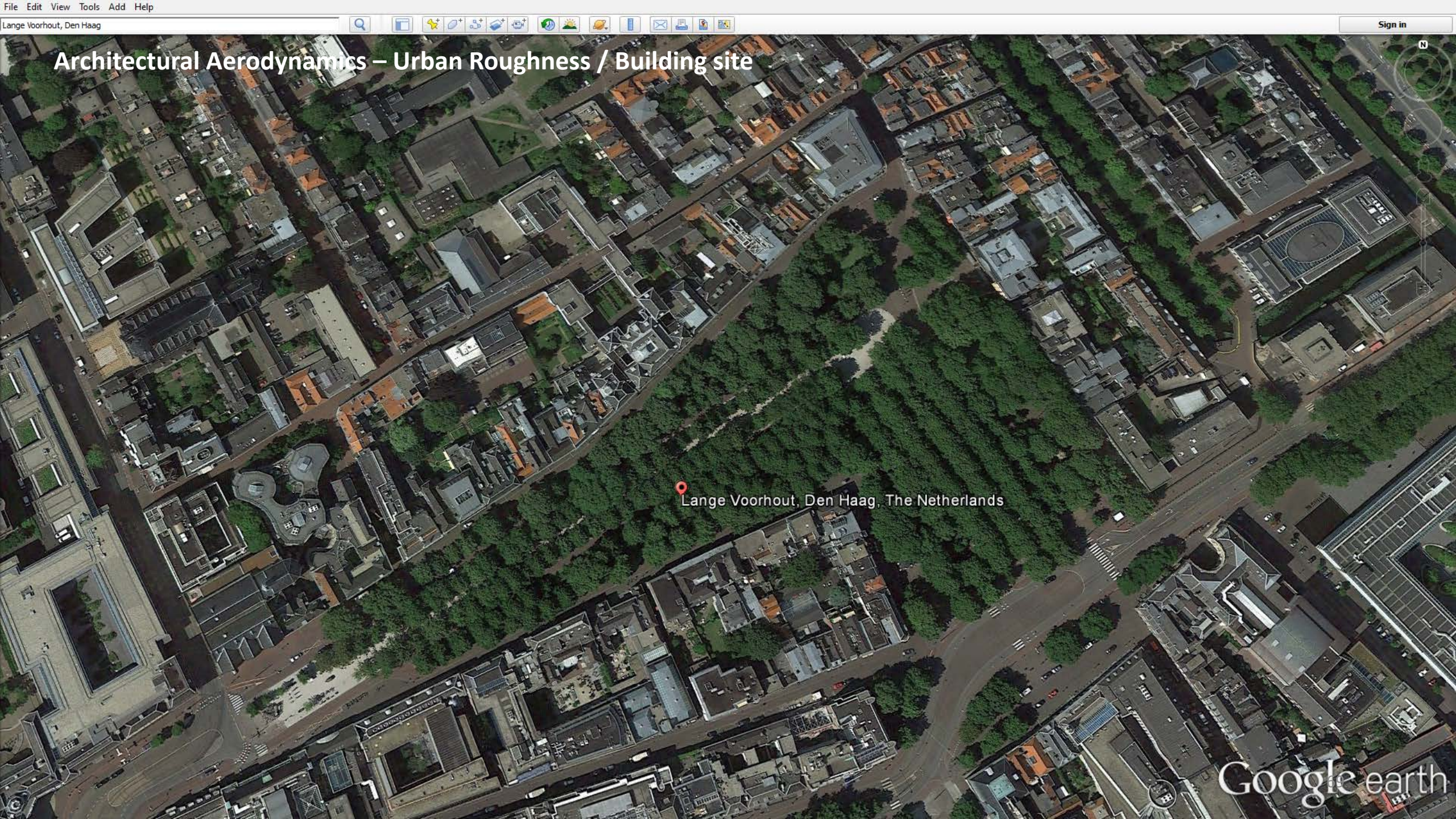
Architectural Aerodynamics – Urban Roughness / Building site
Lange Voorhout, Den Haag, The Netherlands
Google earth

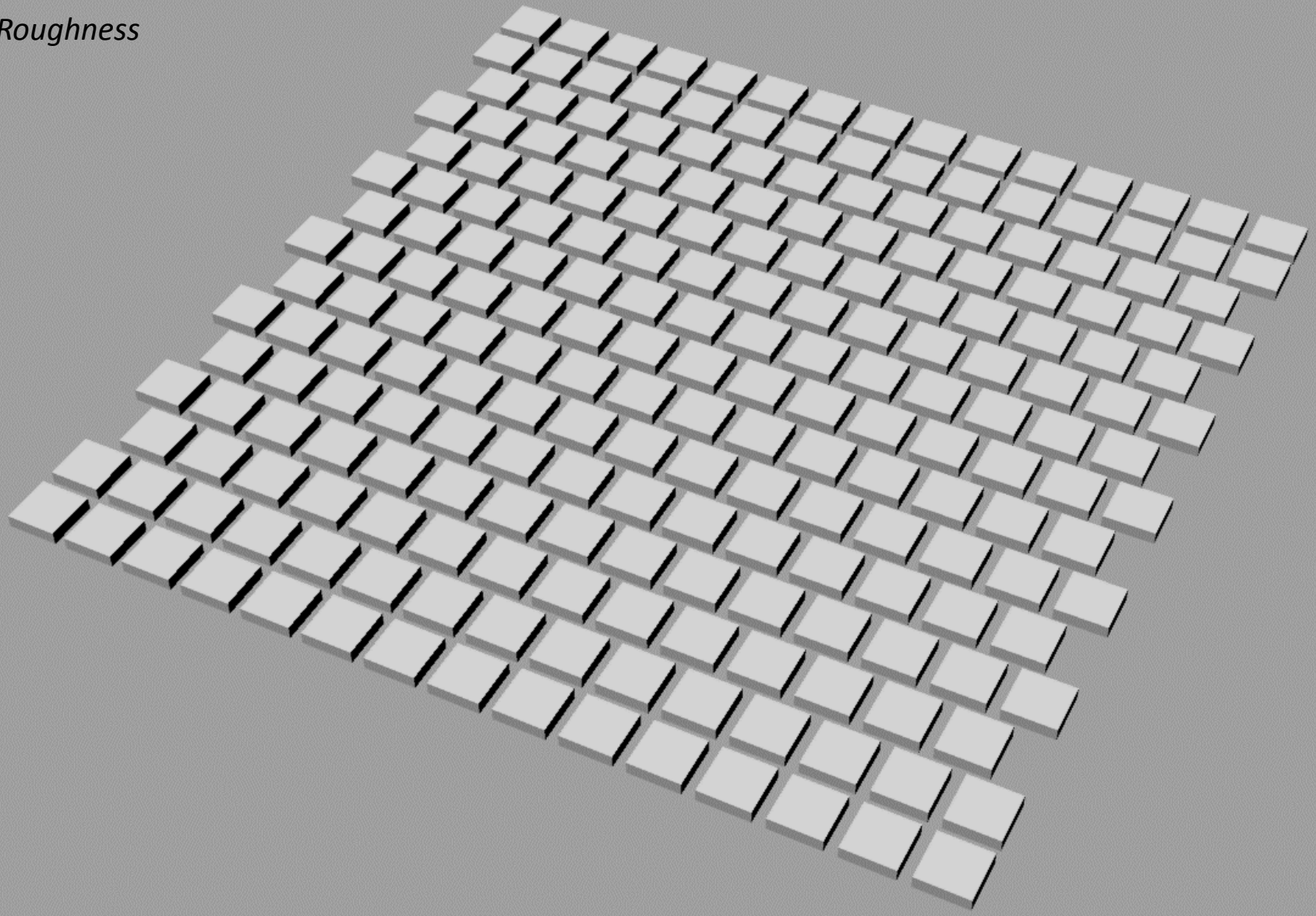

File Edit View Tools Add Help
Lange Voorhout, Den Haag
Sign in
Architectural Aerodynamics – Urban Roughness / Building site
Lange Voorhout, Den Haag, The Netherlands
Google earth

Architectural Aerodynamics – Building site

The Hague / Escher Museum / Lange Voorhout

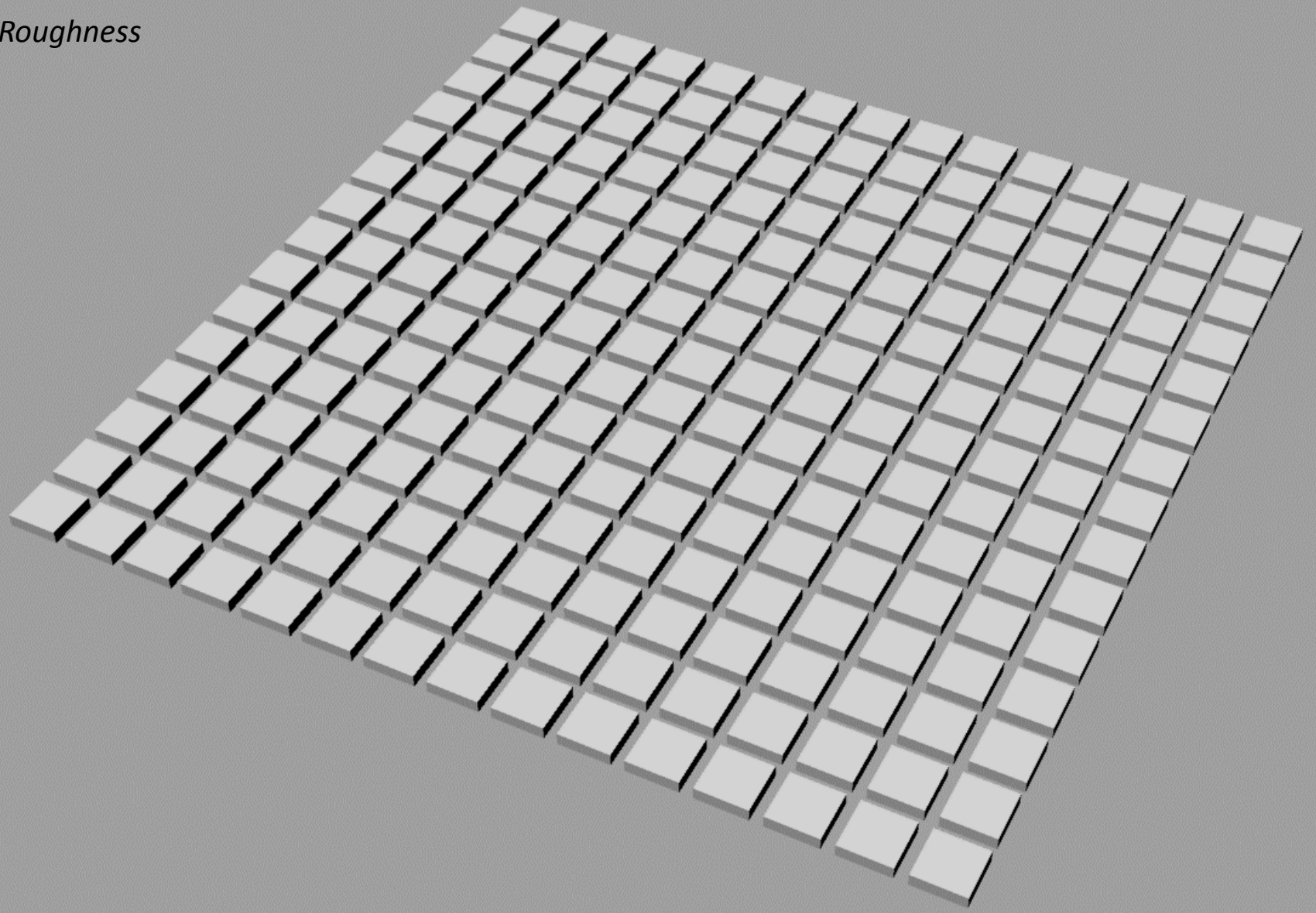
Architectural Aerodynamics and the CAD Model

Parameter: City Roughness



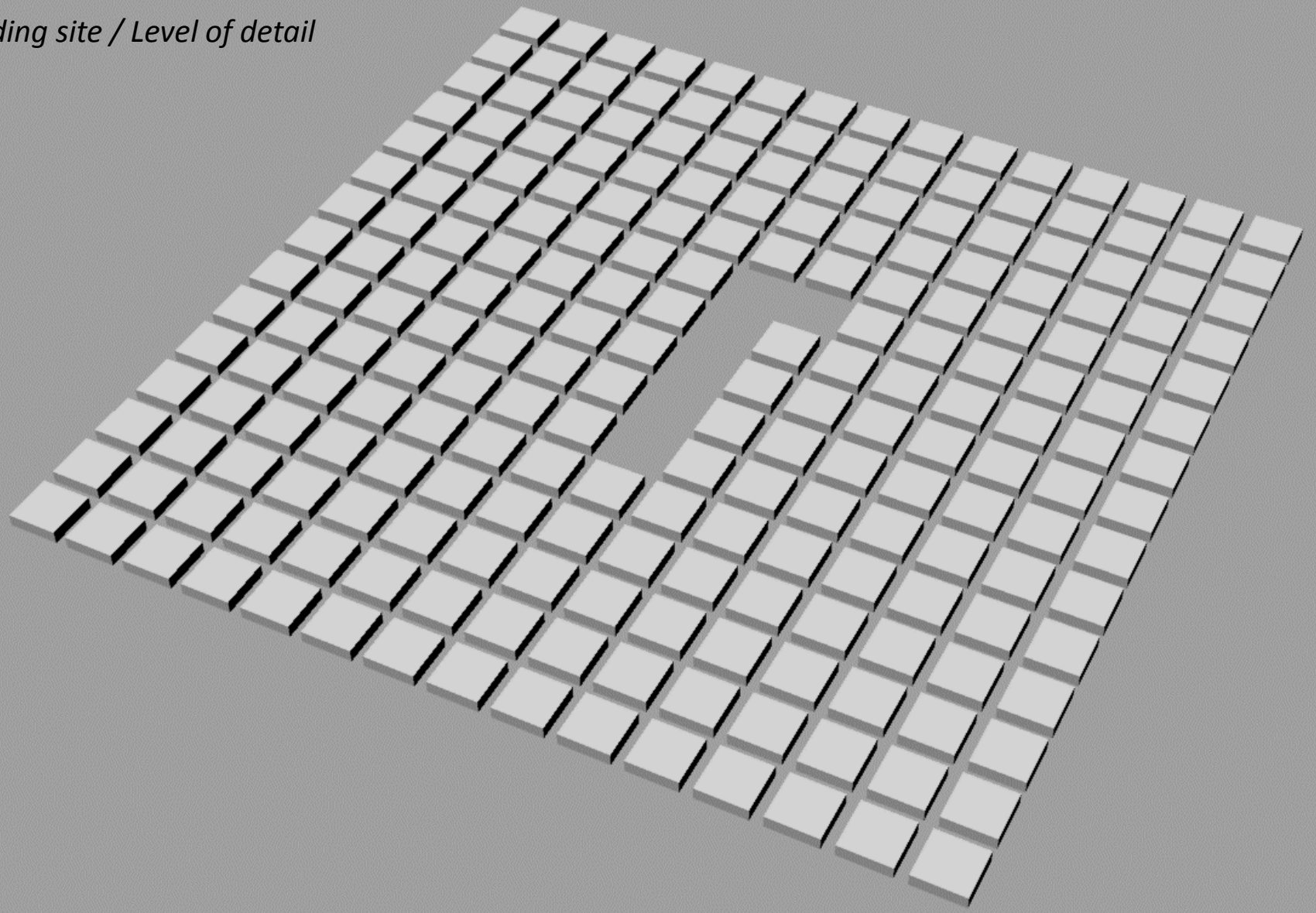
Architectural Aerodynamics and the CAD Model

Parameter: City Roughness



Architectural Aerodynamics and the CAD Model

Parameter: Building site / Level of detail

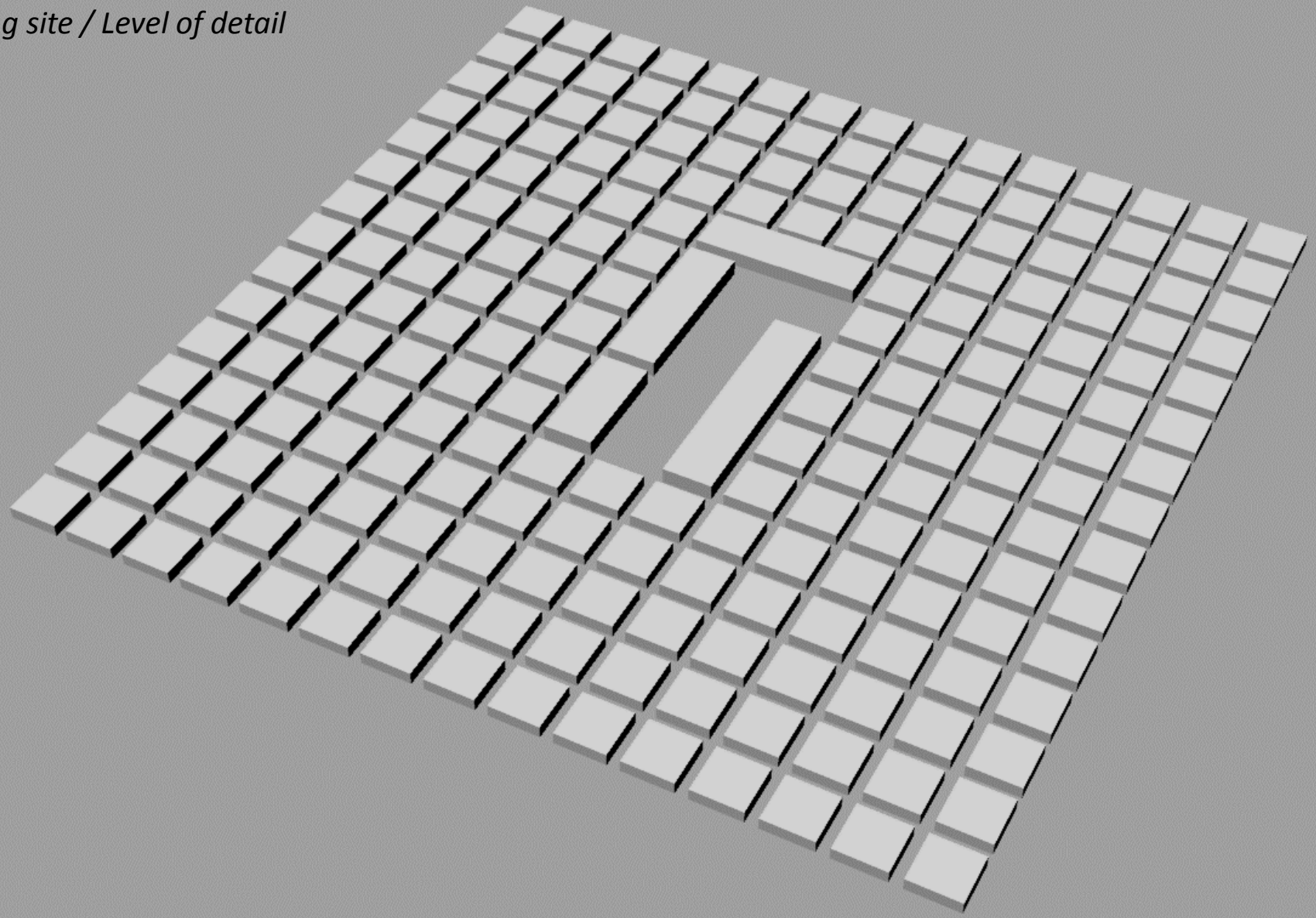


Architectural Aerodynamics and the CAD Model

Parameter: Building site / level of detail

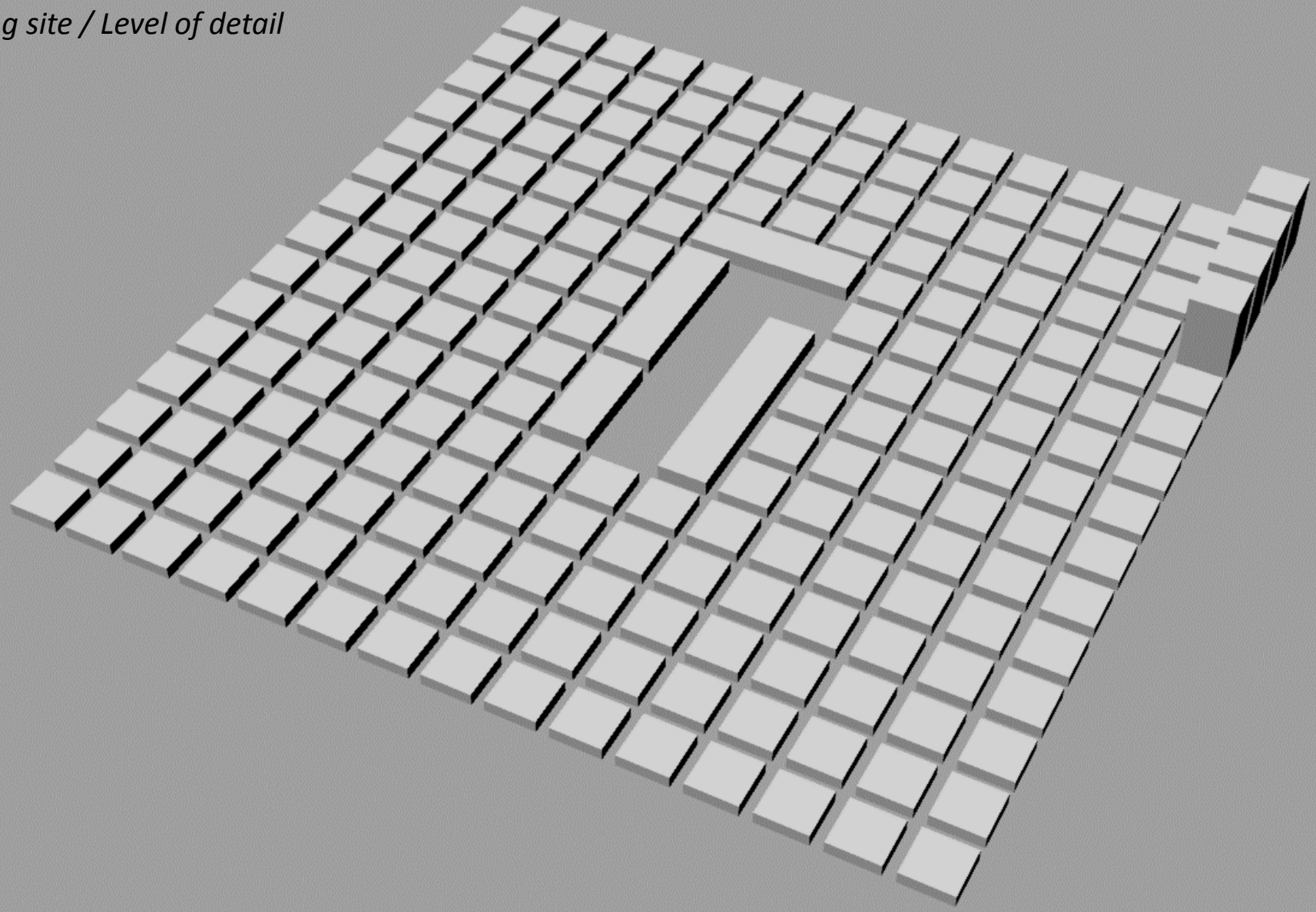
Architectural Aerodynamics and the CAD Model

Parameter: Building site / Level of detail



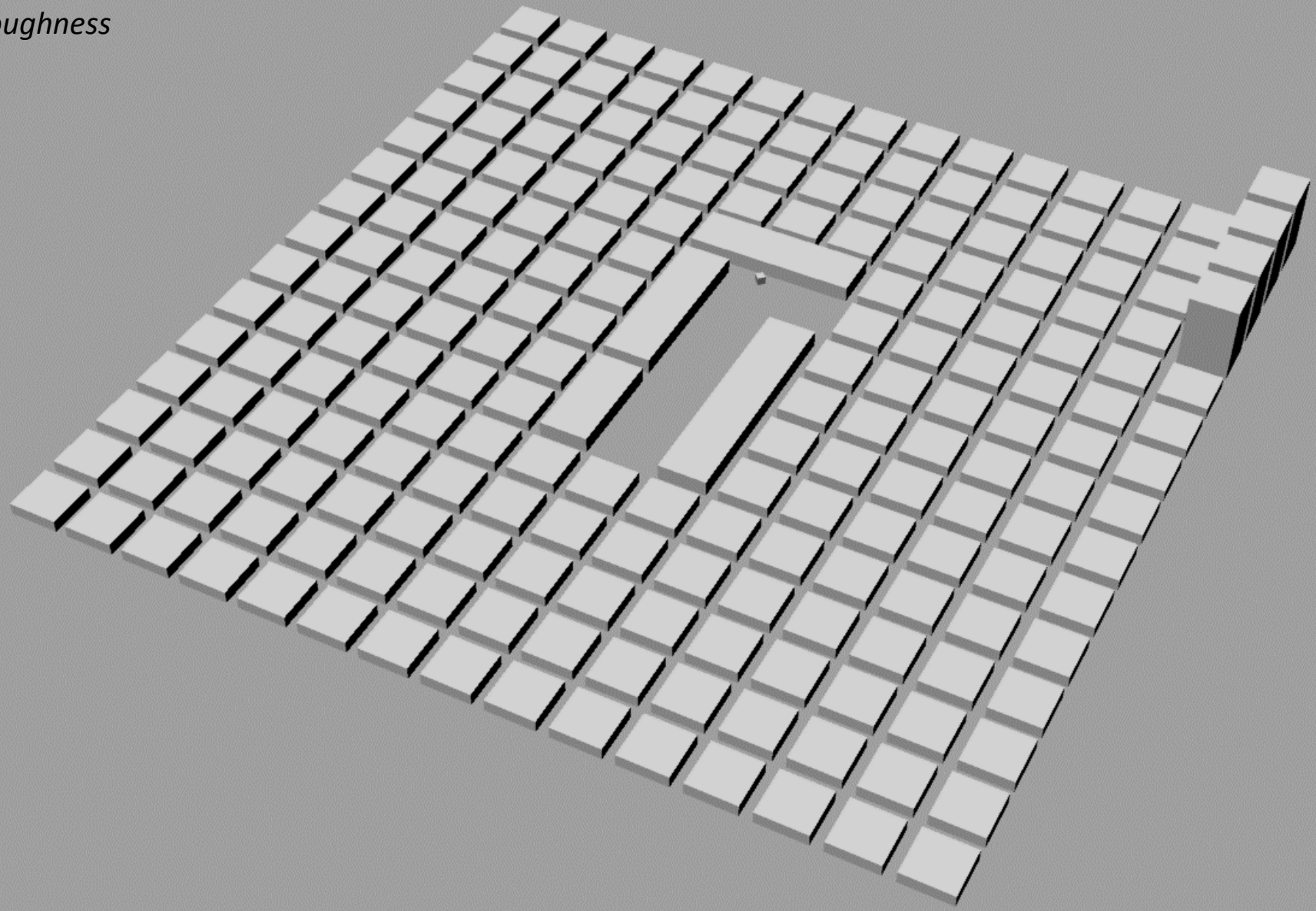
Architectural Aerodynamics and the CAD Model

Parameter: Building site / Level of detail



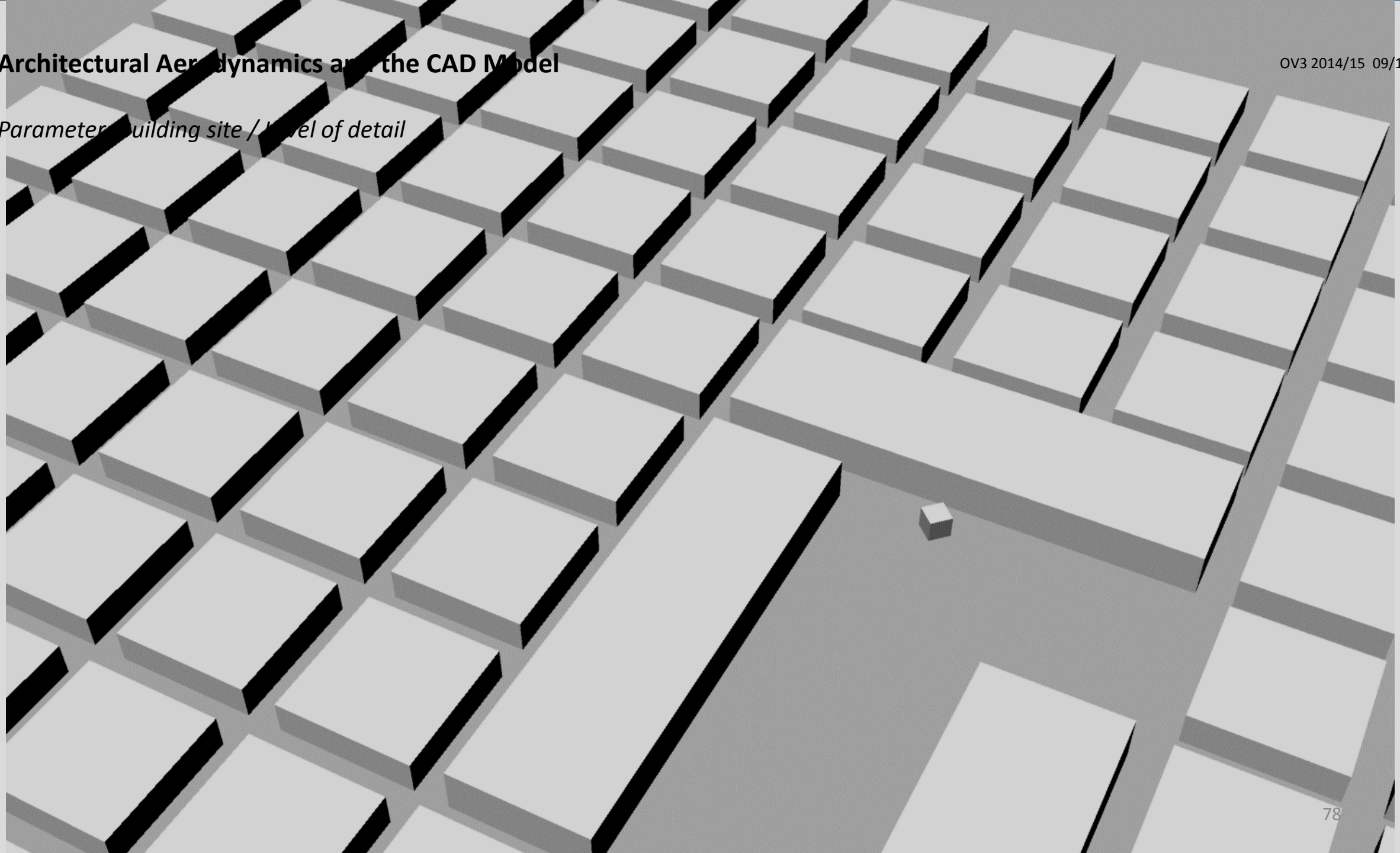
Architectural Aerodynamics and the CAD Model

Parameter: City Roughness



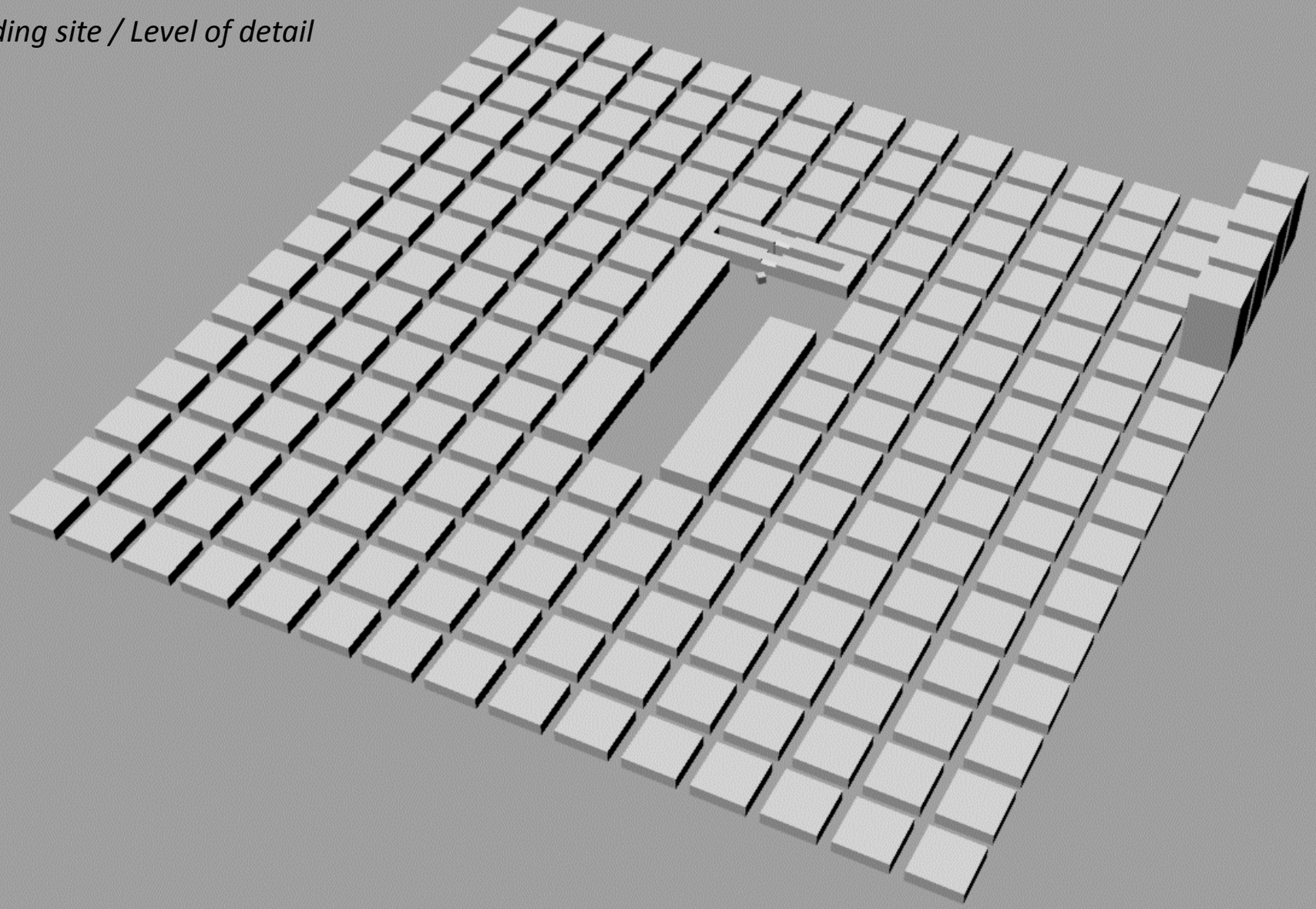
Architectural Aerodynamics and the CAD Model

Parameter: building site / level of detail



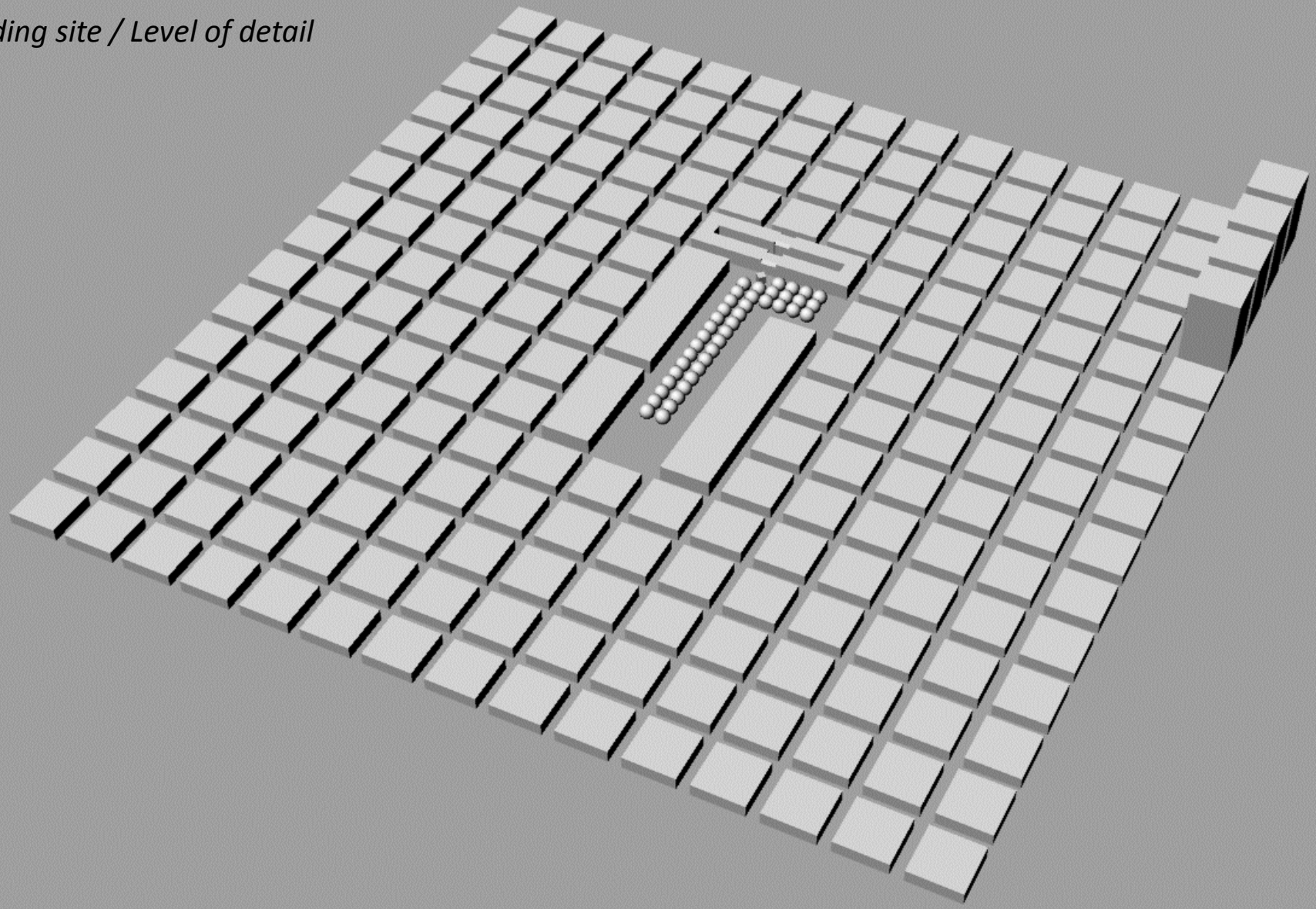
Architectural Aerodynamics and the CAD Model

Parameter: Building site / Level of detail



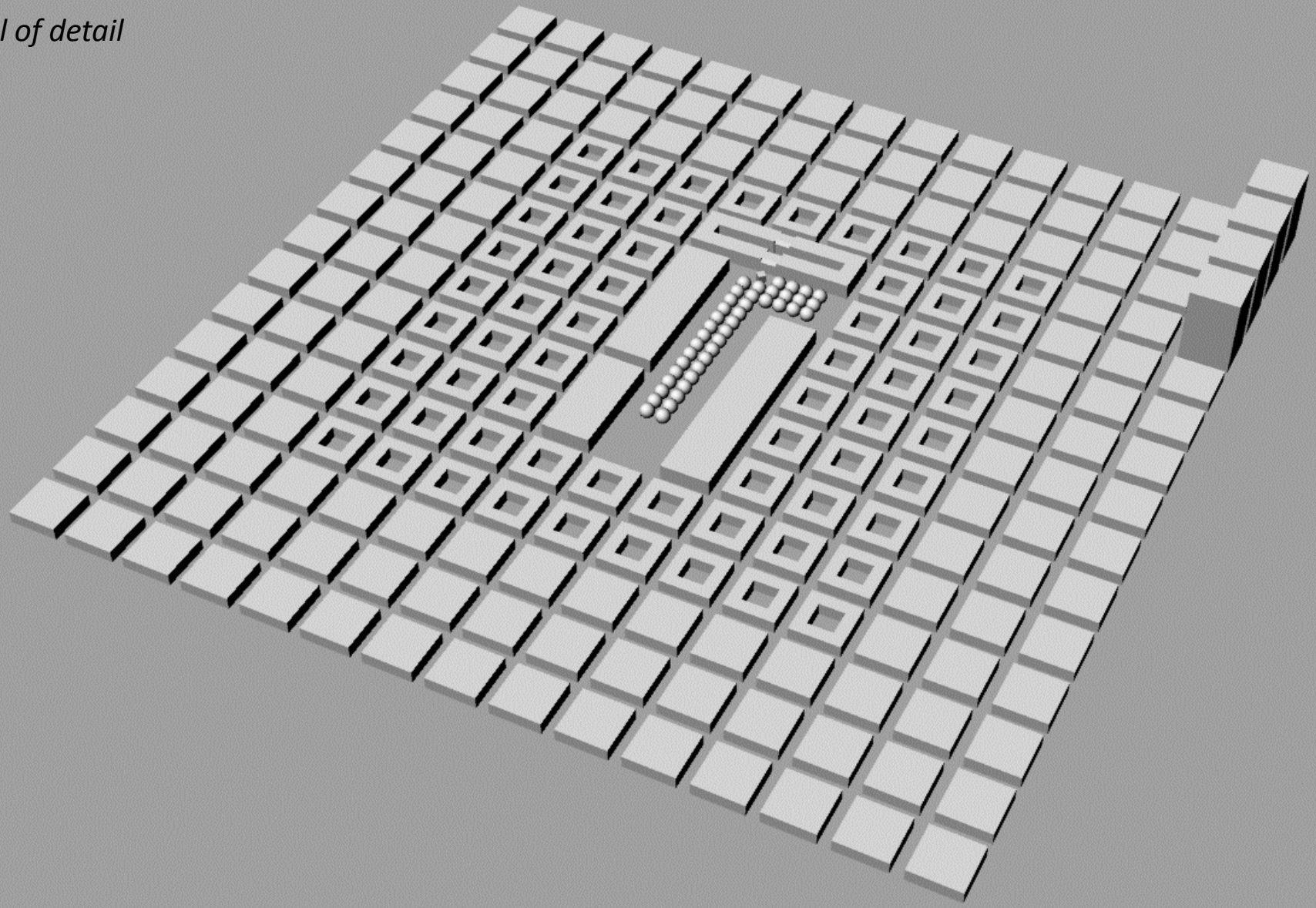
Architectural Aerodynamics and the CAD Model

Parameter: Building site / Level of detail



Architectural Aerodynamics and the CAD Model

Parameter: Level of detail



Architectural Aerodynamics and the CAD Model

20140820DH606015R8 - Rhinoceros (Educational) - [Perspective]

File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render Help

Meshing... Press Esc to cancel

Command:

Perspective

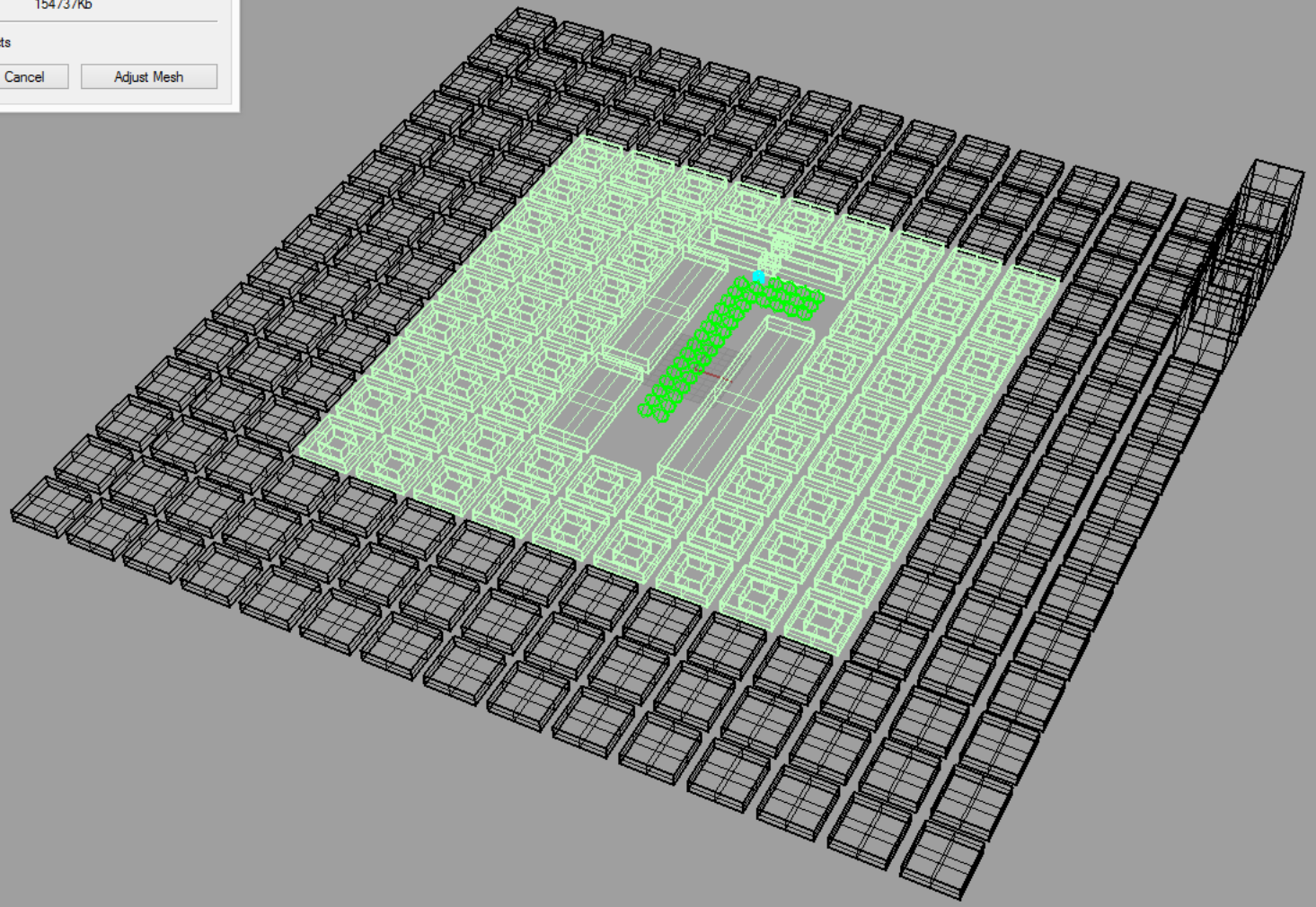
STL Export Options

File type	Approximate Size
Binary	27730Kb
Ascii	154737Kb

Export open objects

OK Cancel Adjust Mesh

*Parameter: STL **File size***



Layers - All Layers

Name	Material Libr...
Default	
Layer 01	
Layer 02 ✓	
Layer 03	
Layer 04	
Layer 05	

Architectural Aerodynamics and the CAD Model

20140820DH606015R6b - Rhinoceros (Educational) - [Perspective]

File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render Help

Meshing... Press Esc to cancel

Command:

Perspective

STL Export Options

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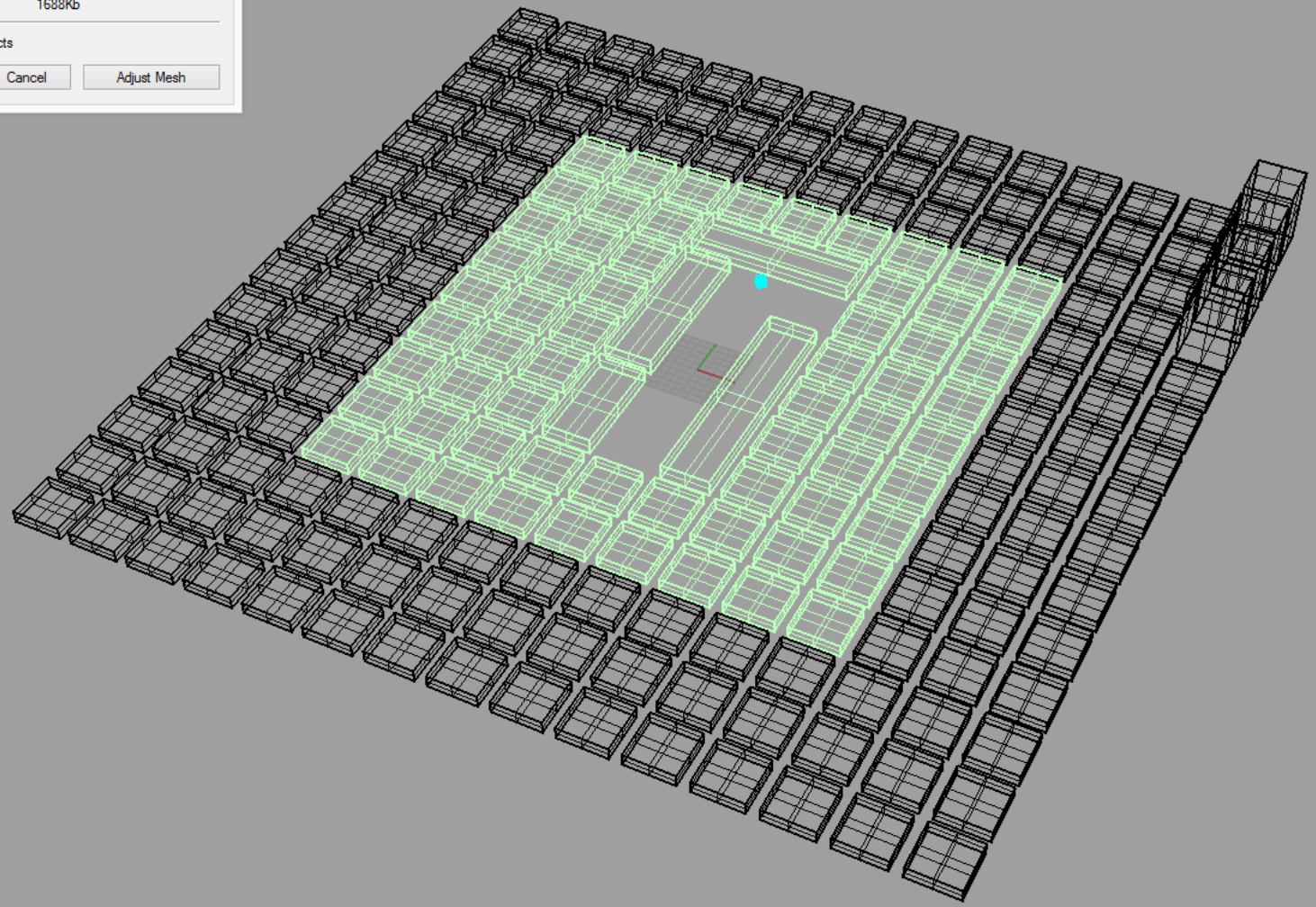


Layers - All Layers

Name	Material Libr...
Default	
Layer 01	
Layer 02	
Layer 03	
Layer 04	

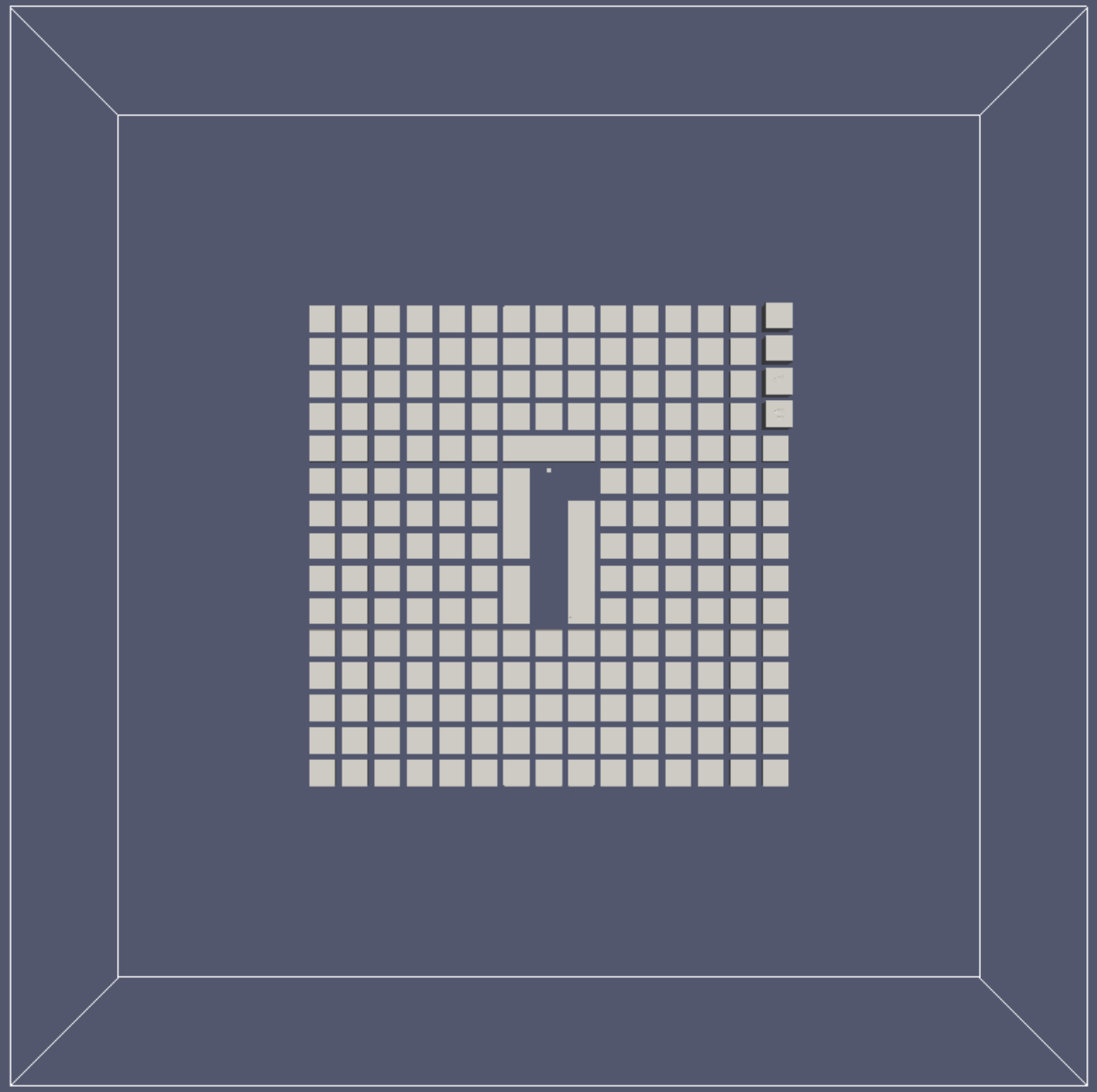
Architectural Aerodynamics

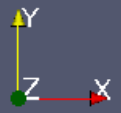
CAD model

+

CFD calculation model

Mesh resolution





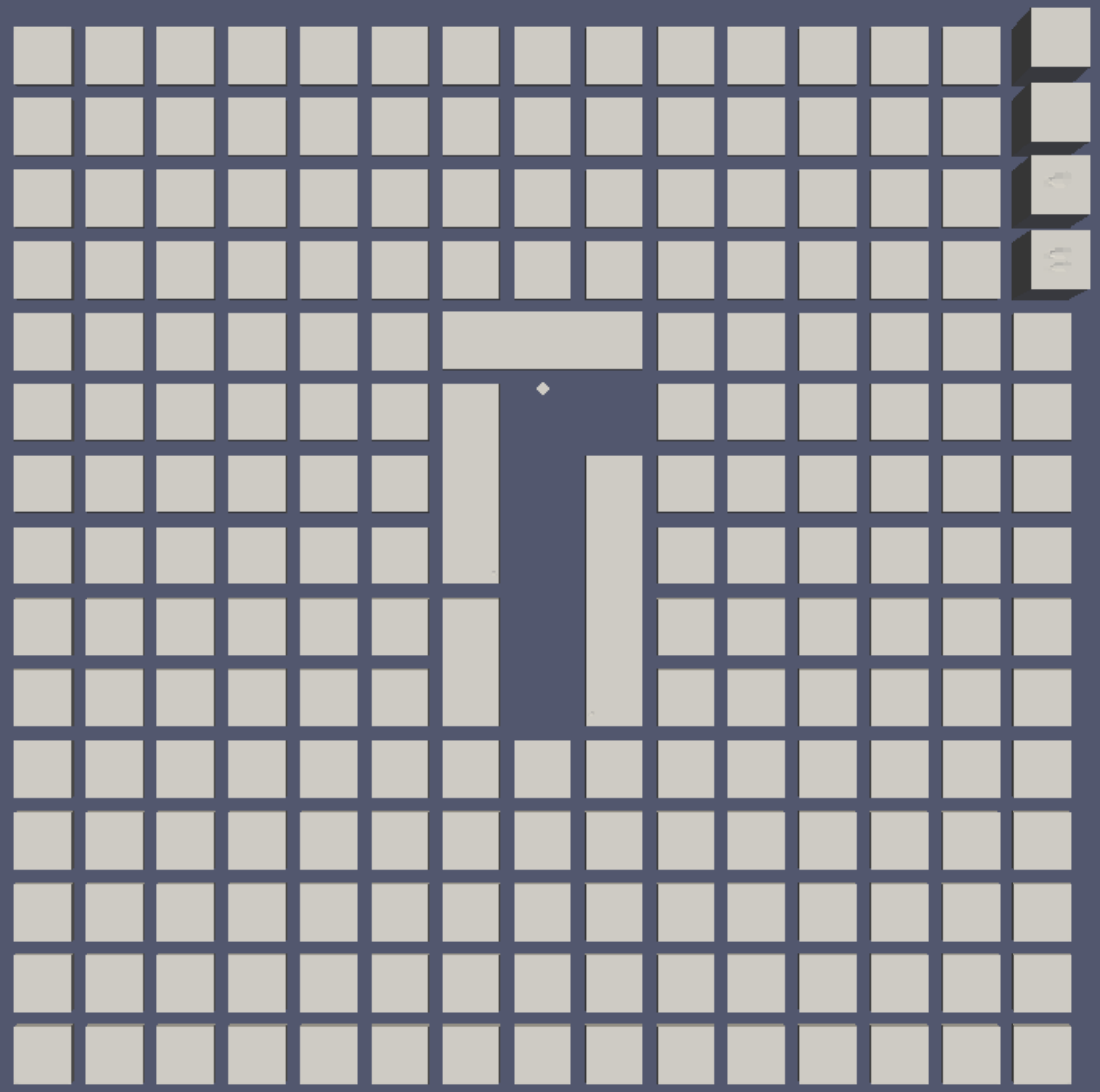
Architectural Aerodynamics

CAD model

+

CFD calculation model

Mesh resolution



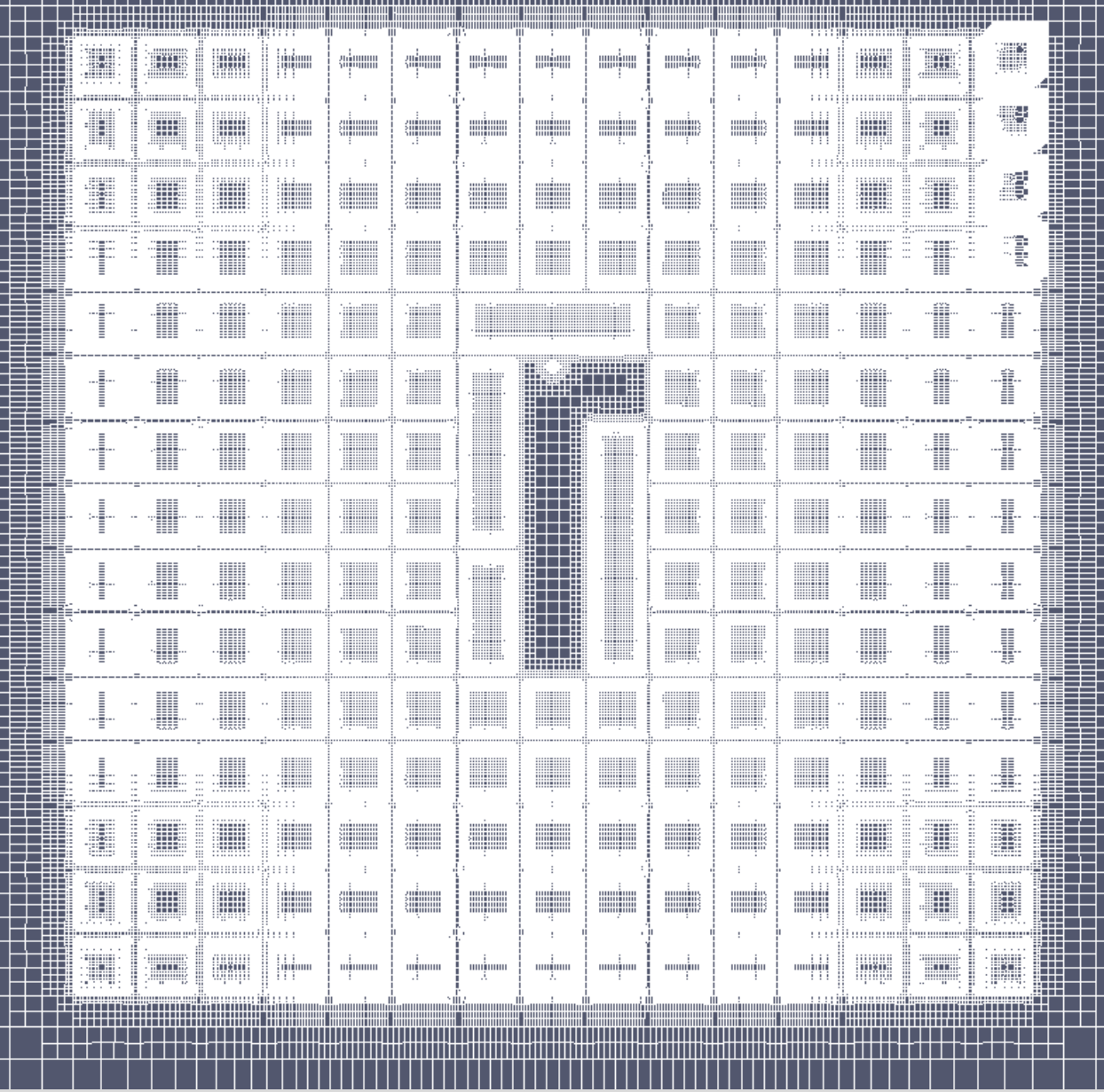
Architectural Aerodynamics

CAD model

+

CFD calculation model

Mesh resolution

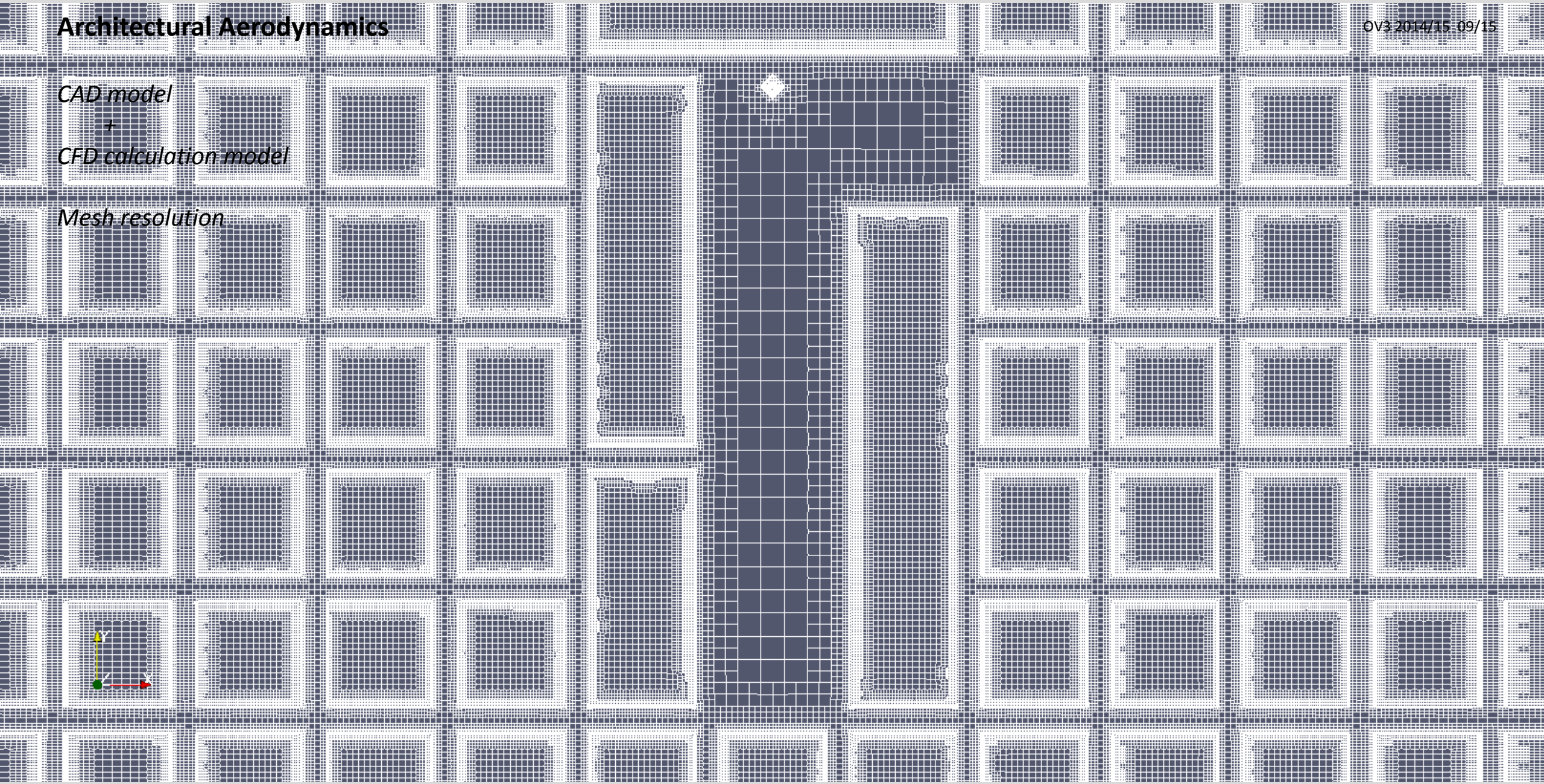


CAD model

+

CFD calculation model

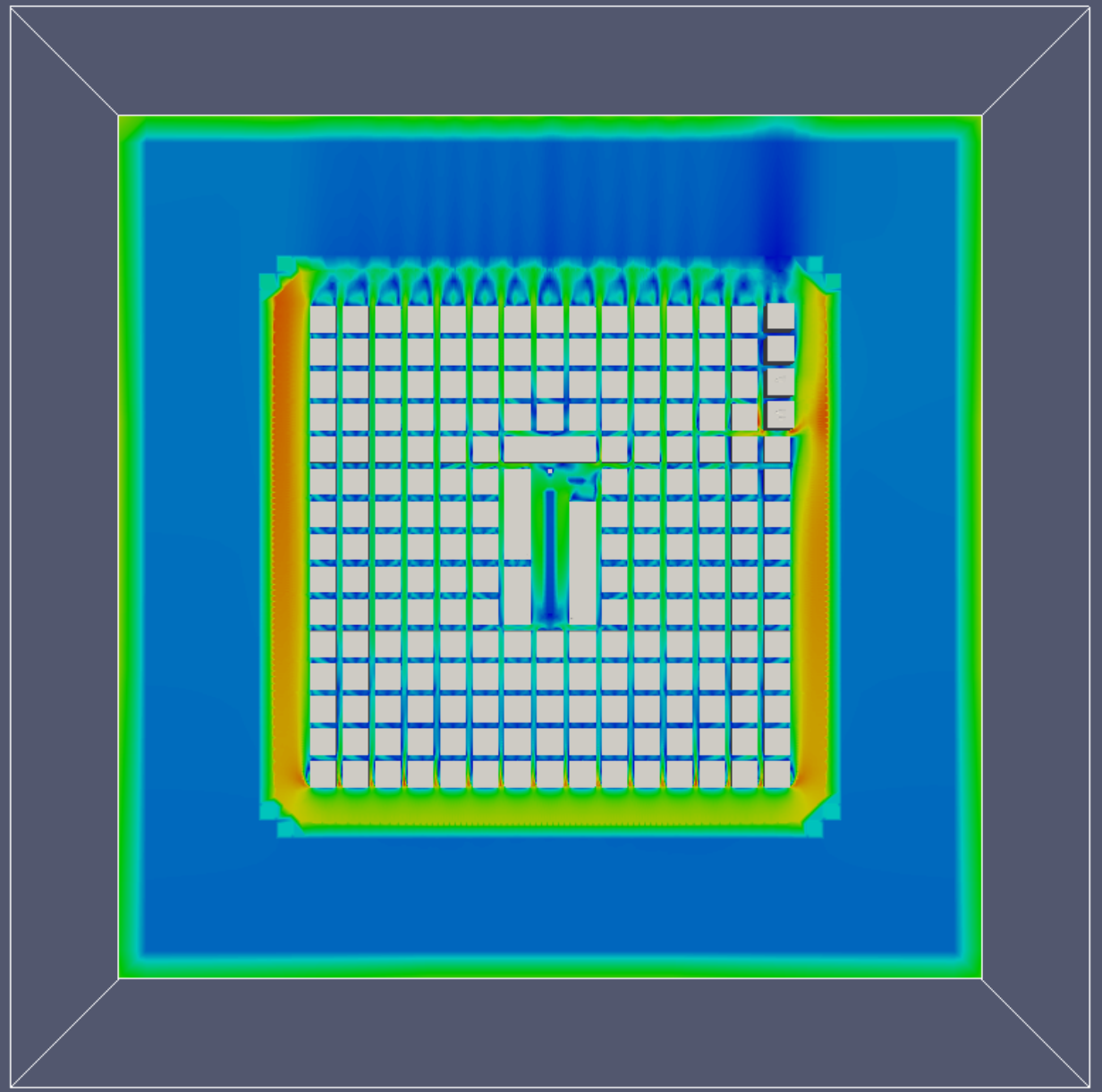
Mesh resolution

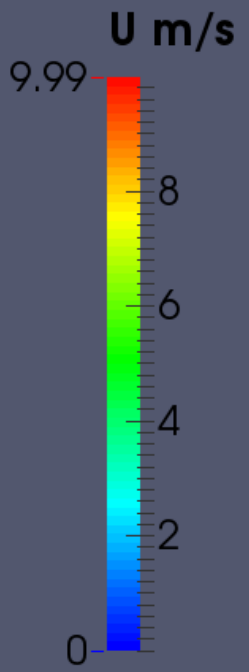


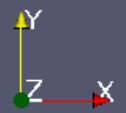
RESULTS

Simulation Result

Wind speed at 2m height



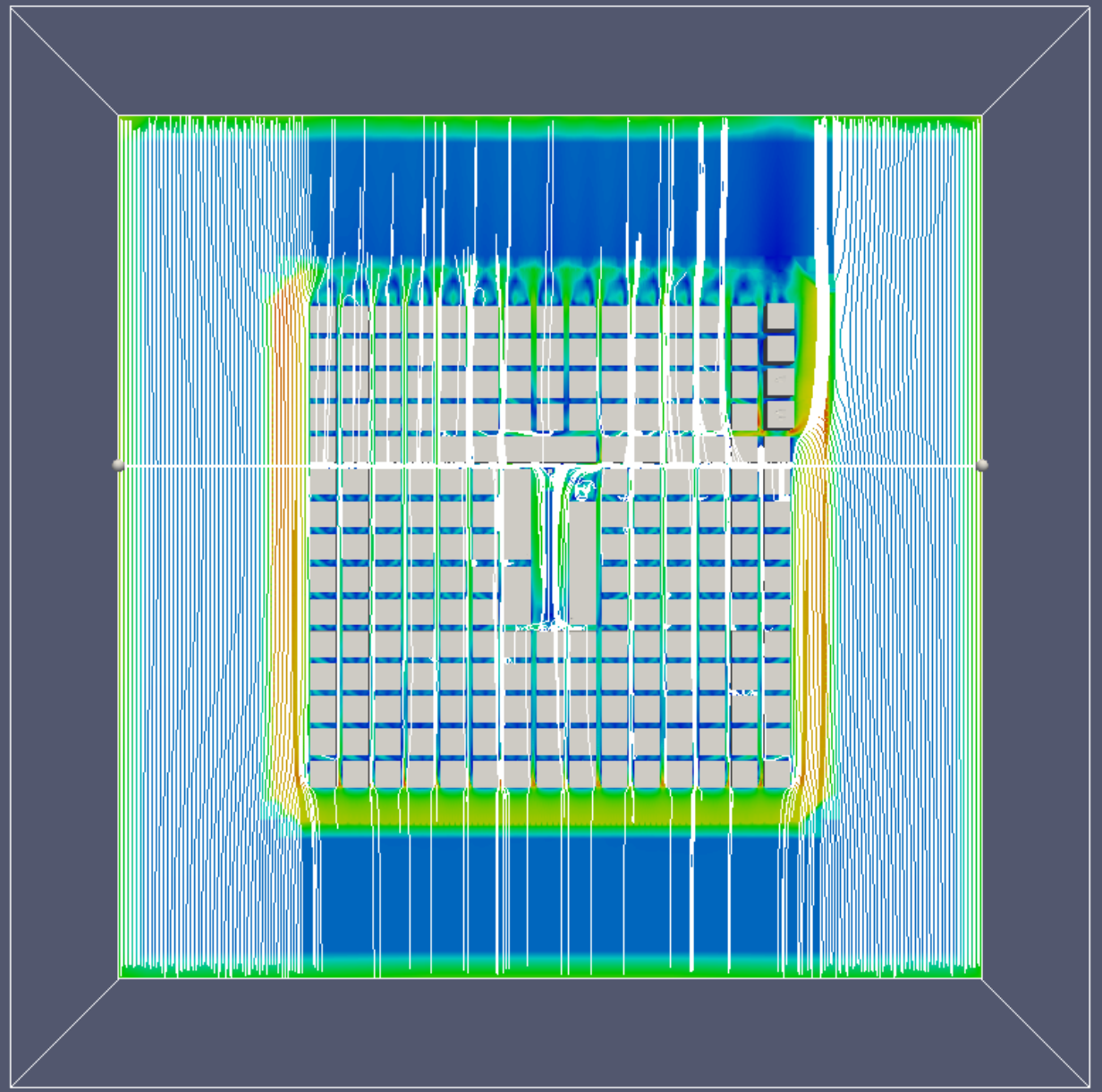




Simulation Result

Wind speed at 2m height

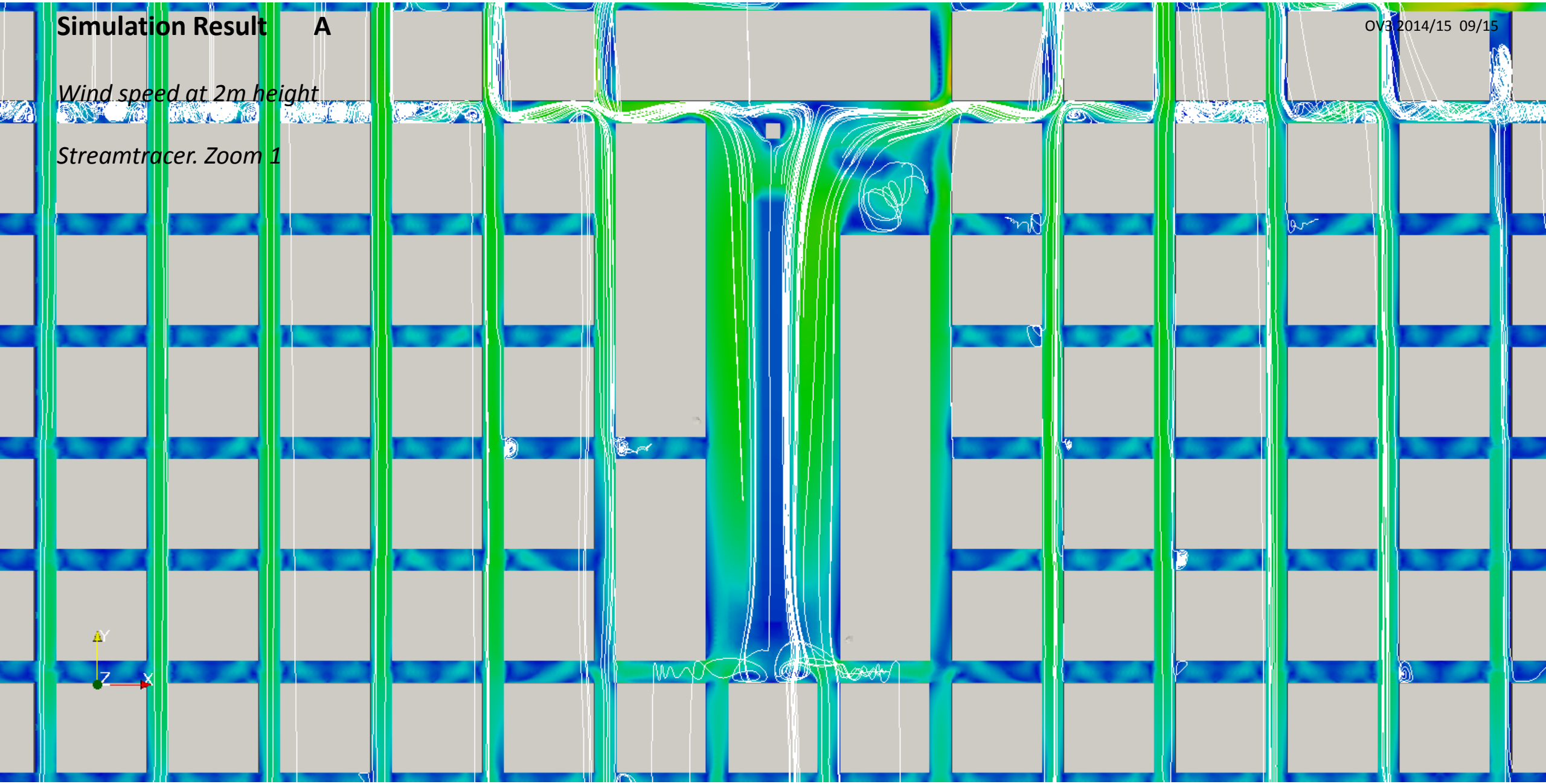
Streamtracer.



Simulation Result A

Wind speed at 2m height

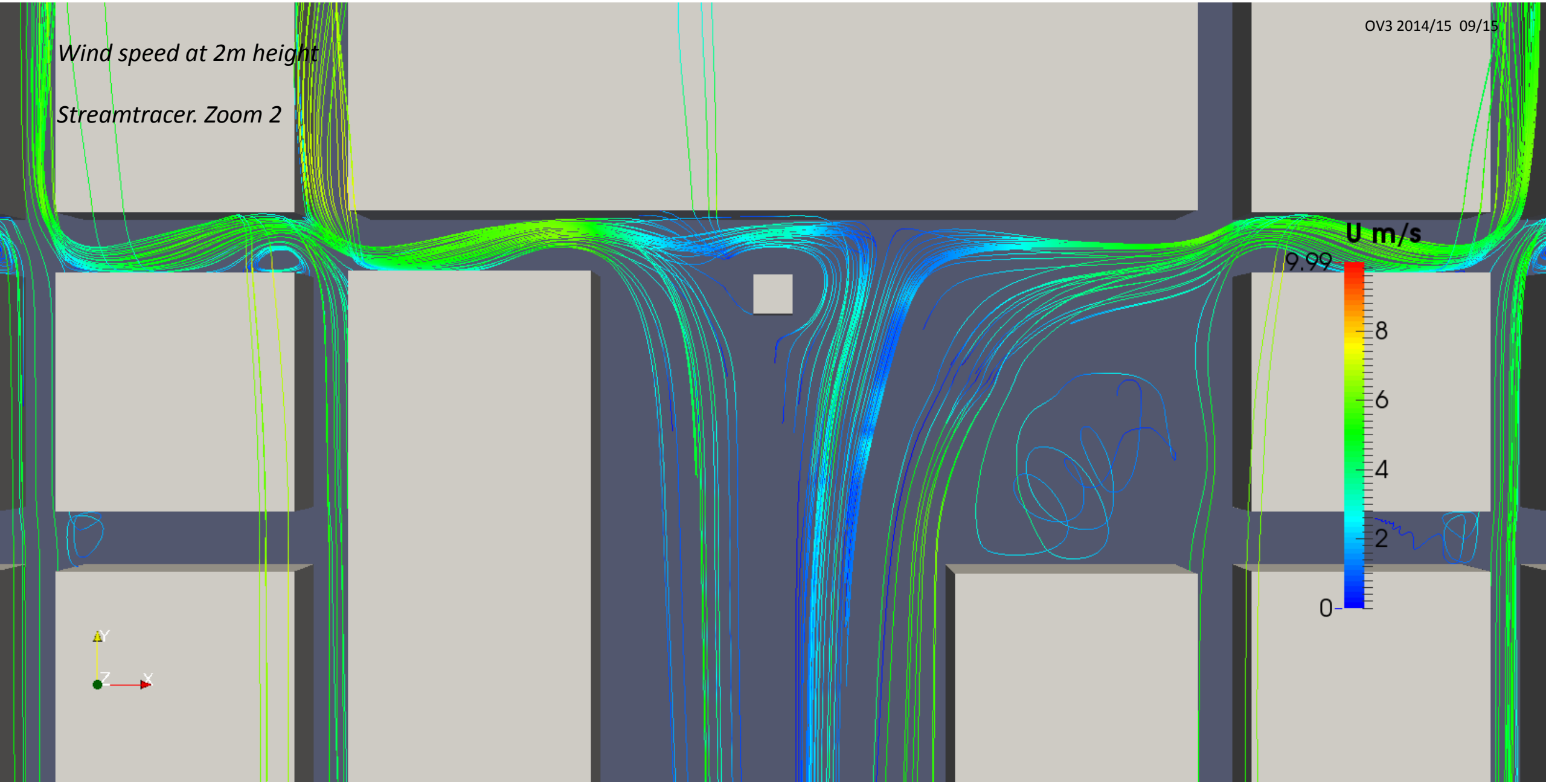
Streamtracer. Zoom 1



Simulation Result A

Wind speed at 2m height

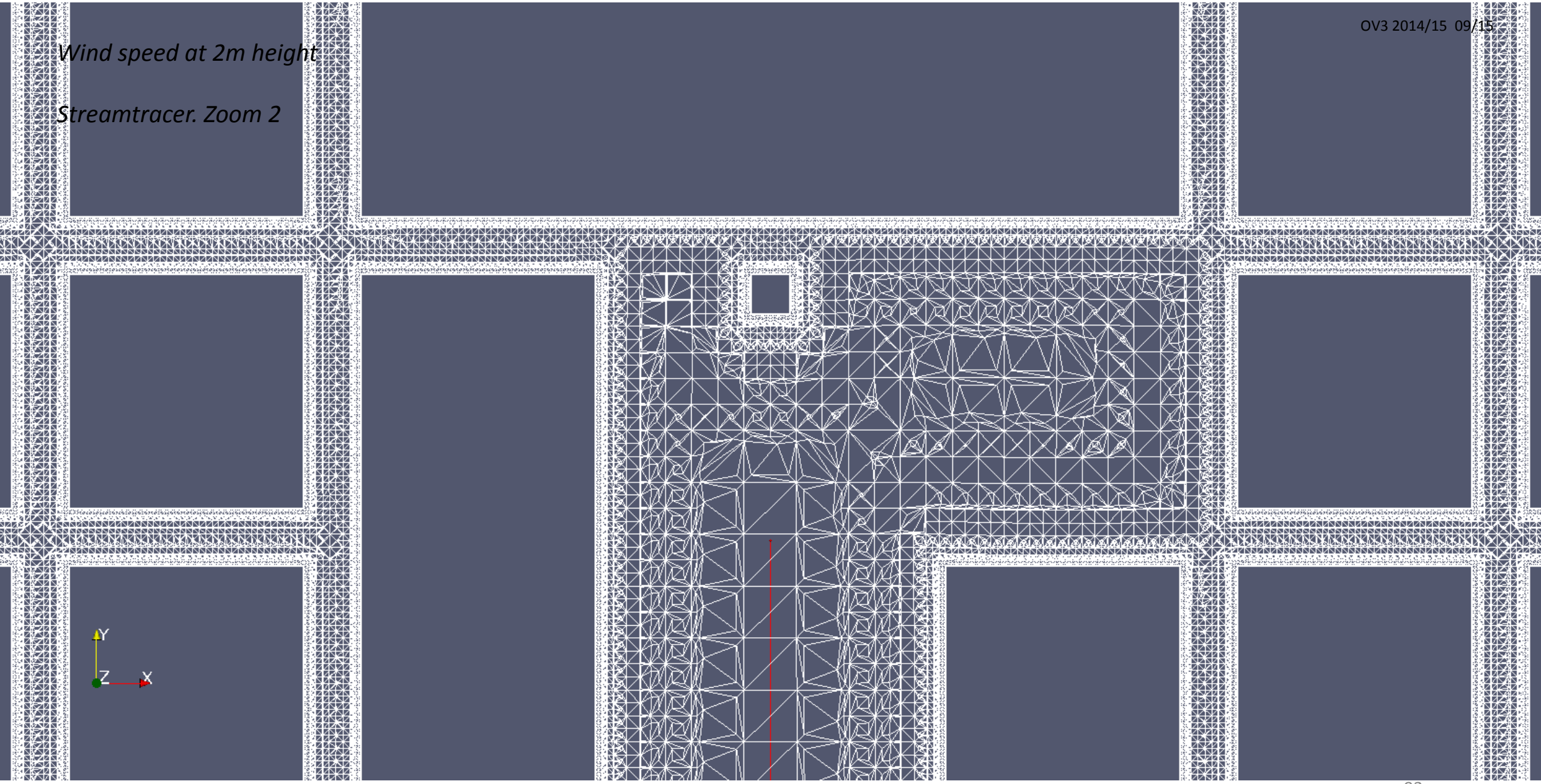
Streamtracer. Zoom 2



Simulation Result A

Wind speed at 2m height

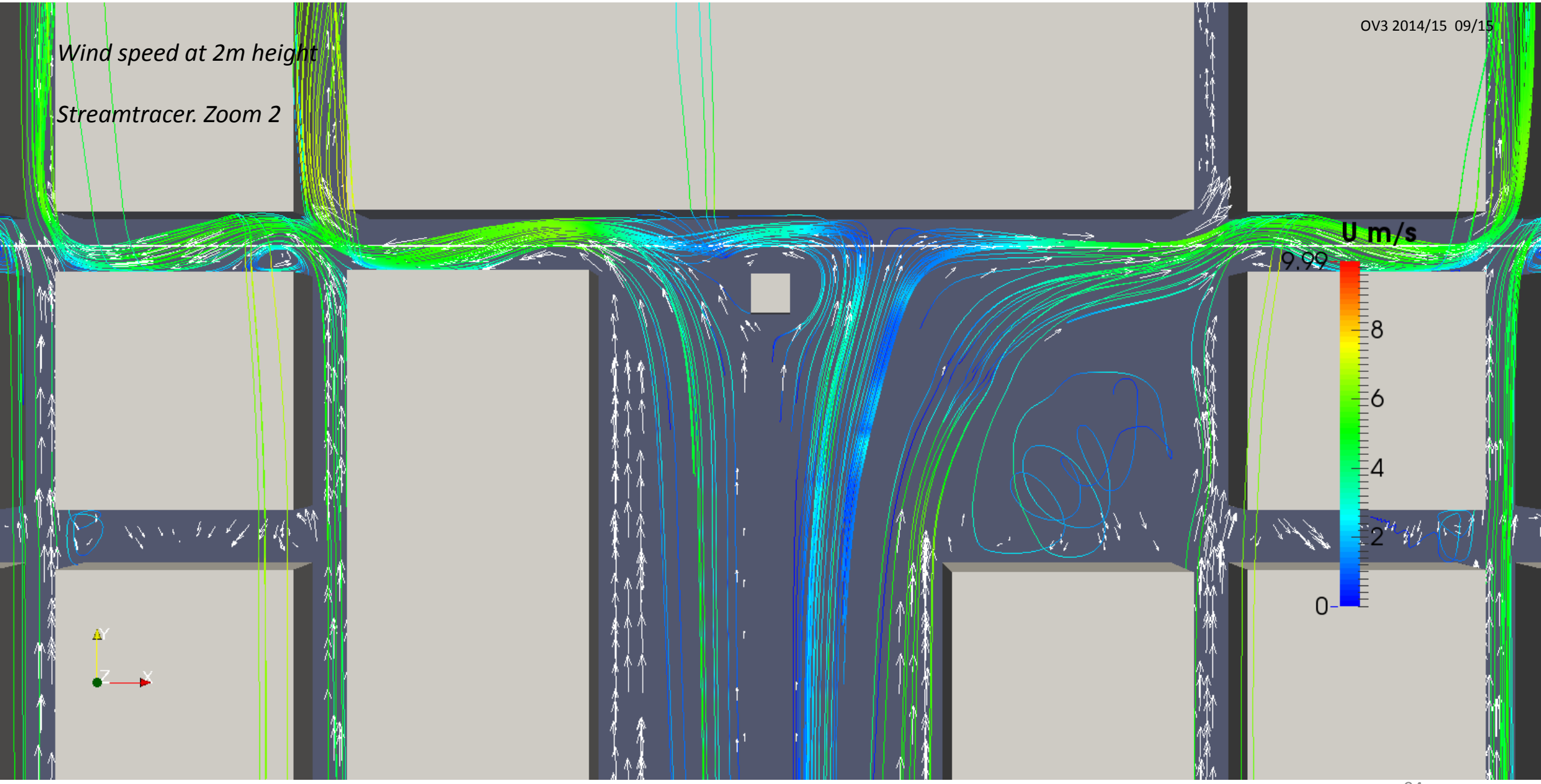
Streamtracer. Zoom 2

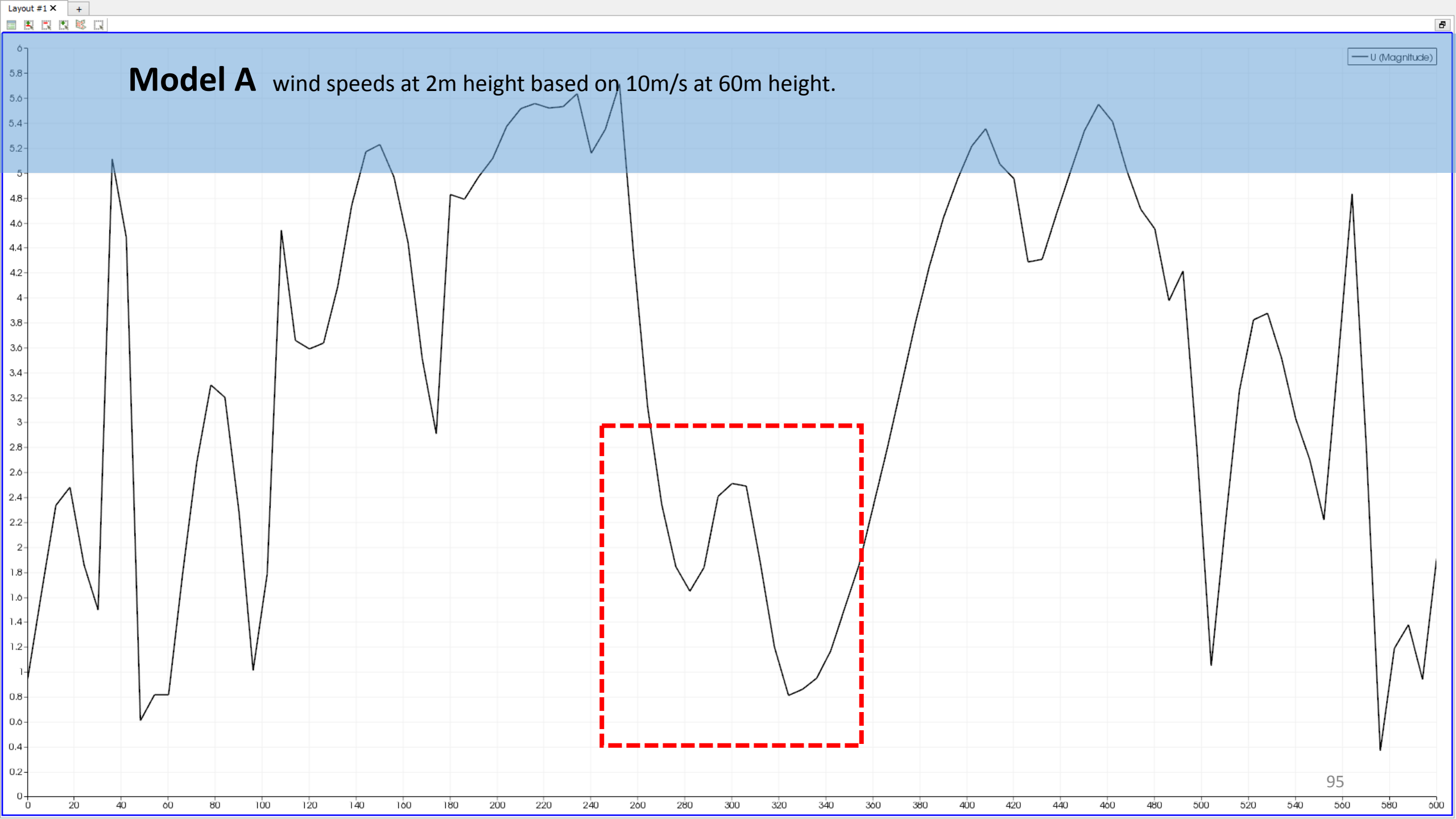


Simulation Result A

Wind speed at 2m height

Streamtracer. Zoom 2

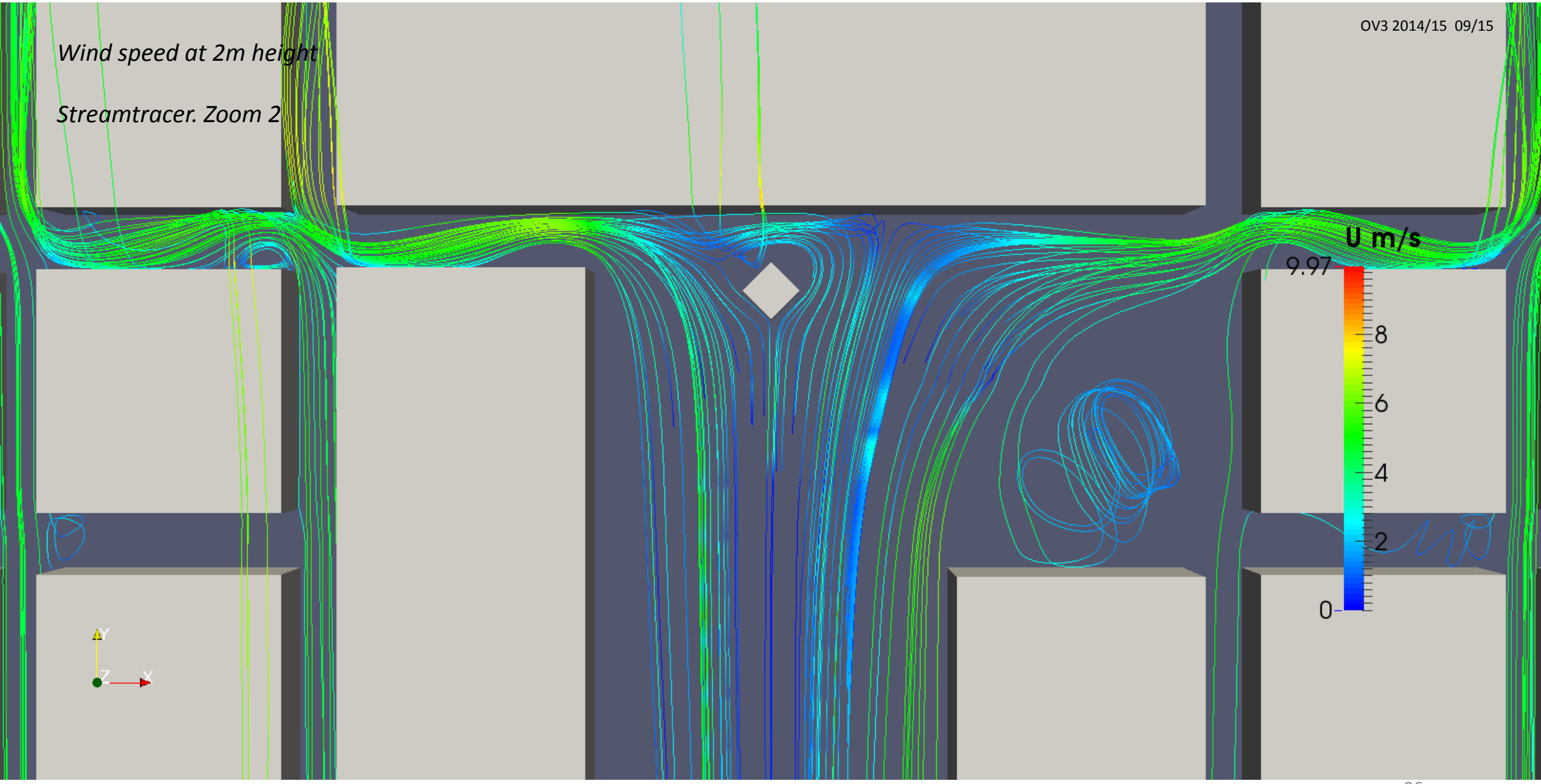



Layout #1
Model A wind speeds at 2m height based on 10m/s at 60m height.
U (Magnitude)
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600

Simulation Result B

Wind speed at 2m height

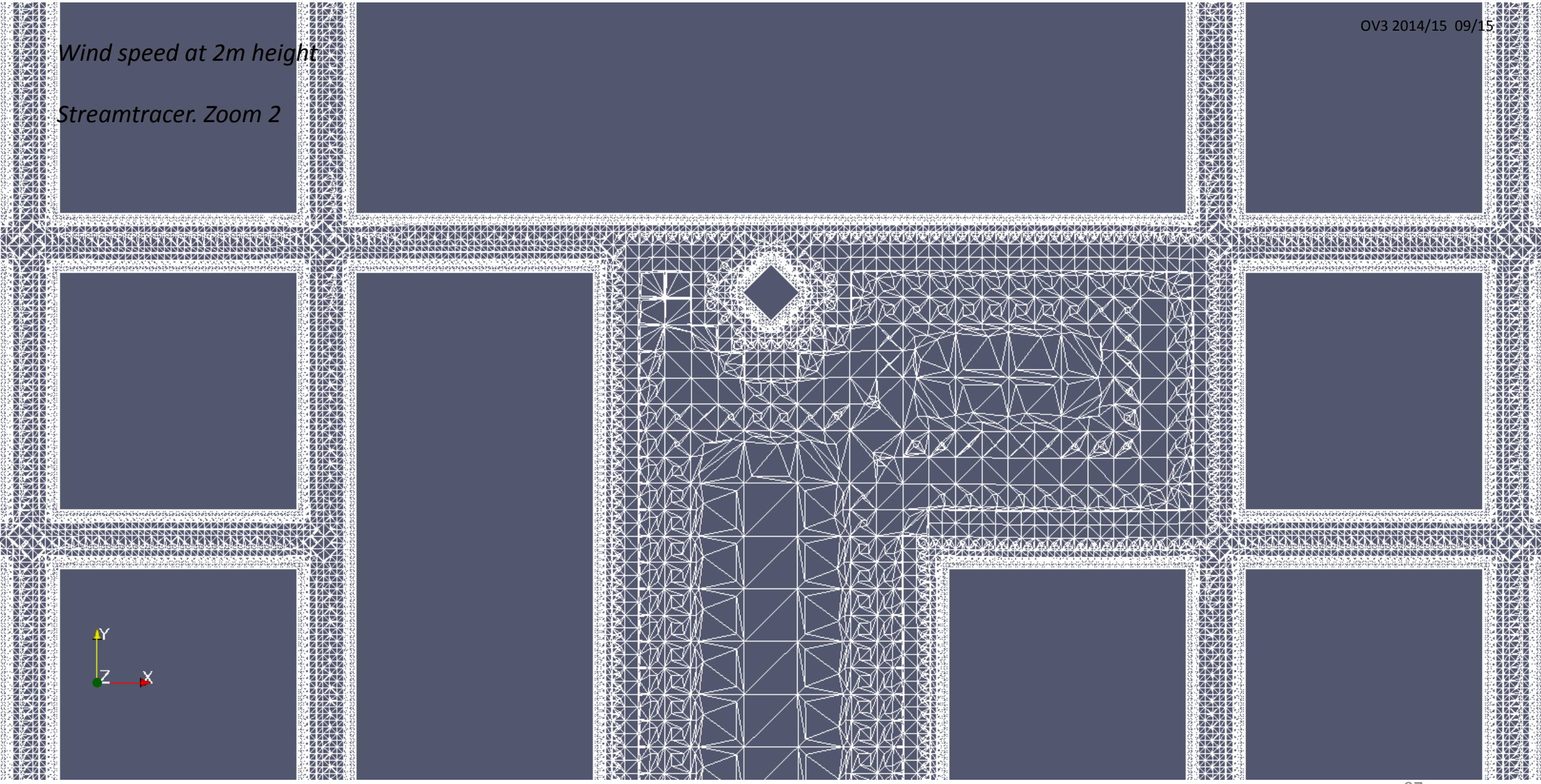
Streamtracer. Zoom 2



Simulation Result B

Wind speed at 2m height

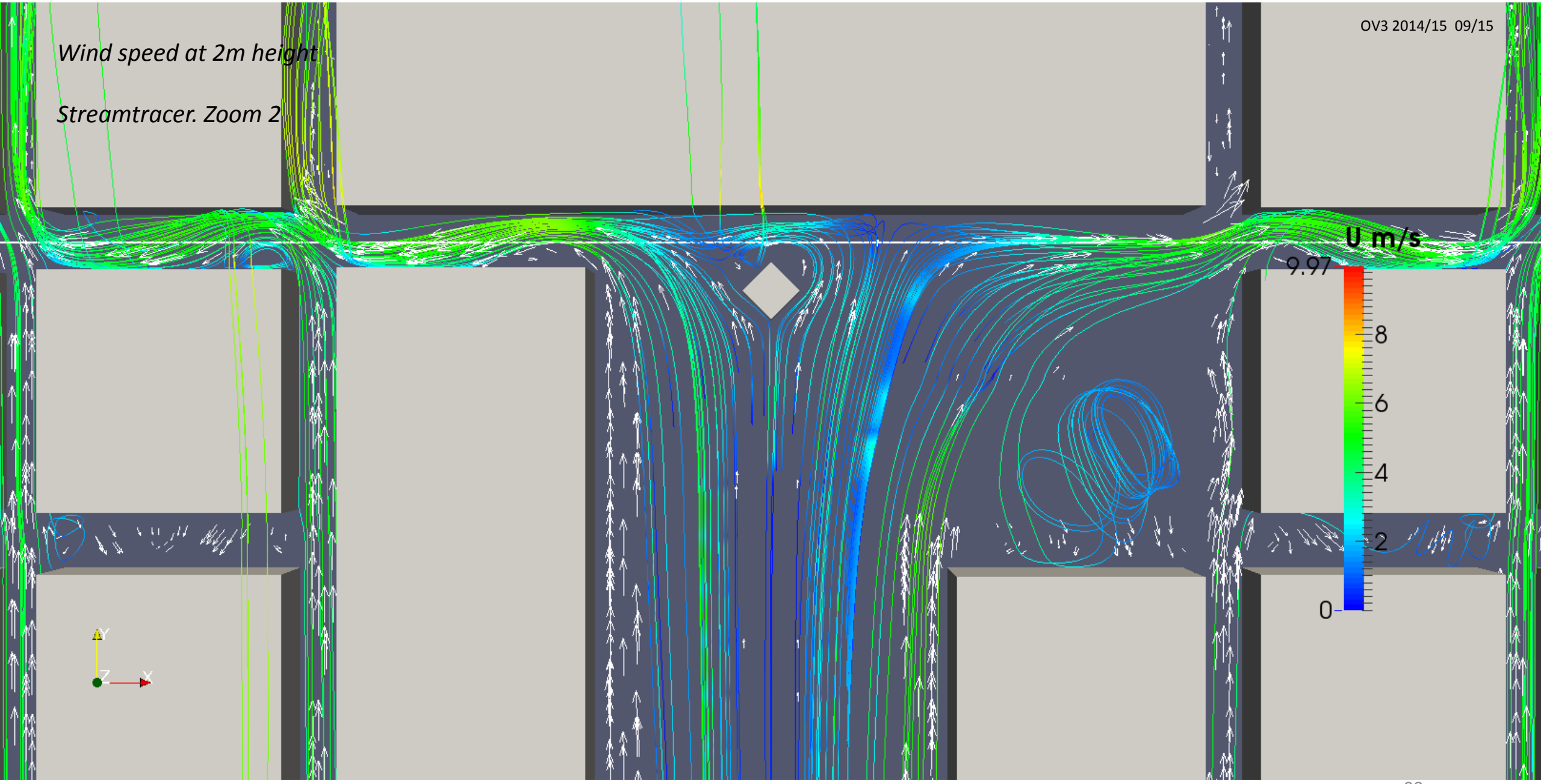
Streamtracer. Zoom 2

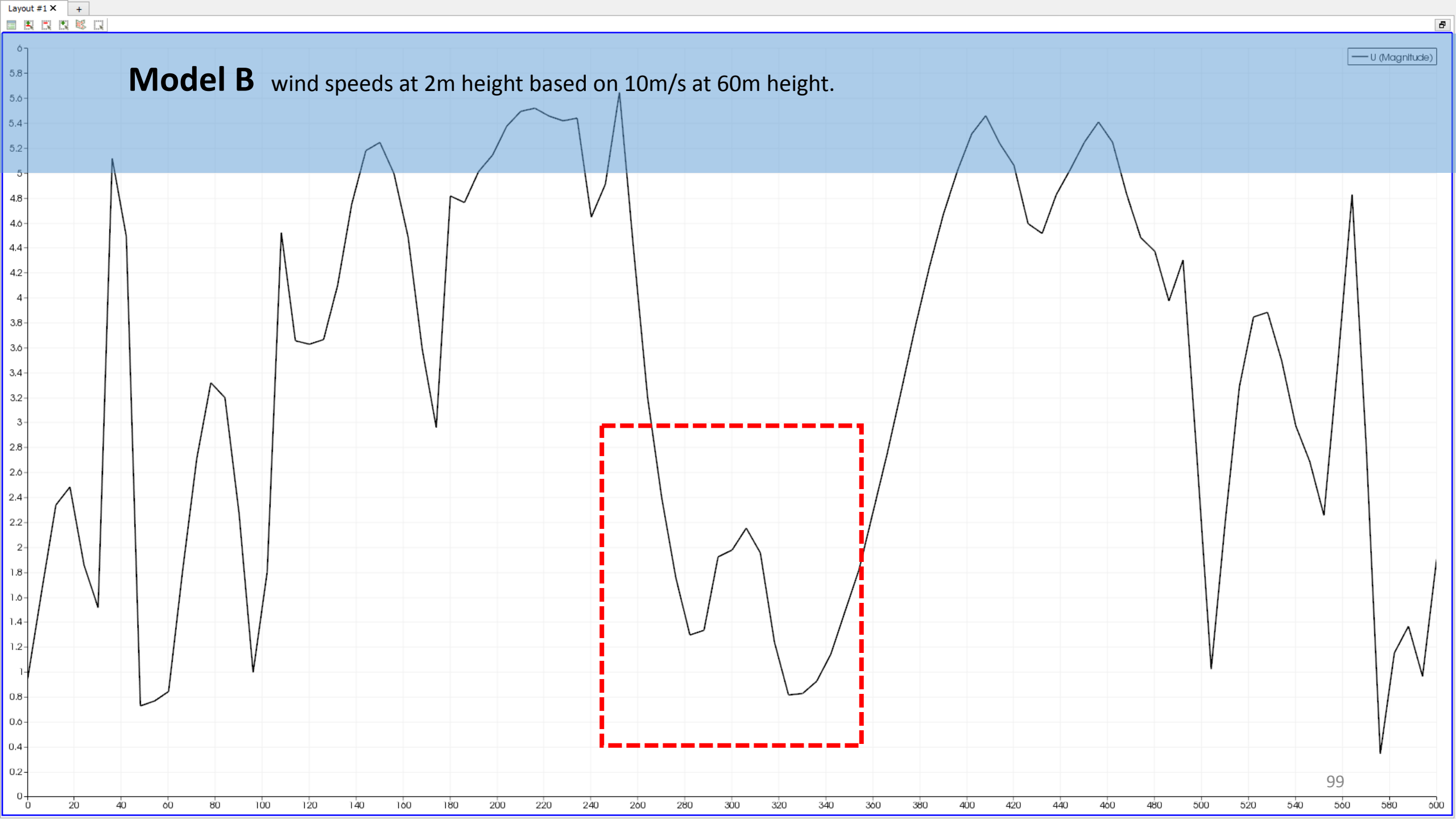


Simulation Result B

Wind speed at 2m height

Streamtracer. Zoom 2

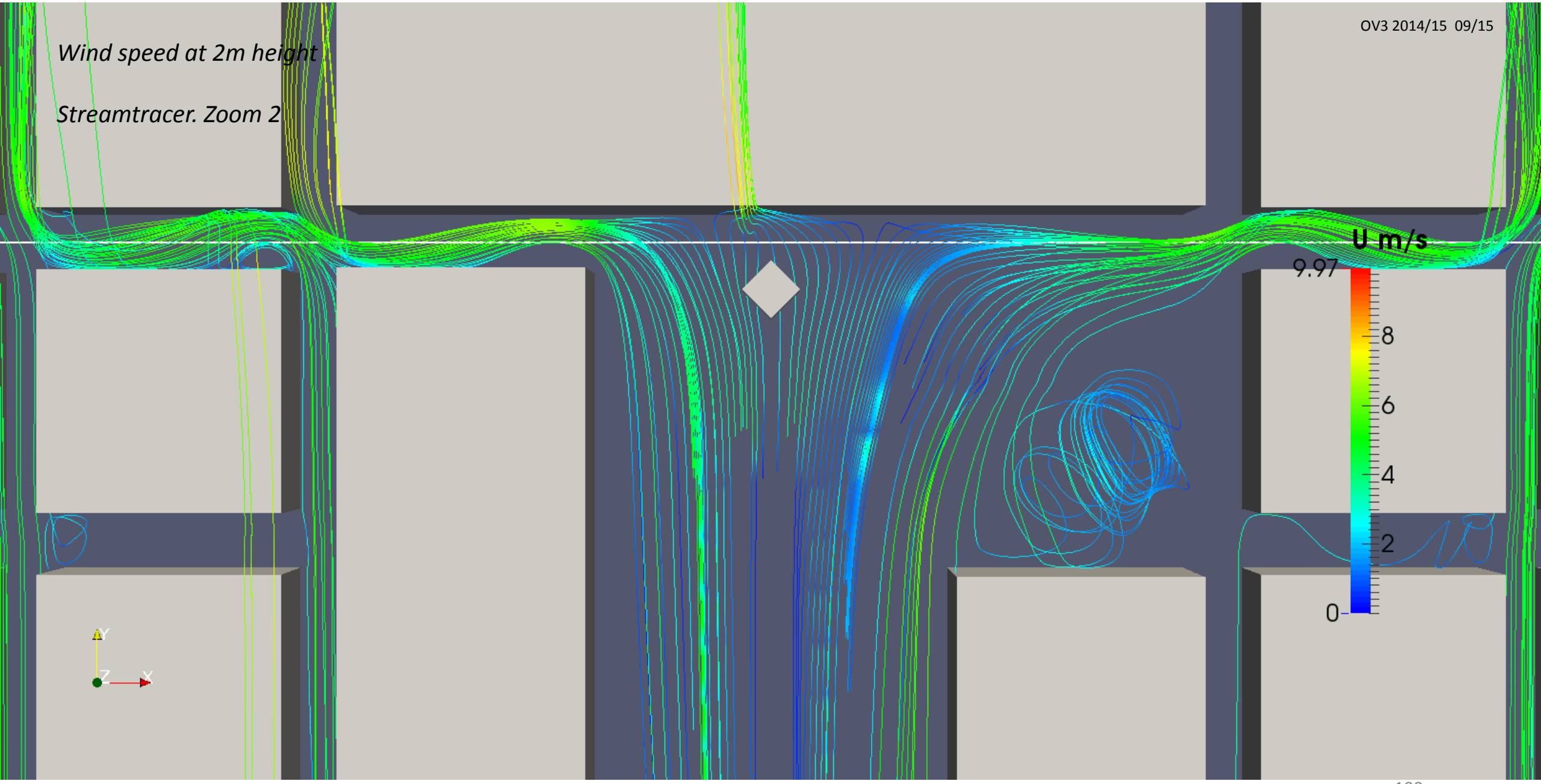



Layout #1
Model B wind speeds at 2m height based on 10m/s at 60m height.
U (Magnitude)
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600

Simulation Result C

Wind speed at 2m height

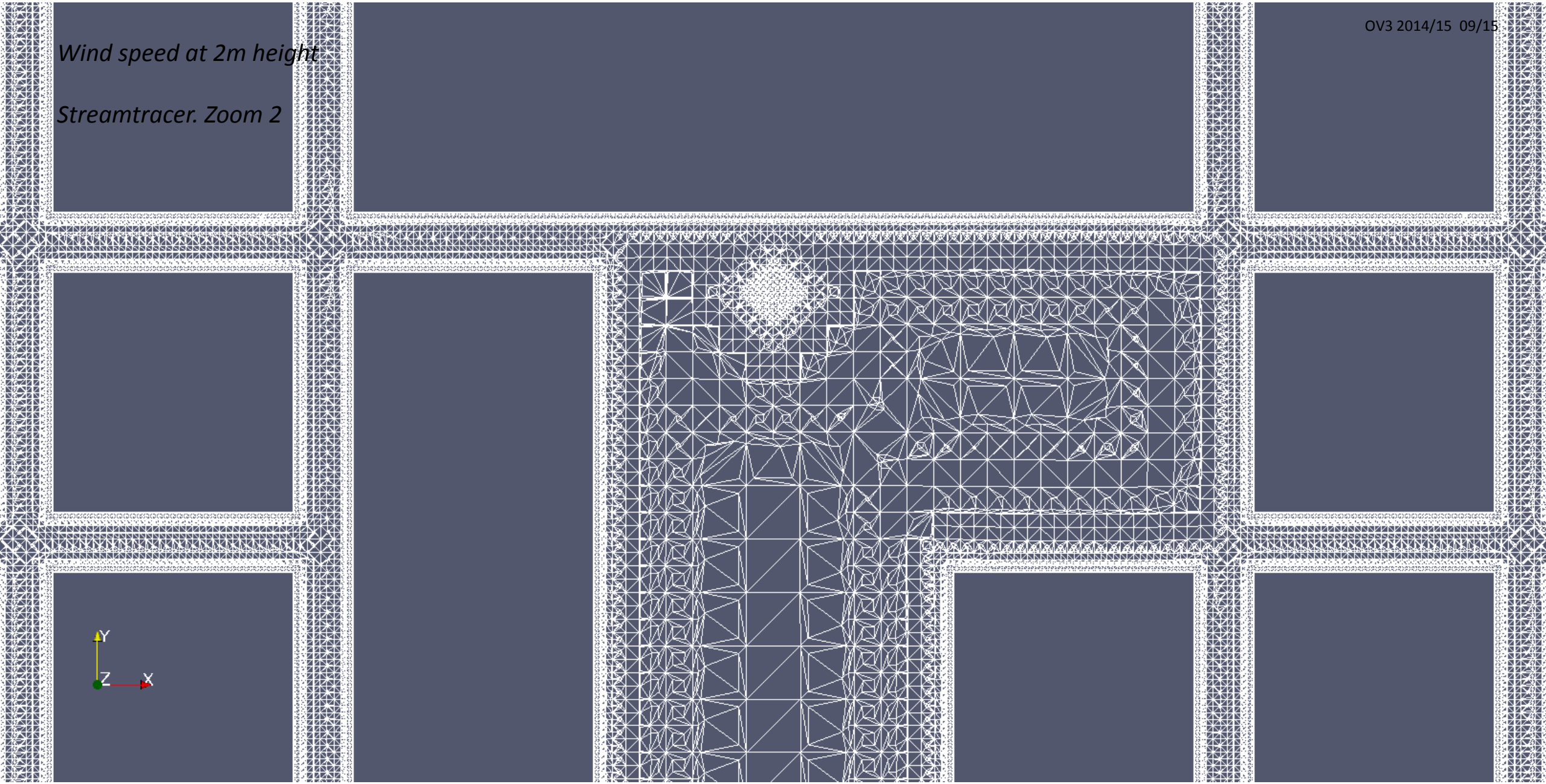
Streamtracer. Zoom 2



Simulation Result C

Wind speed at 2m height

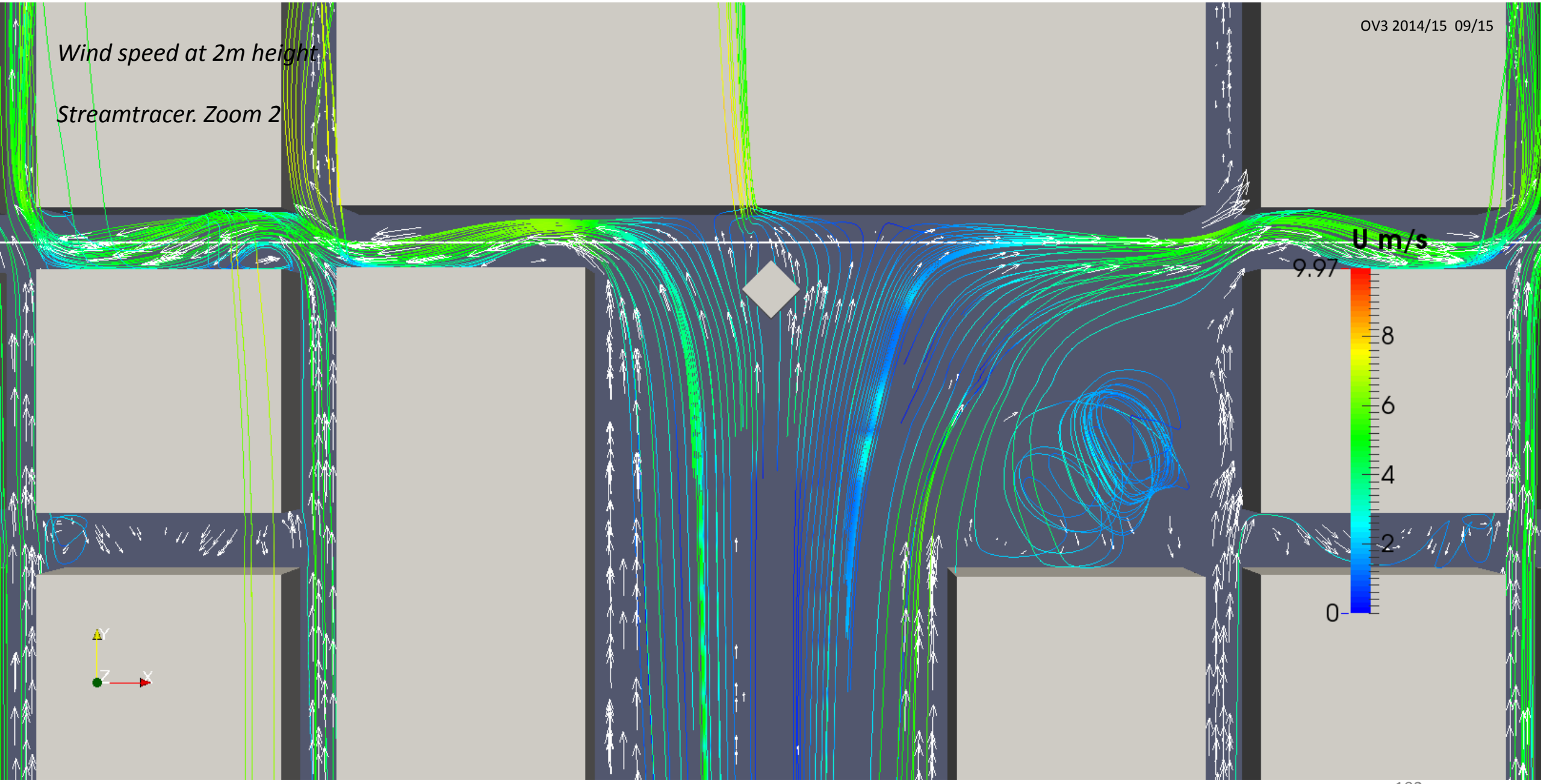
Streamtracer. Zoom 2



Simulation Result C

Wind speed at 2m height

Streamtracer. Zoom 2




Layout #1
Model C wind speeds at 2m height based on 10m/s at 60m height.
U (Magnitude)
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600

Comparing RESULTS

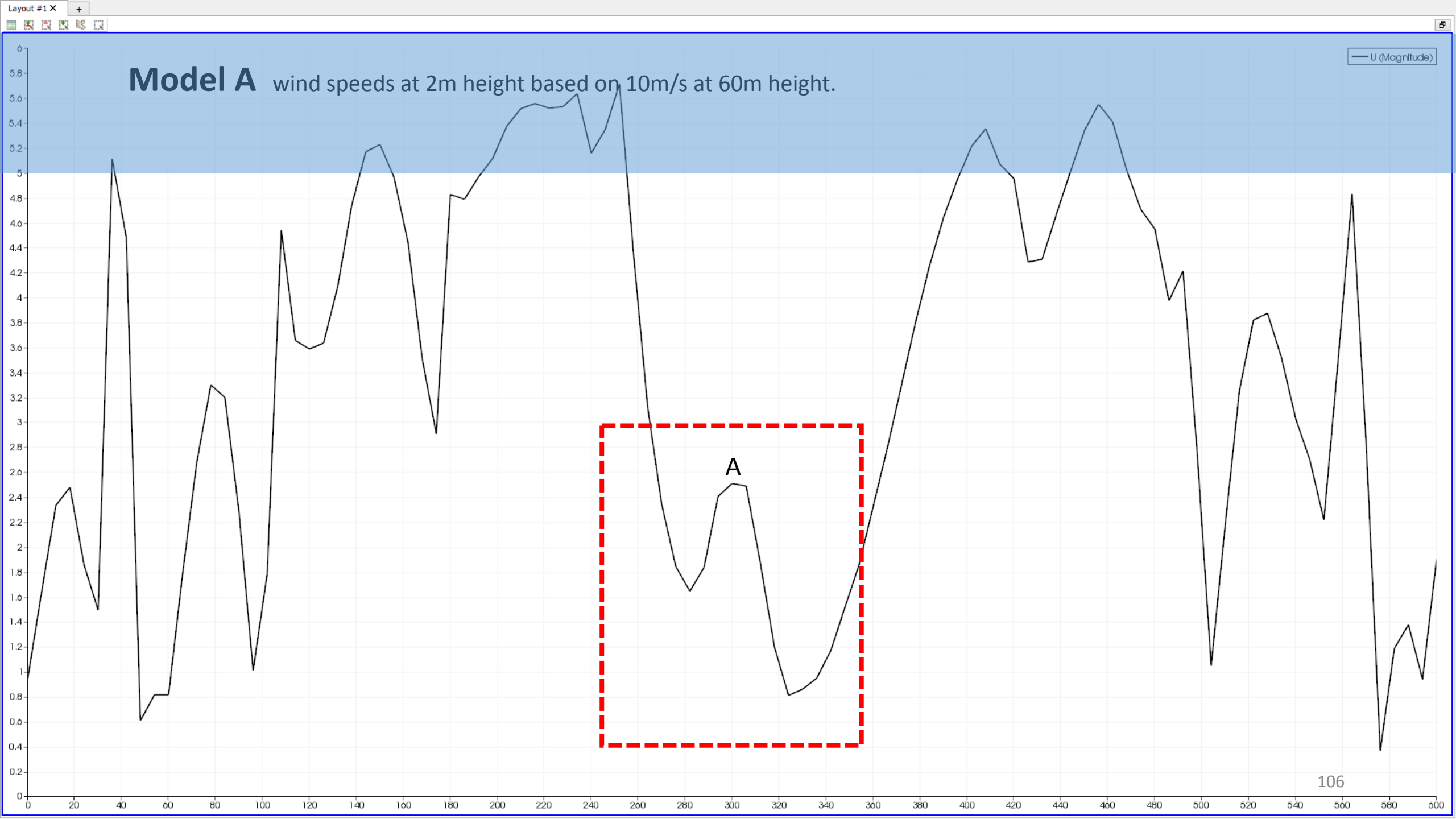
Comparing RESULTS / Model Evaluation Strategies

Rex Britter / Department of Engineering / University of Cambridge

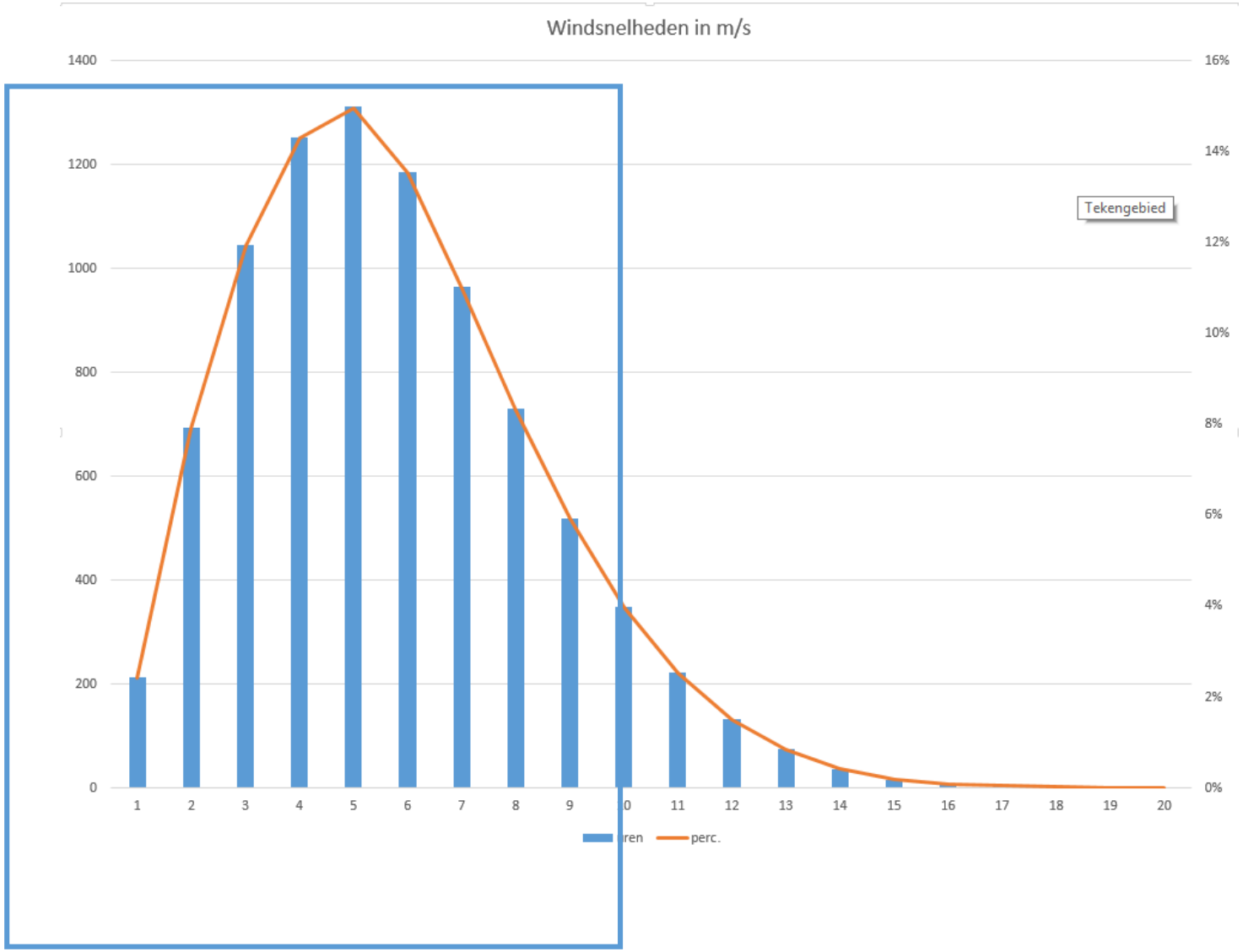
Models of whatever type are only of use if their quality (fitness-for-purpose) has been quantified, documented and communicated to potential users.

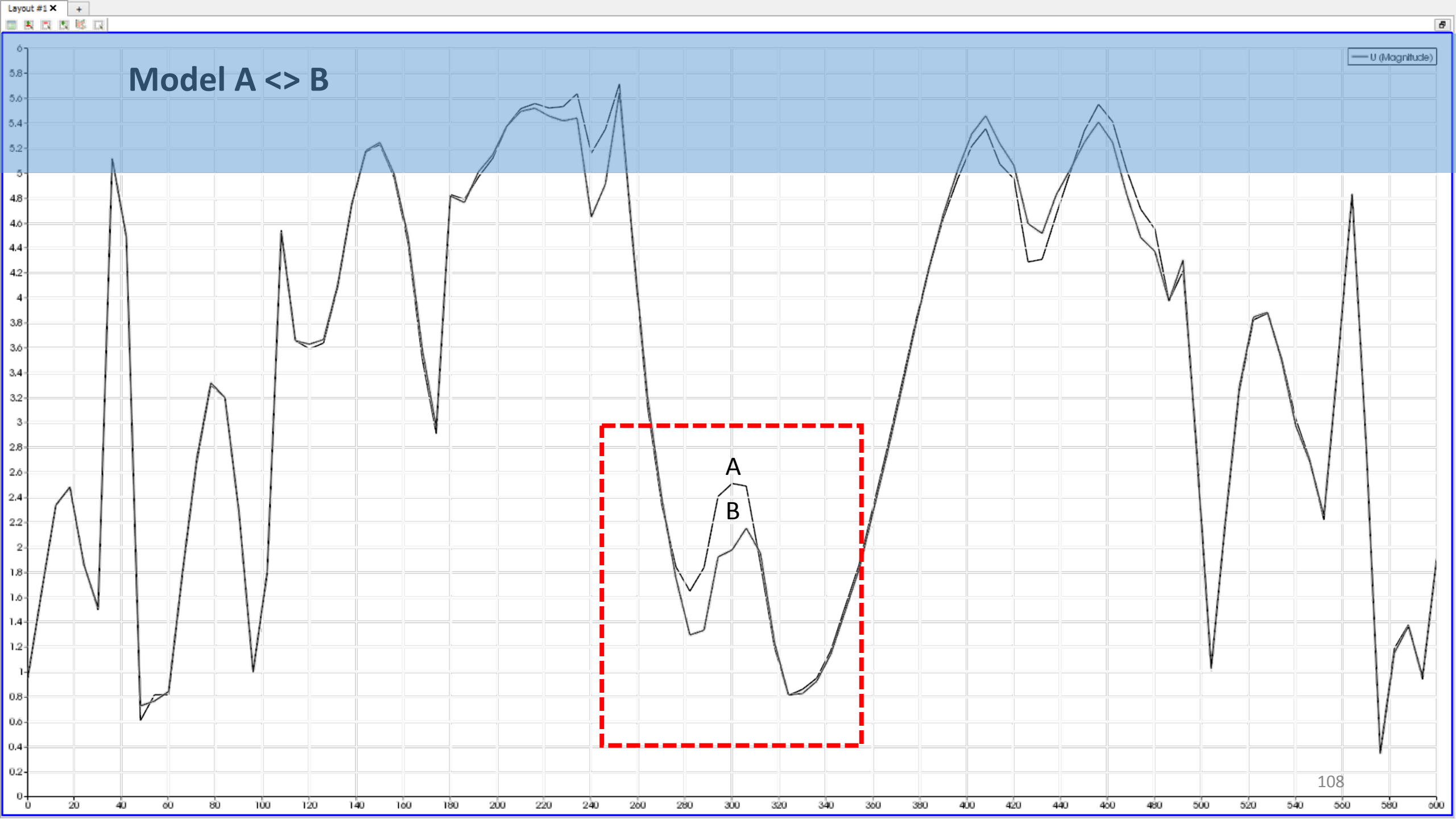
It may not be appropriate to talk of a valid model, but only of a model that has agreed upon regions of applicability and quantified levels of performance (accuracy) when tested upon certain specific and appropriate data sets.

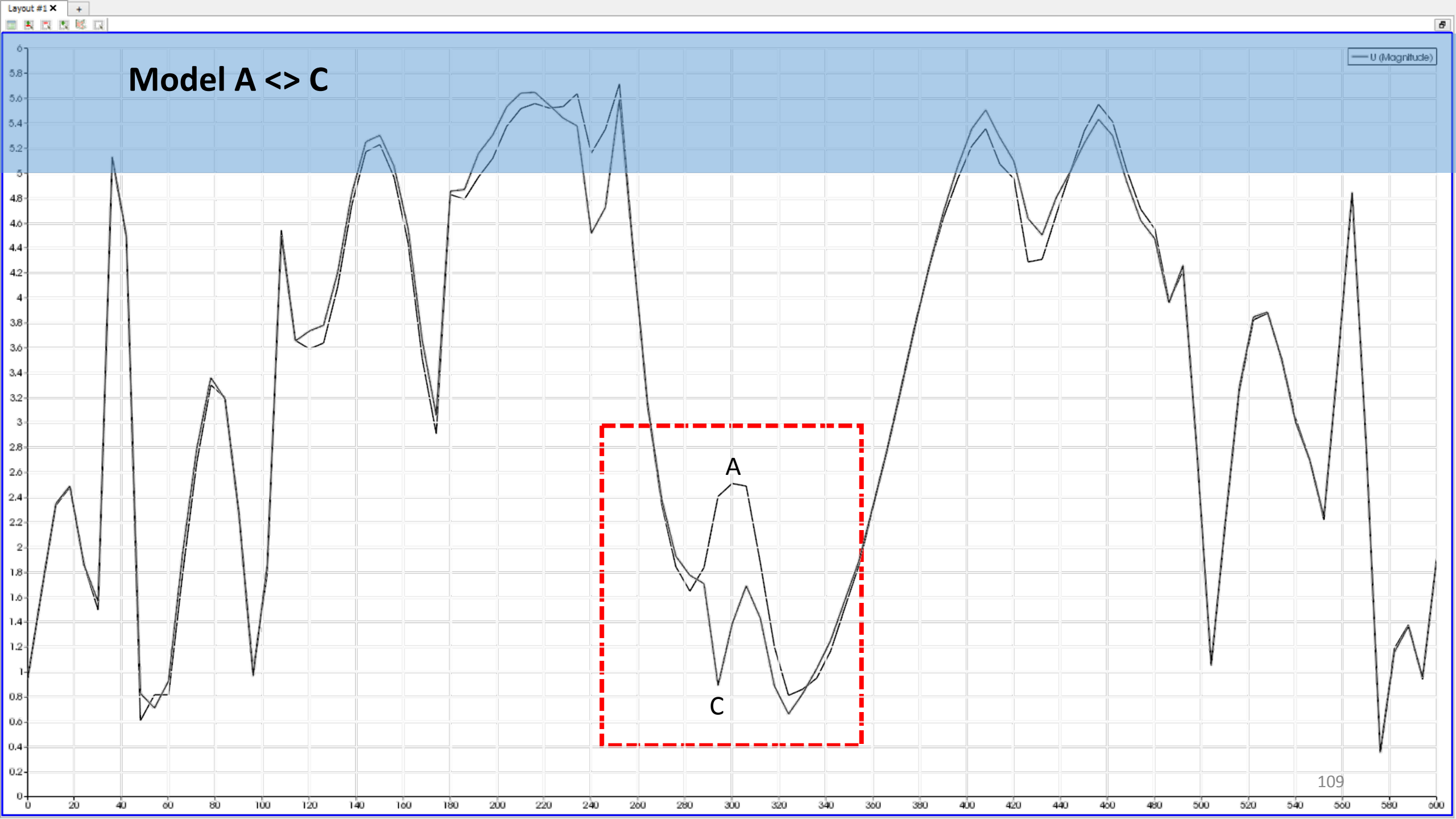
COST 732 Quality Assurance of Microscale Meteorological Models (2005)


Model A wind speeds at 2m height based on 10m/s at 60m height.
U (Magnitude)
A

Condition: Windspeed 10 m/s at height 60m




Layout #1
Model A <> B
U (Magnitude)
A
B
108


Layout #1
Model A <> C
U (Magnitude)
A
C
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
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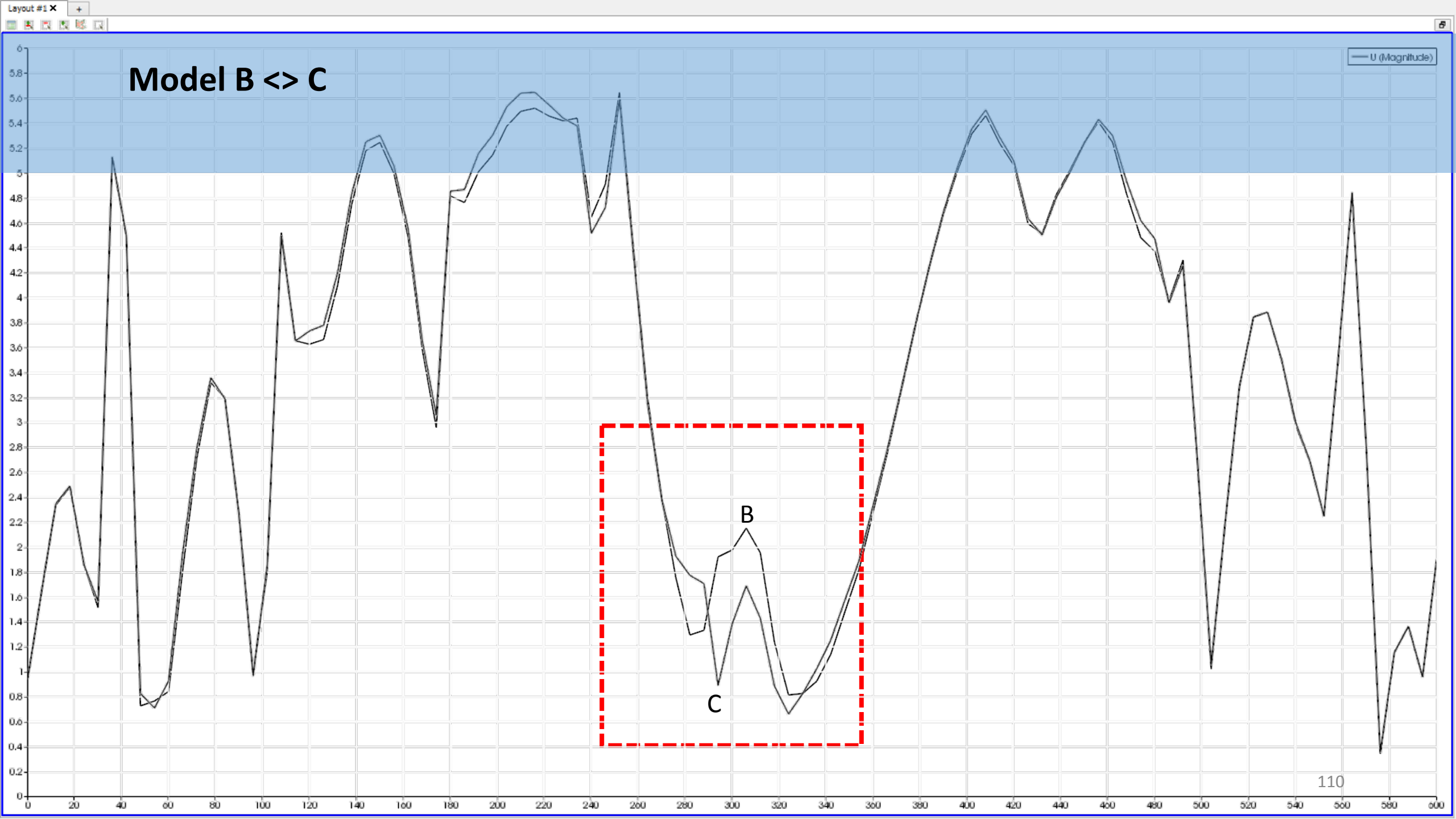
5
5.2
5.4
5.6
5.8
6


Layout #1
Model B <> C
U (Magnitude)
B
C

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Journal of Wind Engineering and Industrial Aerodynamics 94 (2006)

Towards rules of thumb for wind comfort and air quality
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Atmospheric Environment 33 (1999)

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ELSEVIER Journal of Wind Engineering & Industrial Aerodynamics
www.journals.elsevier.com/journal-of-wind-engineering-and-industrial-aerodynamics/

IAWE International Associations for Wind Engineering
www.iawe.org

IBPSA International Building Performance Simulation Association
www.ibpsa.org/

IBPSA-NVL IBPSA Nederland en Vlaanderen
www.ibpsa-nvl.org/

KNMI Hydra Project Wind climate assessment of the Netherlands
www.knmi.nl/samenw/hydra

REFERENCES / *Urban Flow Features*

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Websites
Wikipedia

Fluid Dynamics

Osborn Reynolds
Claude Navier
George Stokes

Reynolds number
Navier Stokes equations

Conservation laws
Continuity
Momentum
Energy

Atmospheric Boundary Layer
Urban Boundary Layer
Canopy Layer

Von Ekman-layer
Coriolis force
Wind profile

QUESTIONS??


THANK YOU