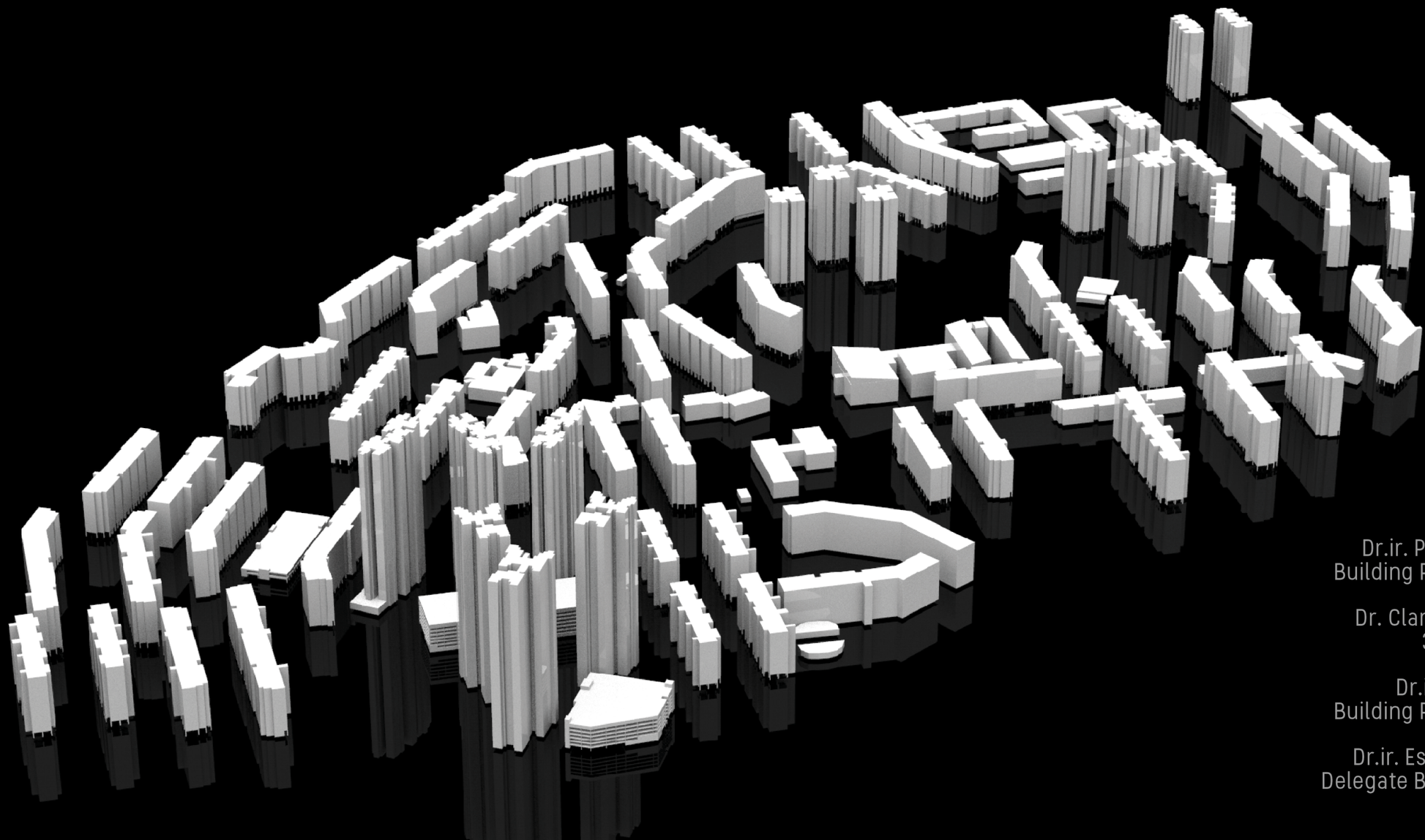
EXPLORING THE EFFECTS OF VOID DECKS ON URBAN VENTILATION IN SINGAPORE

A Computational Design & Simulation Approach for Wind Microclimate-Informed Urban Planning

by
AVIVA OPSOMER



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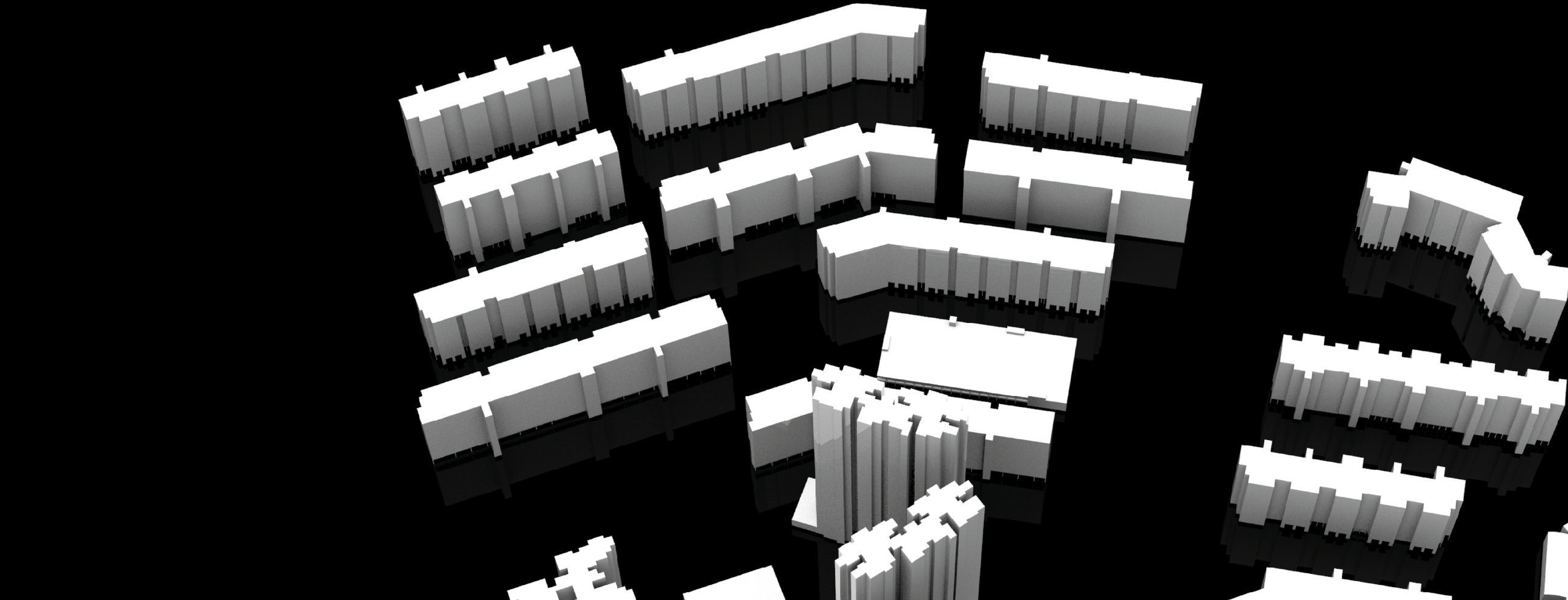
WIND MICROCLIMATE–INFORMED URBAN PLANNING



sunlight hours

air quality

biodiversity

noise

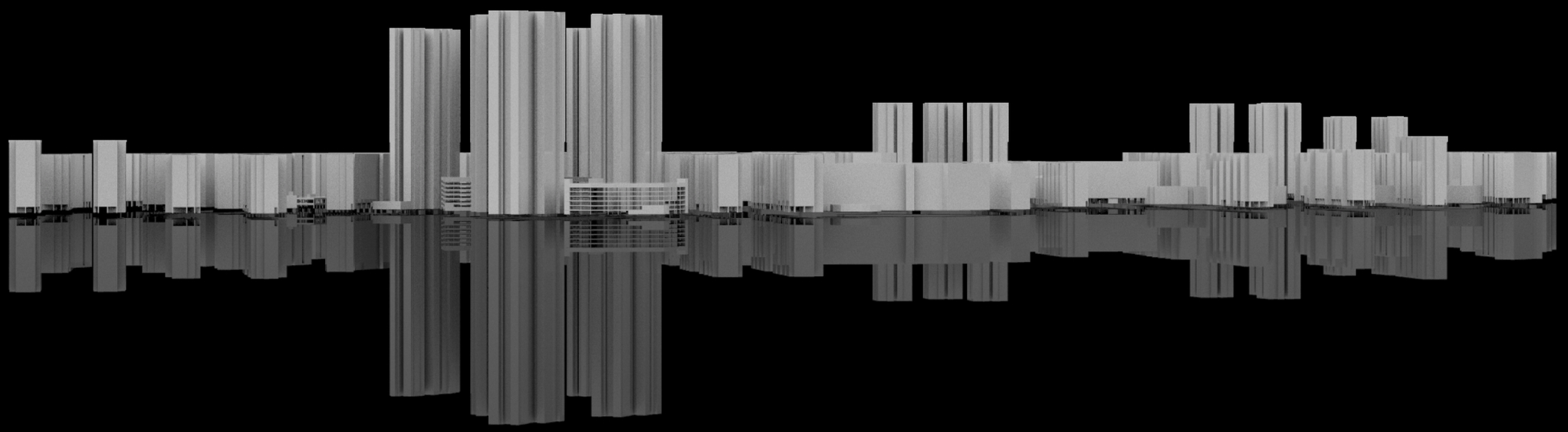
radiation

road network

base map

“Urban planners can use different design tools, adapted to different phases of projects design, to assess qualitatively and quantitatively solar radiation in urban areas. But, *wind is a microclimatic parameter generally neglected by urban planners*. However, wind speed at pedestrian level is one of the most important environmental parameters determining user satisfaction in urban open spaces.”

(Reiter, 2010)



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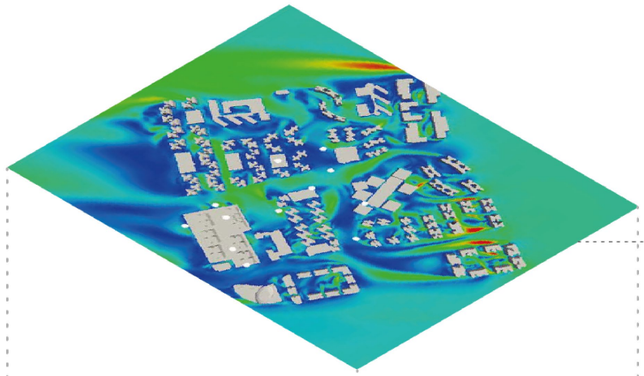
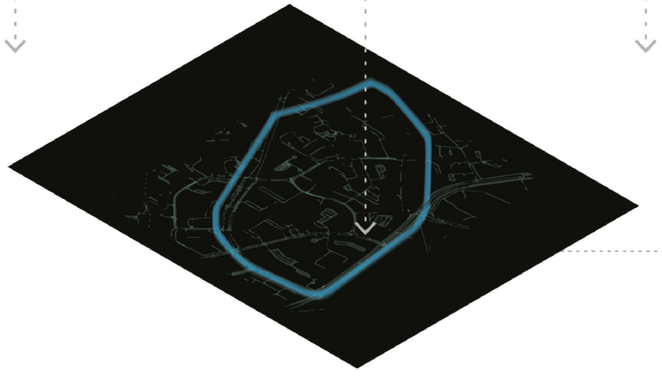
MISSING LAYER?

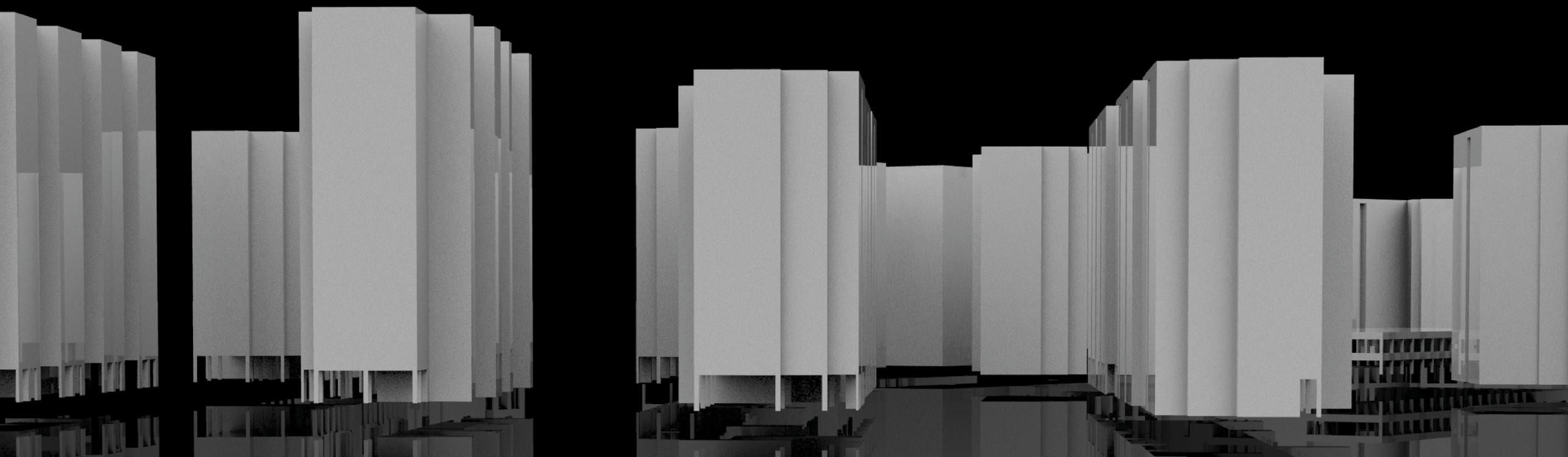


wind microclimate

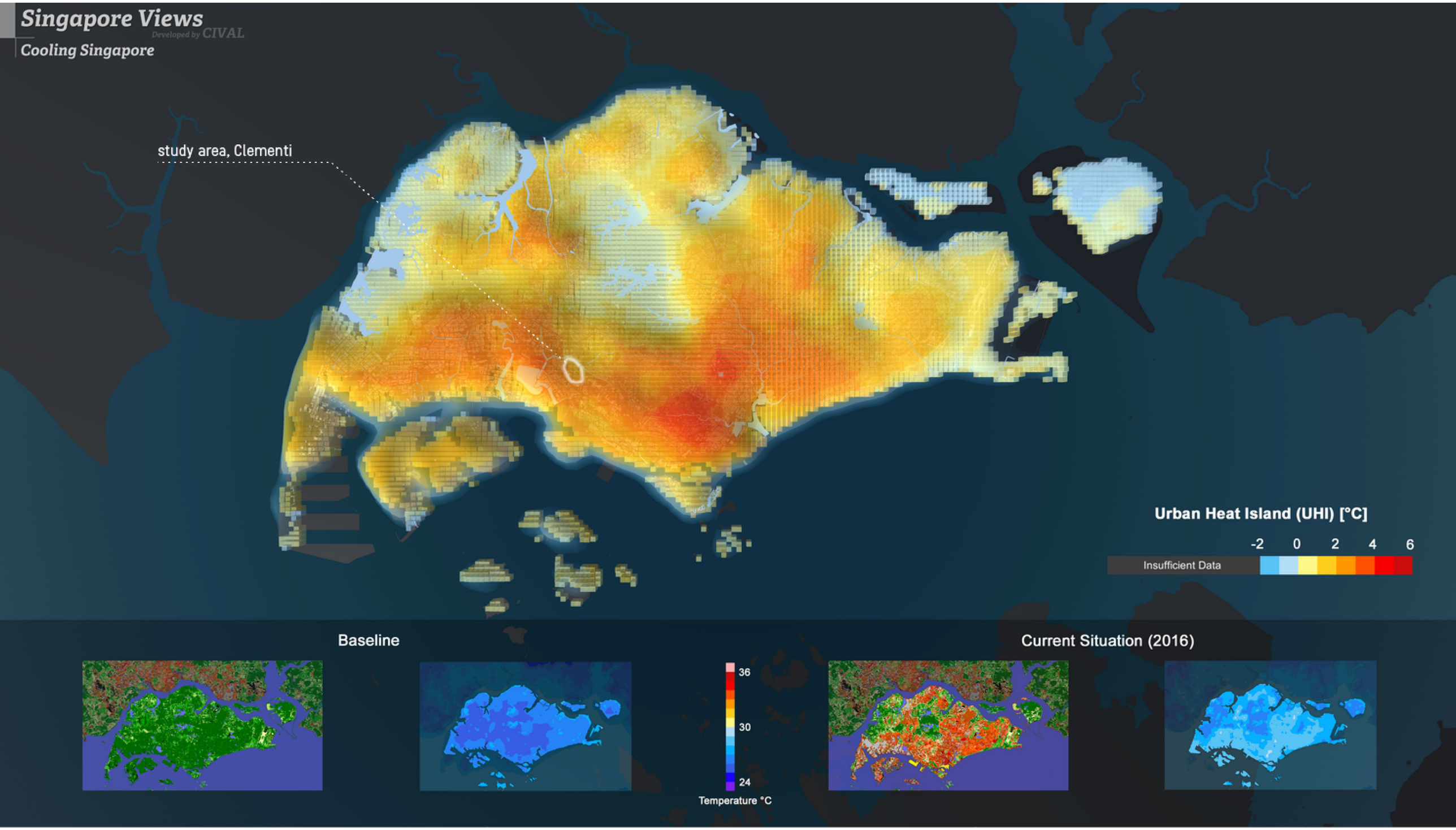


base map

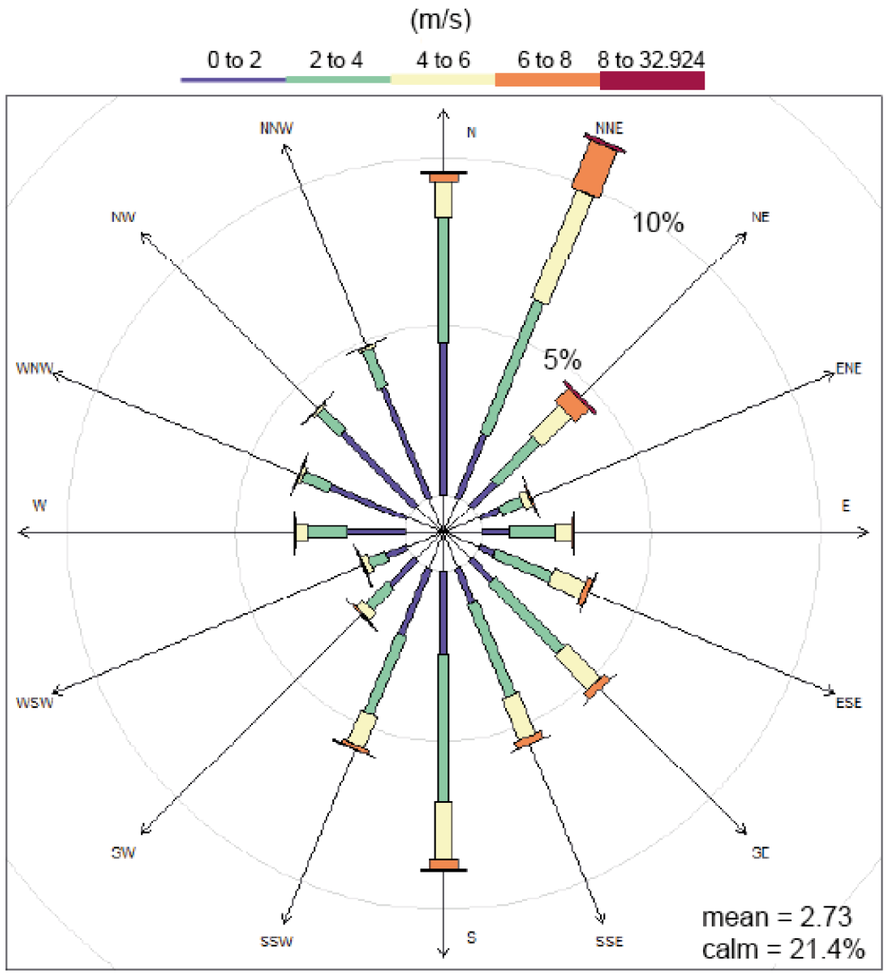
RELEVANCE FOR SINGAPORE



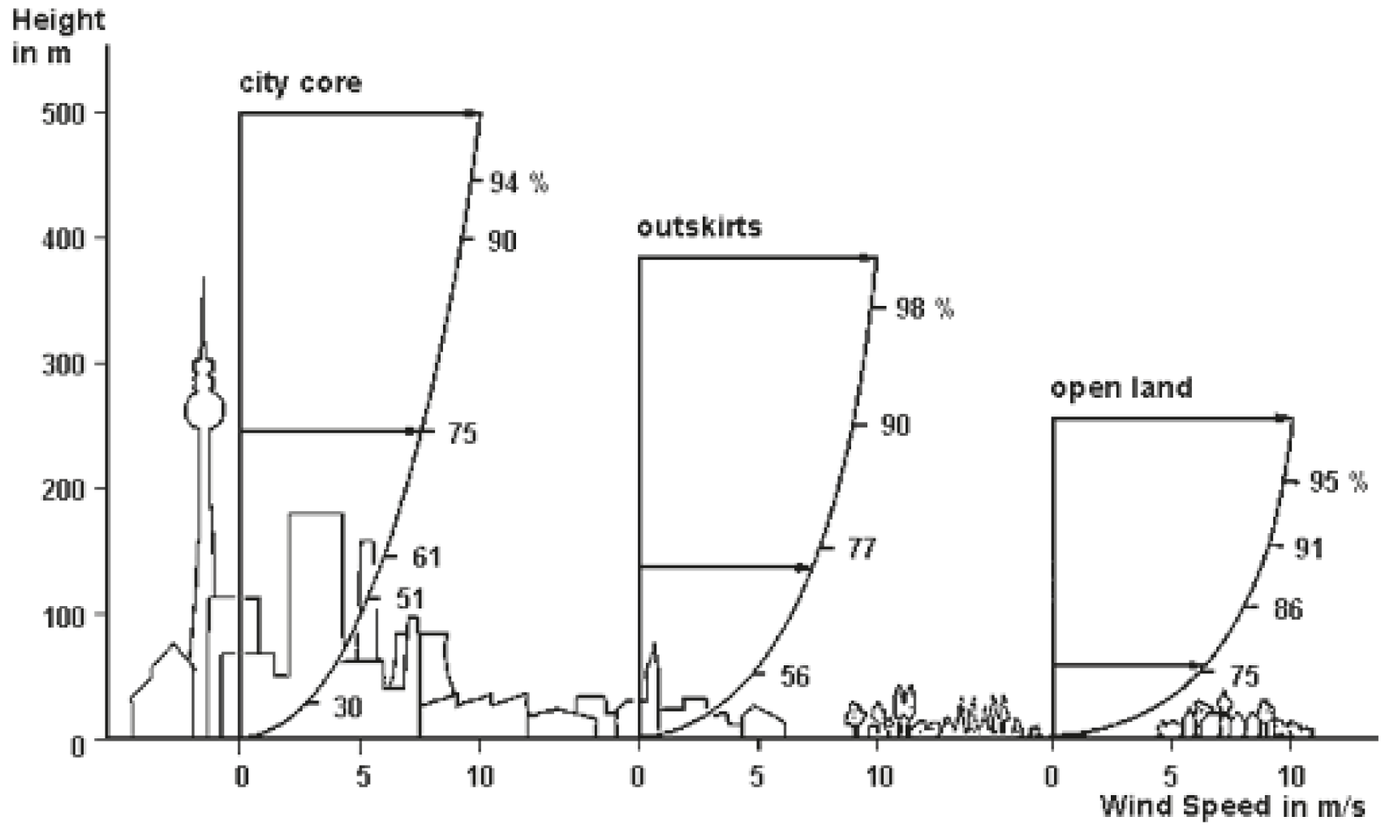
HIGH TEMPERATURES & UHI



LOW WIND SPEEDS DUE TO GEOGRAPHICAL LOCATION & URBAN CONTEXT



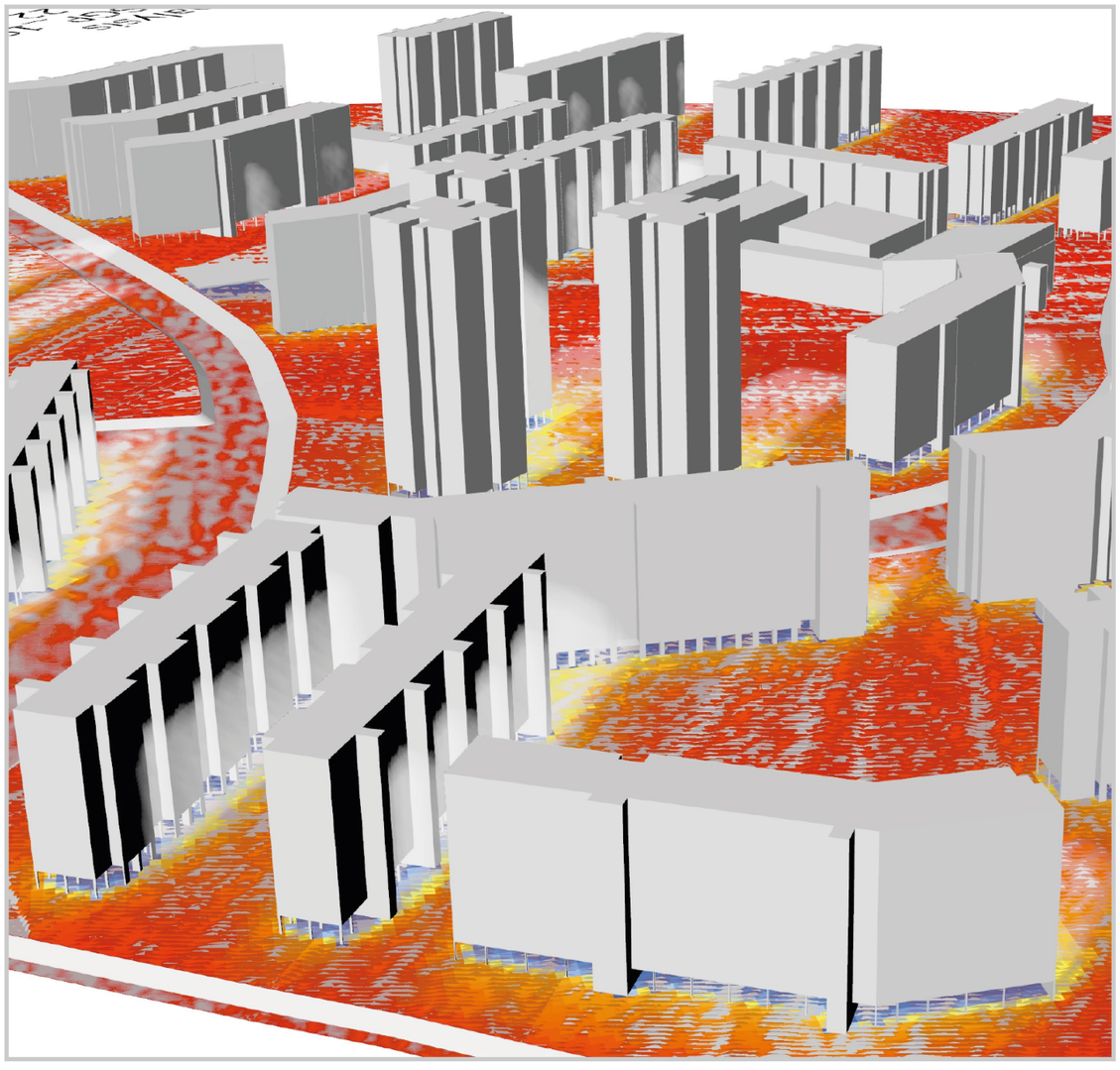
Percentage of counts by wind direction (%)



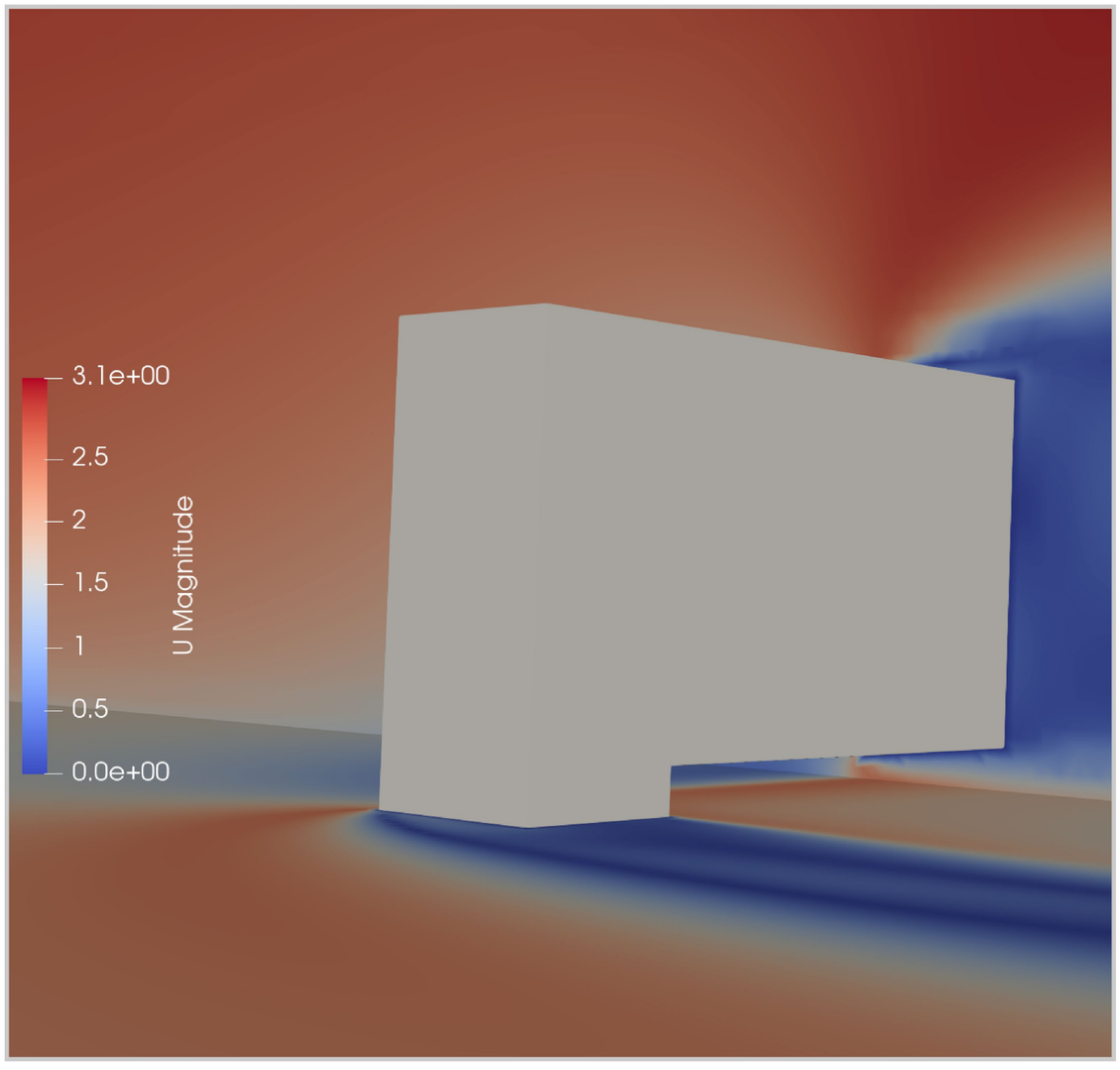
VOID DECKS AS EXPANSION OF PEDESTRIAN ROUTE NETWORK

VOID DECKS AS OUTDOOR INTERACTIONAL SPACE

VOID DECKS & THE URBAN MICROCLIMATE



PROVIDING SHADE & SHELTER FROM RAIN



INCREASING WIND SPEEDS

MAIN RESEARCH QUESTION:

How can the geometry design of void decks be optimized to enhance urban ventilation for outdoor thermal comfort in Singapore while ensuring good pedestrian comfort?

STUDY AREA

STUDY AREA
Clementi

Clementi Avenue 6

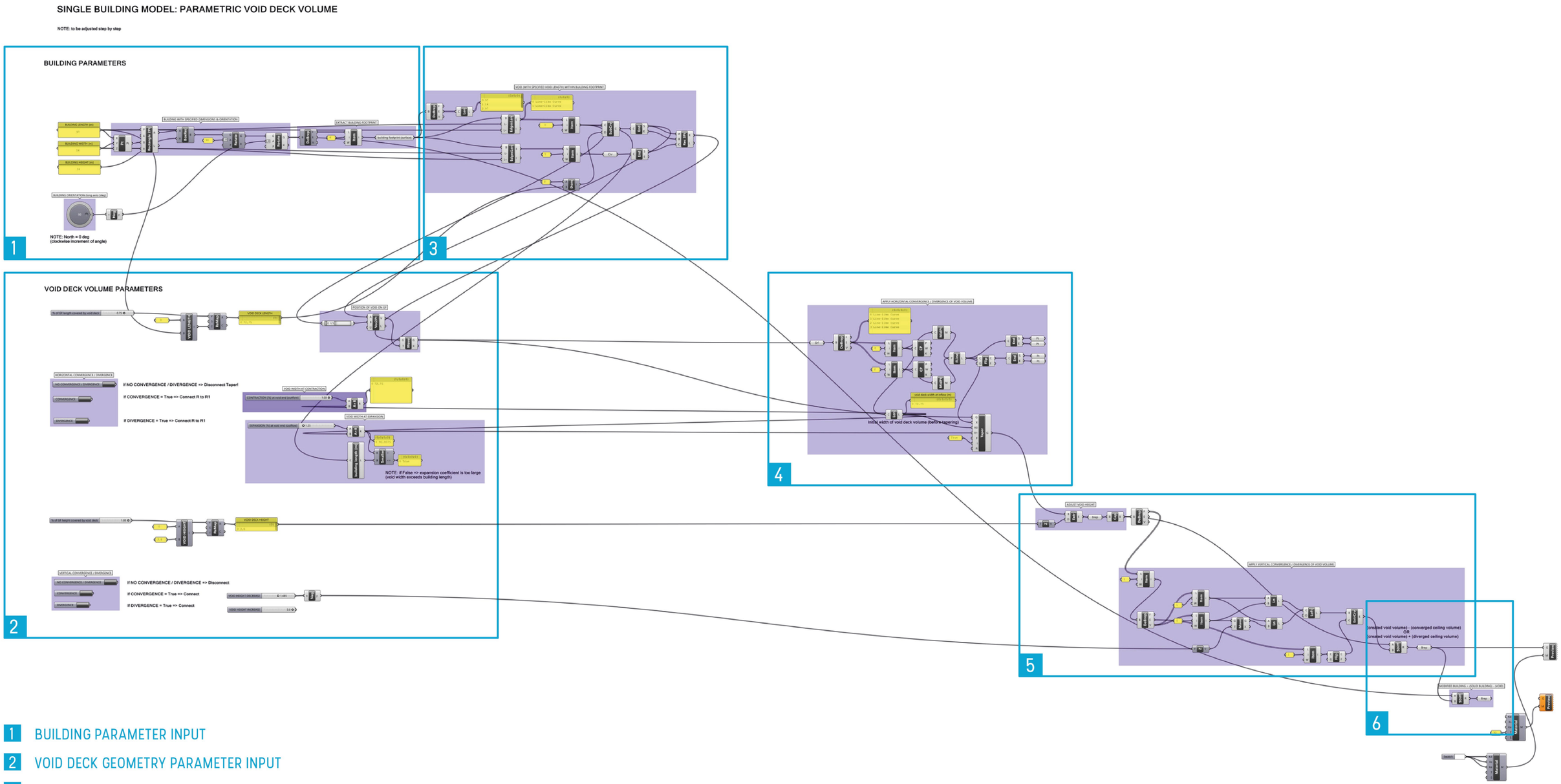
Ulu Pandan Park Connector

Commonwealth Avenue West

Clementi Road

VOID DECK GEOMETRY STUDY

PARAMETRIC VOID DECK MODEL – BUILDING SCALE



1 BUILDING PARAMETER INPUT

2 VOID DECK GEOMETRY PARAMETER INPUT

3 VOID DECK BASE GEOMETRY CREATION (SPECIFIED VOID LENGTH)

4 VOID GEOMETRY MODIFICATIONS: HORIZONTAL CONVERGENCE / DIVERGENCE

5 VOID GEOMETRY MODIFICATIONS: VOID HEIGHT & VERTICAL CONVERGENCE / DIVERGENCE

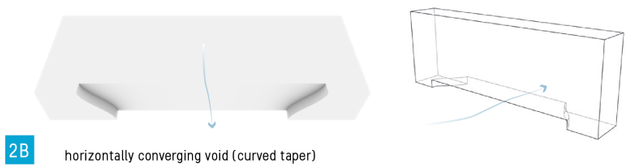
6 SUBTRACTION OF BUILDING VOLUME WITH CREATED VOID DECK VOLUME

REPRESENTATIVE BUILDING FOR VOID GEOMETRY VARIANT STUDY

building length = 97 m
building width = 14 m
building height = 34 m

1 BASE CASE: no horizontal / vertical convergence or divergence

2A horizontally converging void (straight taper)



2B horizontally converging void (curved taper)

3A horizontally diverging void (straight taper)

3B horizontally diverging void (curved taper)

4 vertically converging void

5 vertically diverging void

6 horizontally & vertically converging void

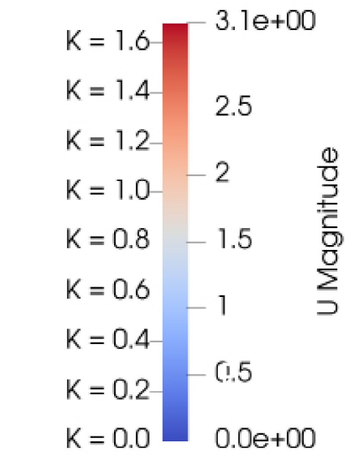
7 horizontally converging & vertically diverging void

8 horizontally diverging & vertically converging void

9 horizontally & vertically diverging void

VOID GEOMETRY VARIANTS OVERVIEW

VARIANT	void geometry	description
1	BASE CASE	• no convergence/divergence in horizontal nor vertical direction • % of ground floor length covered by void deck: 75% • % of ground floor height covered by void height: 100% (void deck height = 3.6m)
2A	horizontally converging void - straight taper	contraction at void outflow: 75% of void inflow
2B	horizontally converging void - curved taper	contraction at void outflow: 75% of void inflow
3A	horizontally diverging void - straight taper	expansion at void outflow: 125% of void inflow
3B	horizontally diverging void - curved taper	expansion at void outflow: 125% of void inflow
4	vertically converging void	void height decrease at outflow: 1.485m
5	vertically diverging void	void height increase at outflow: 1.485m
6	horizontally & vertically converging void	• horizontal contraction at void outflow: 75% of void inflow • void height decrease at outflow: 1.485m
7	horizontally converging & vertically diverging void	• horizontal contraction at void outflow: 75% of void inflow • void height increase at outflow: 1.485m
8	horizontally diverging & vertically converging void	• horizontal expansion at void outflow: 125% of void inflow • void height decrease at outflow: 1.485m
9	horizontally & vertically diverging void	• horizontal expansion at void outflow: 125% of void inflow • void height increase at outflow: 1.485m



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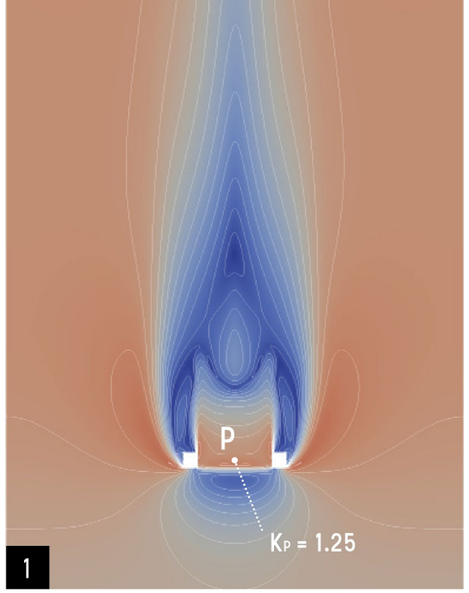
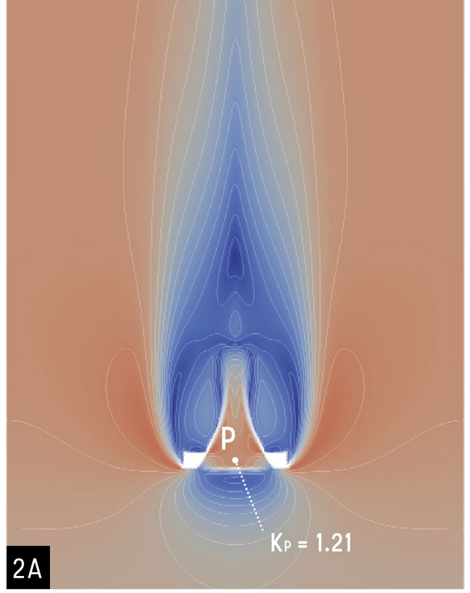
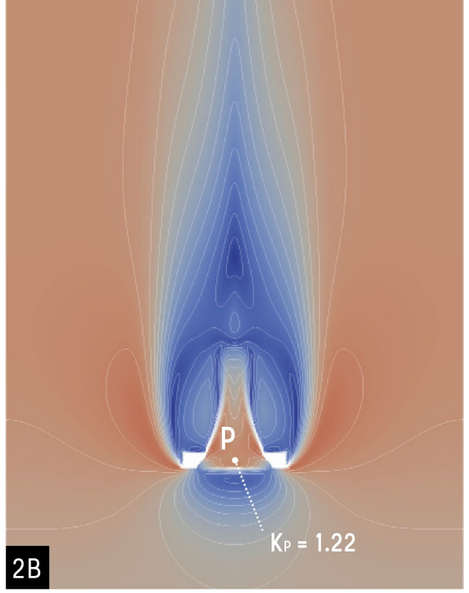
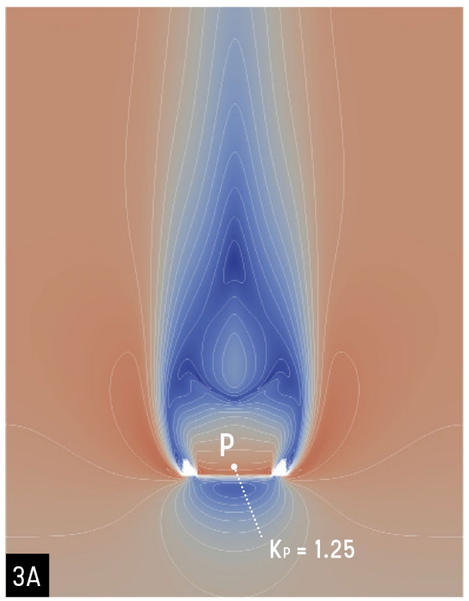
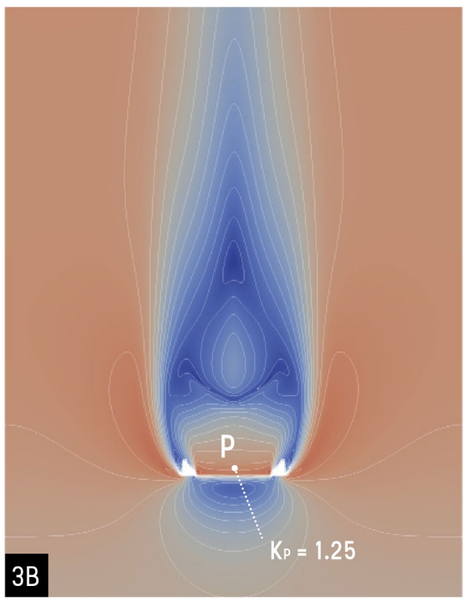
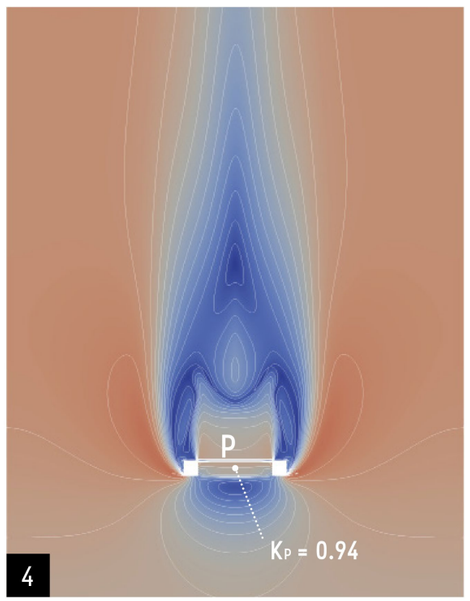


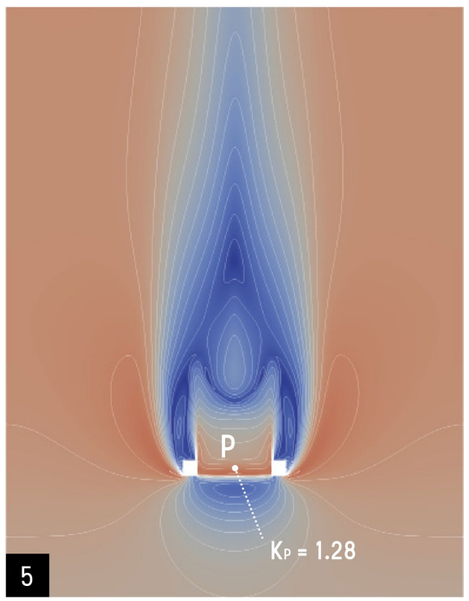


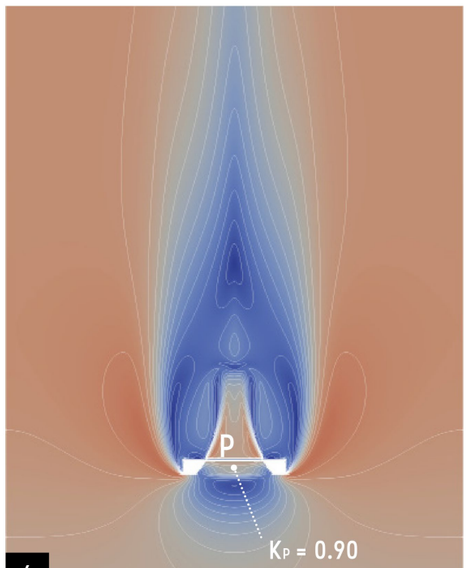


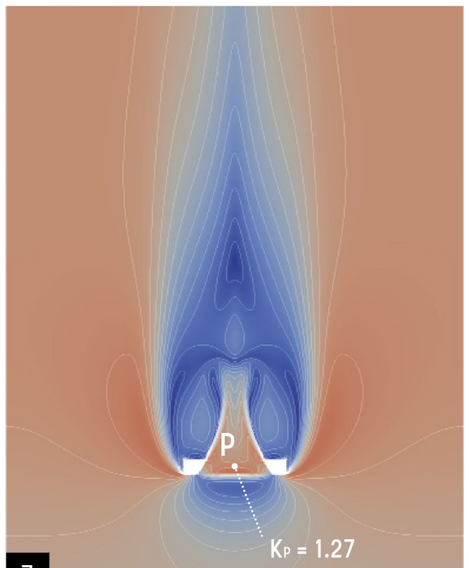


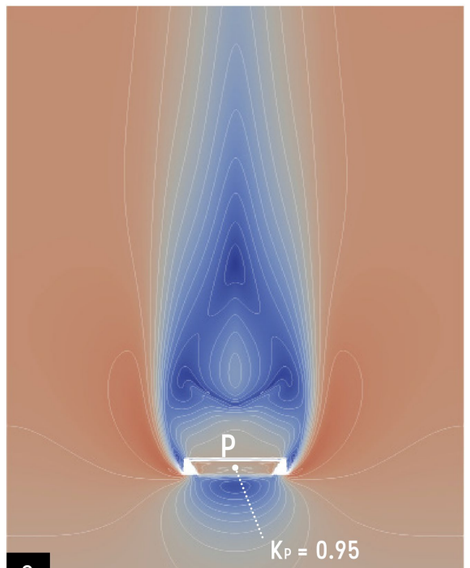


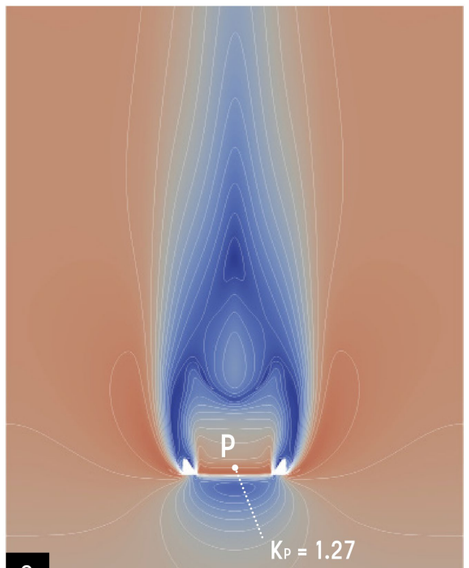




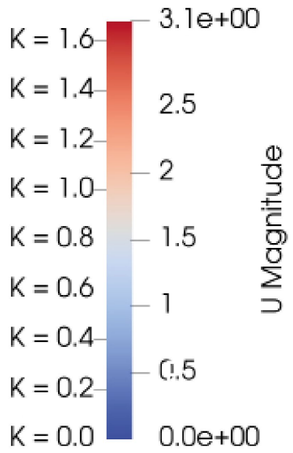








VERTICALLY CONVERGING VOID DECKS



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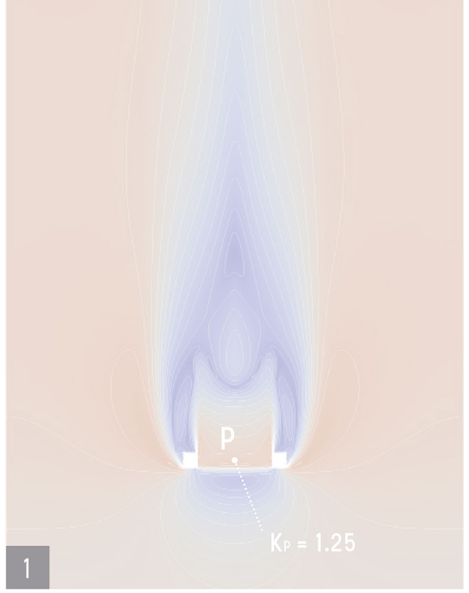
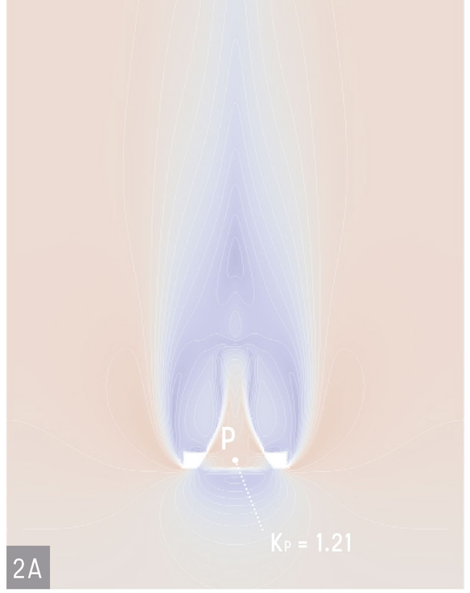
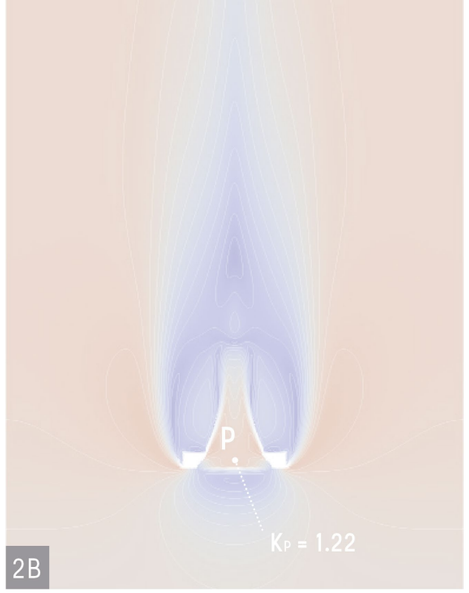
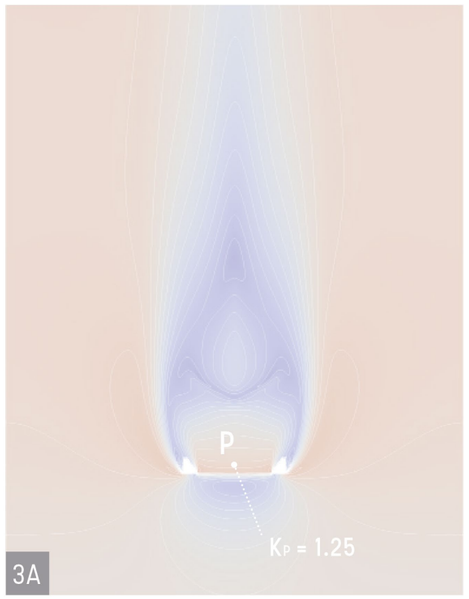
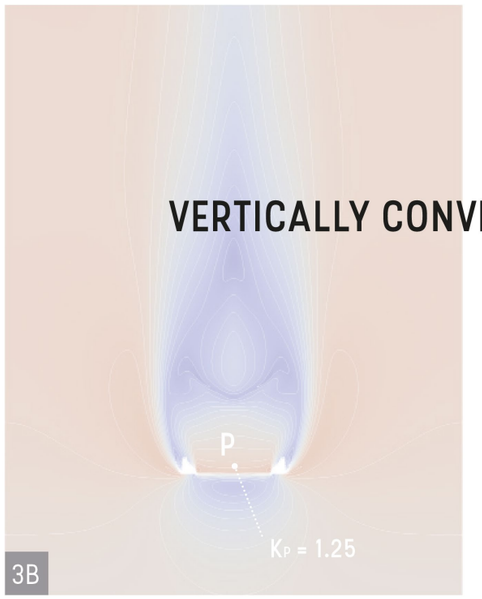
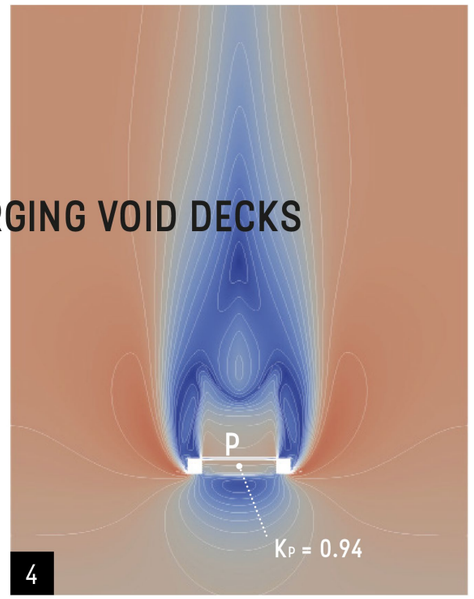


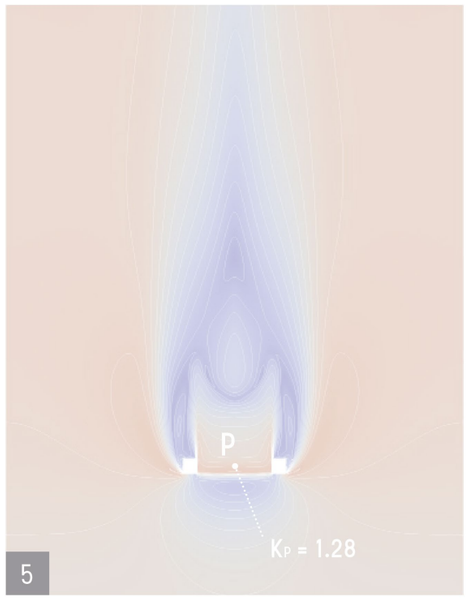


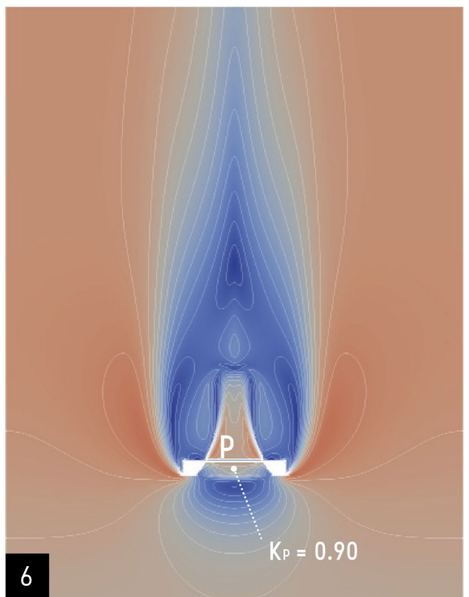


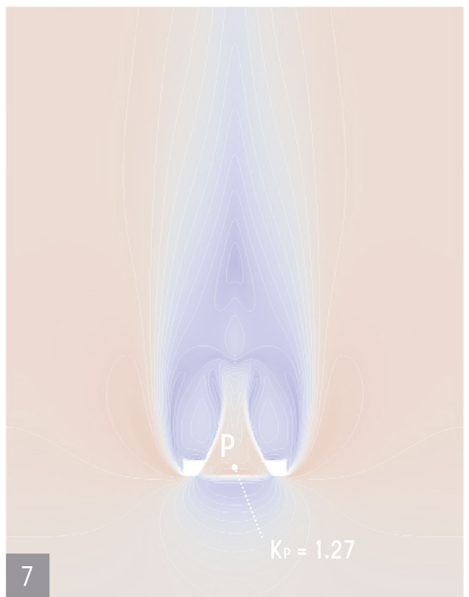


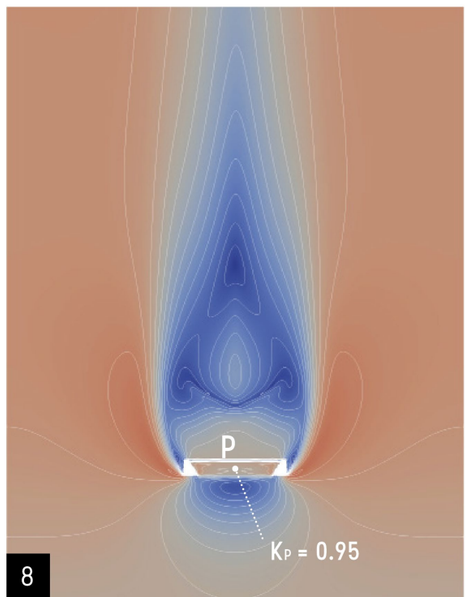


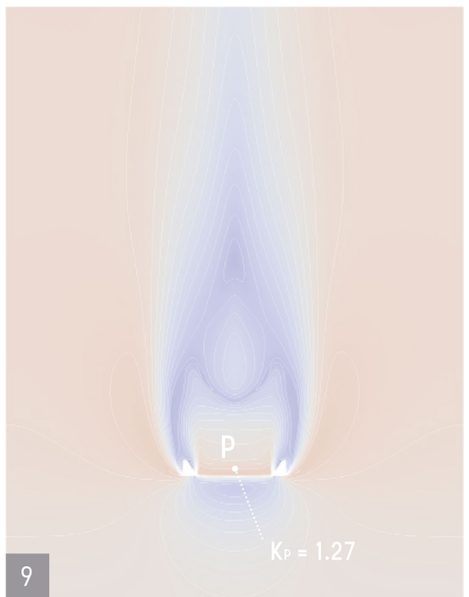




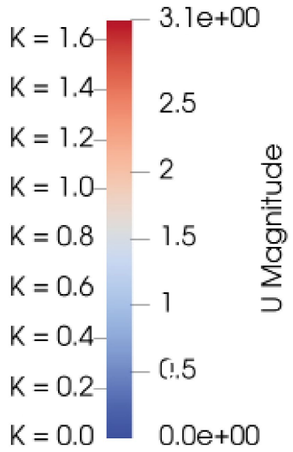








VERTICALLY DIVERGING VOID DECKS



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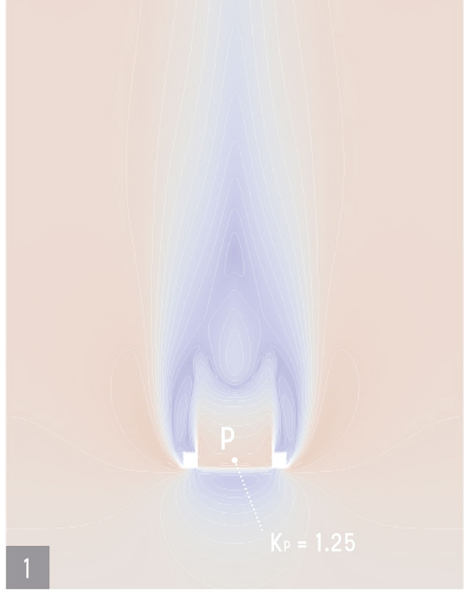
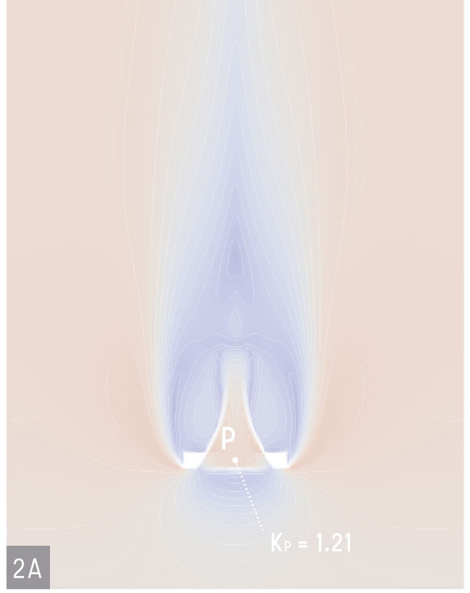
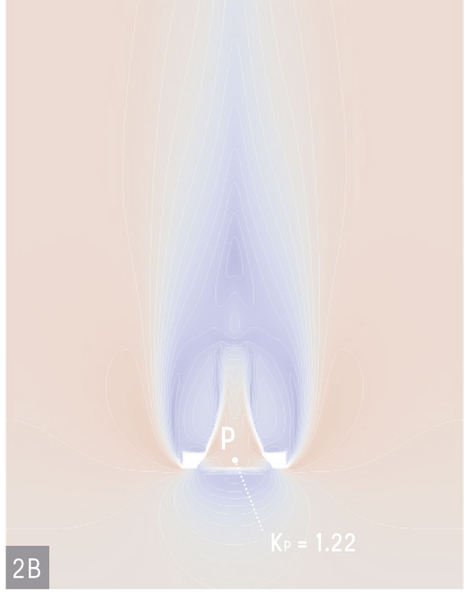
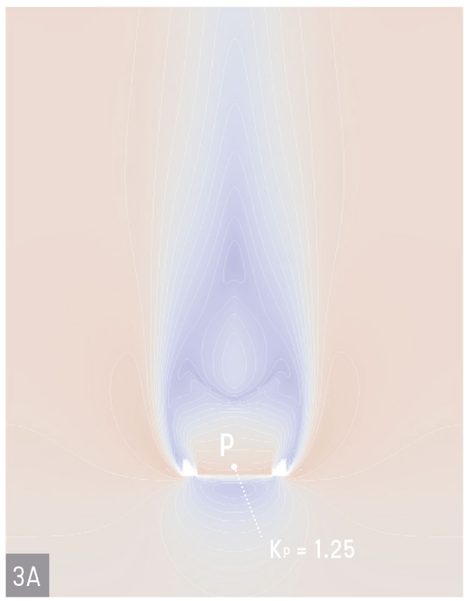
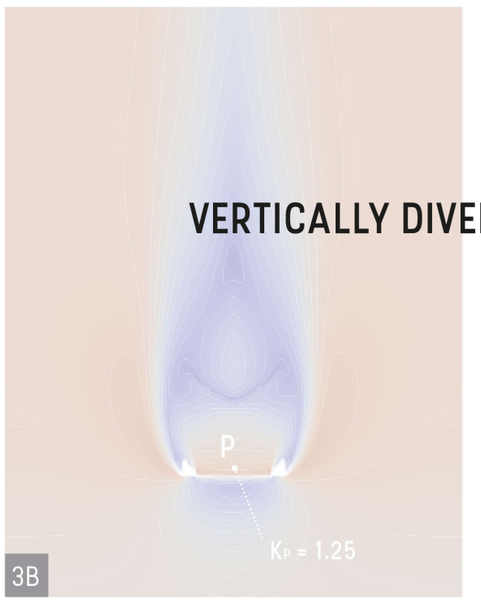
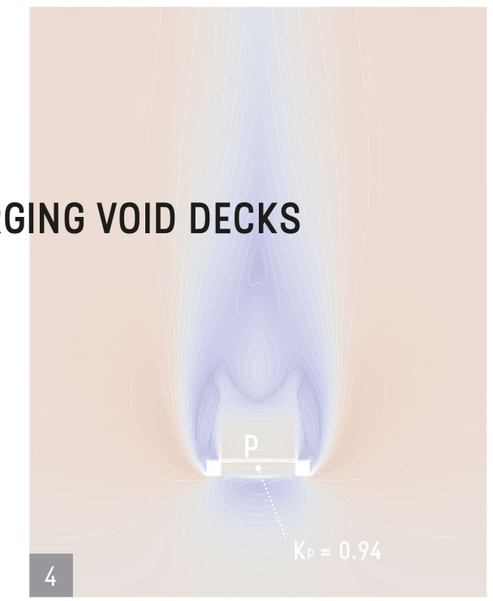


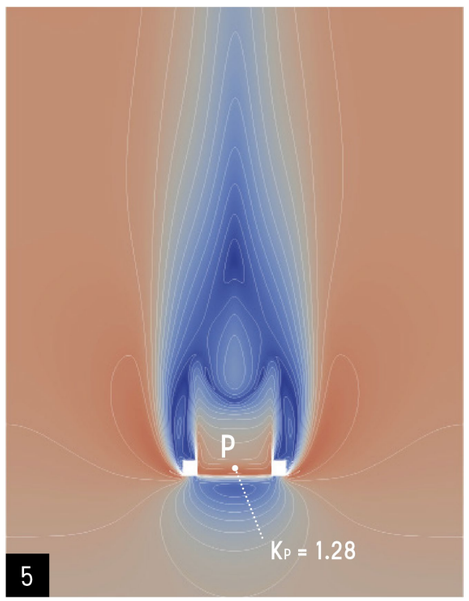


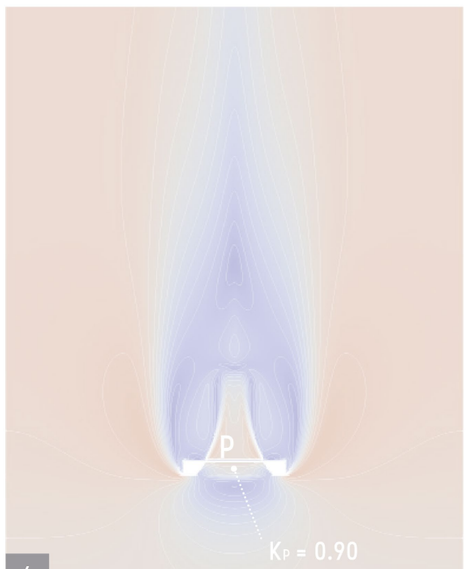


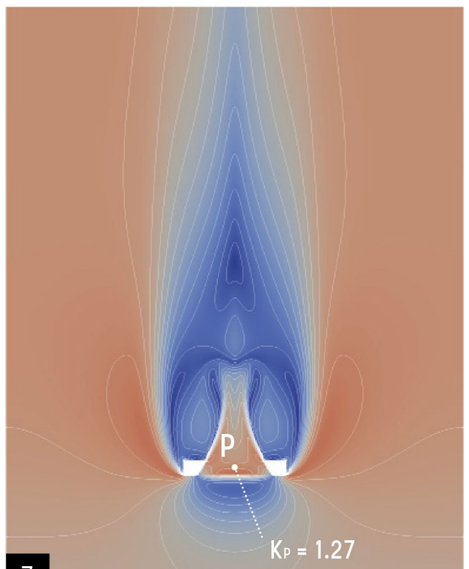


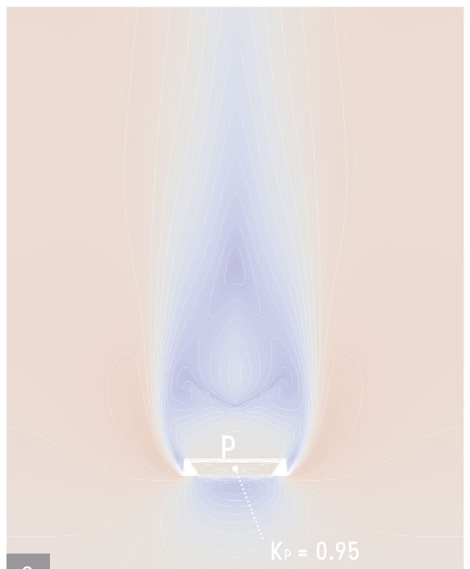


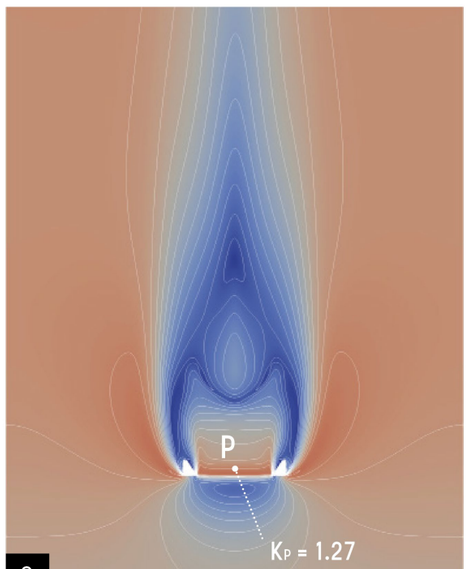


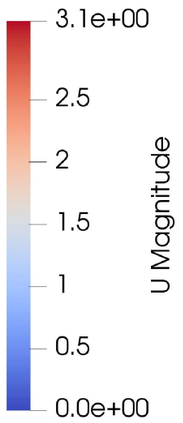




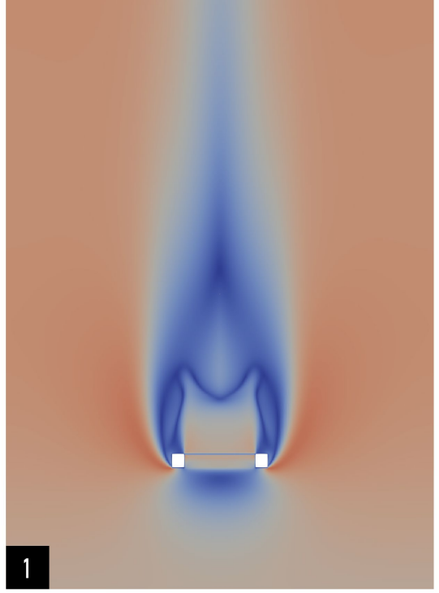


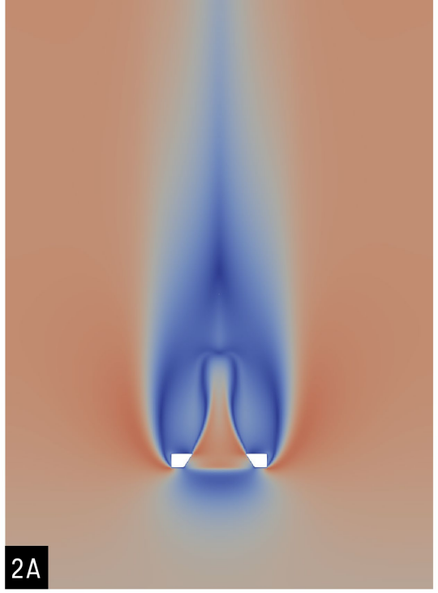


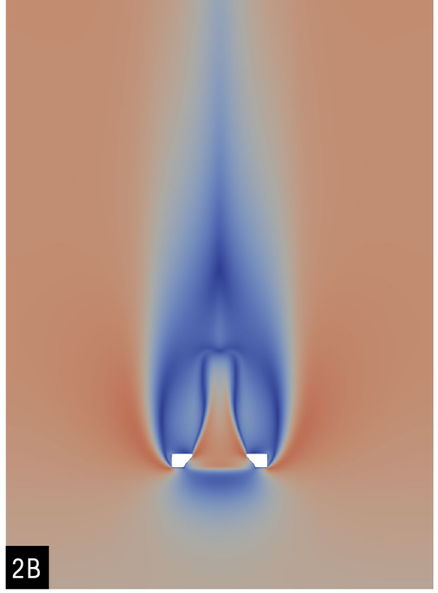


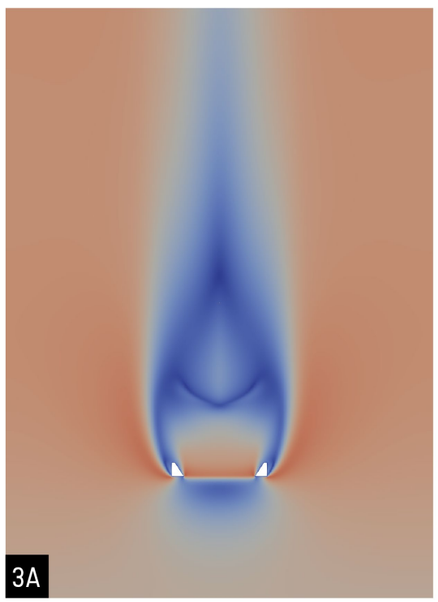


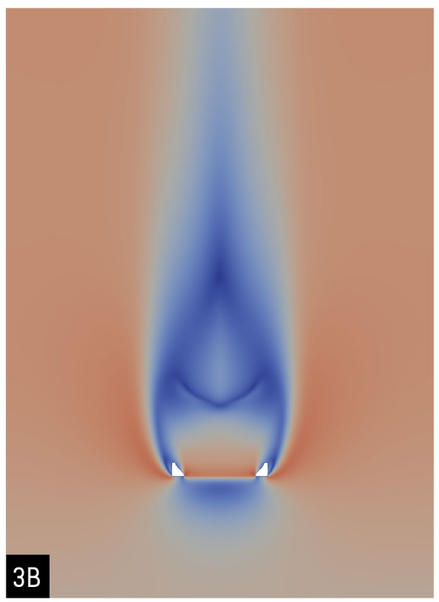
horizontal plane at pedestrian height

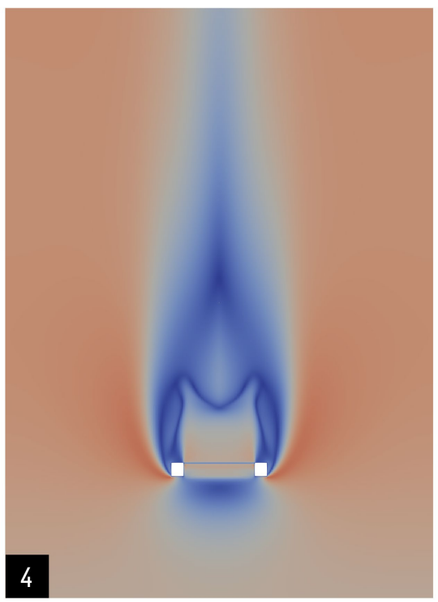


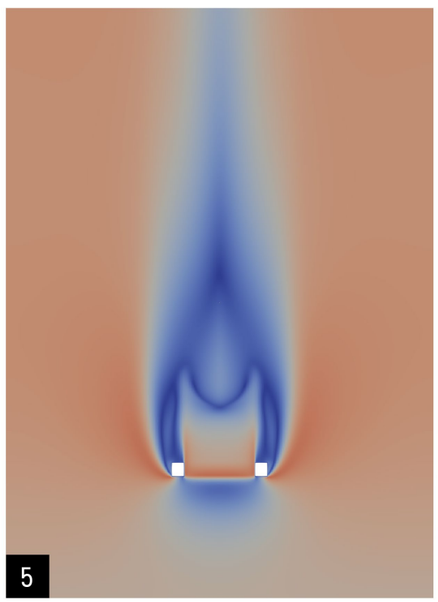


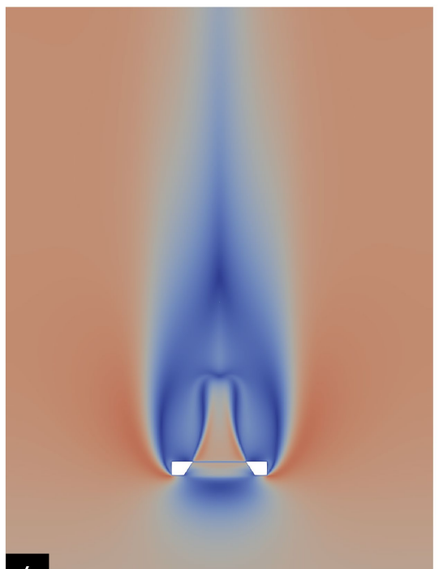


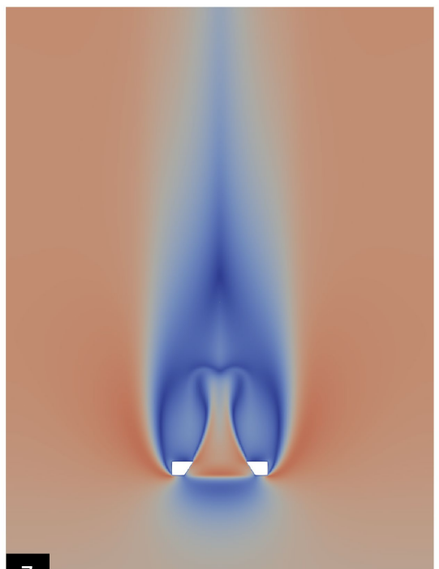


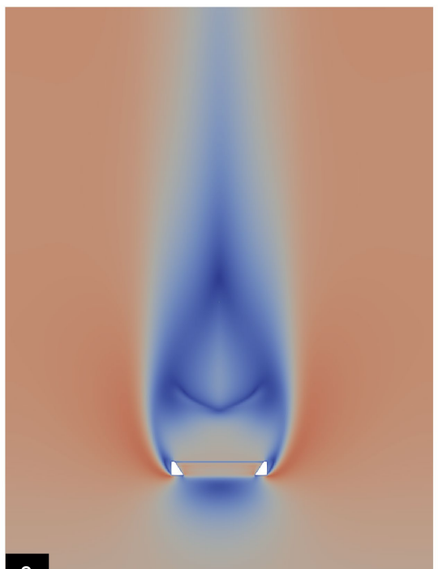


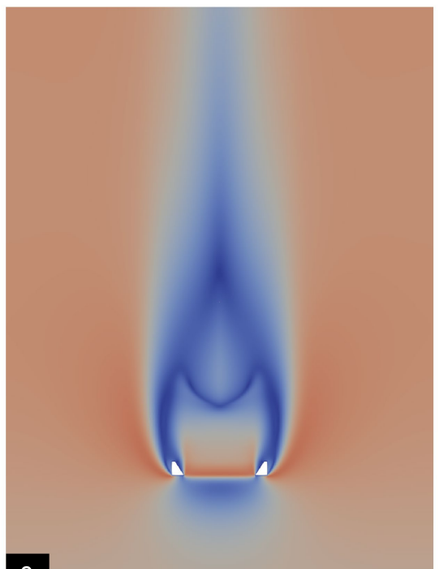


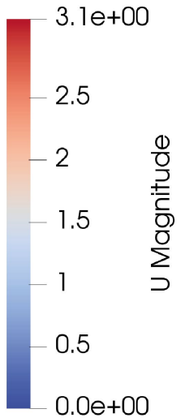


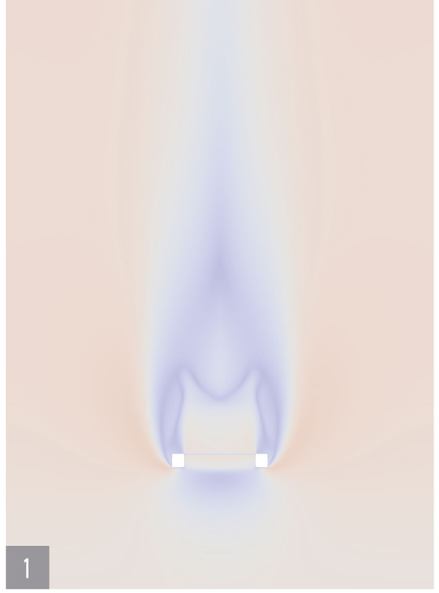


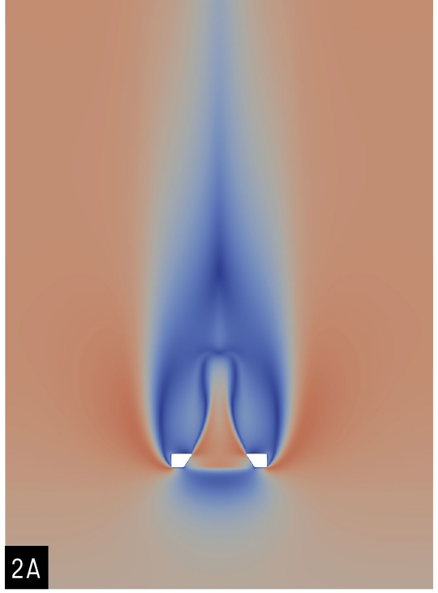


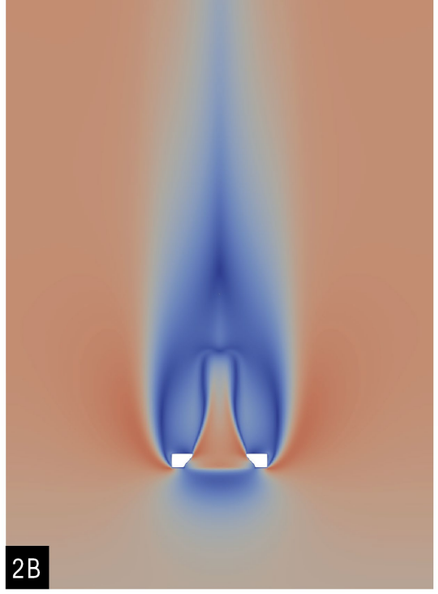




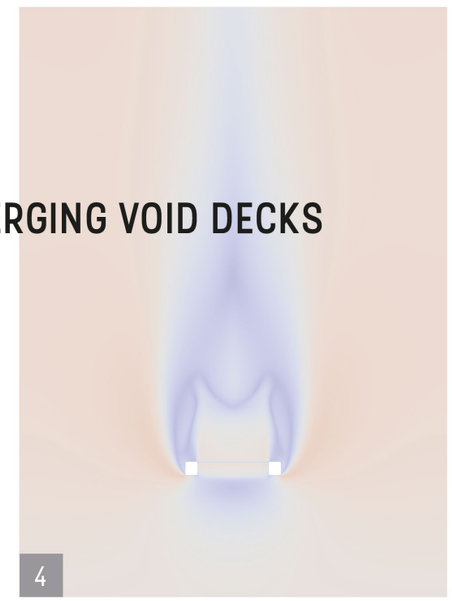


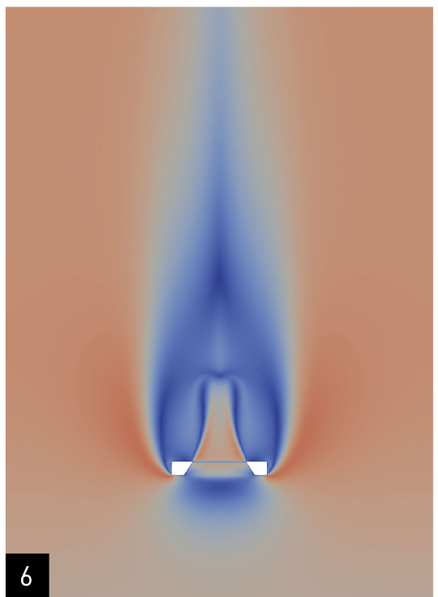


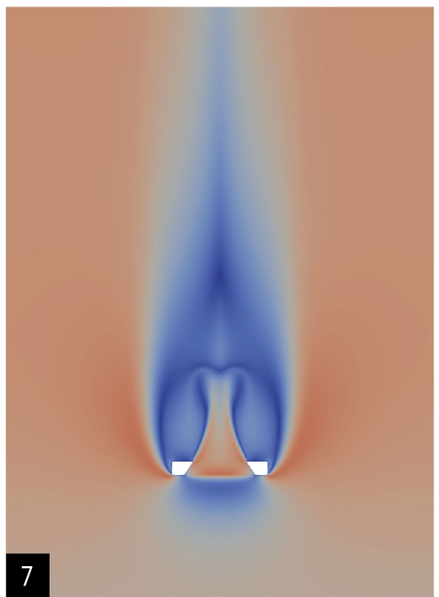


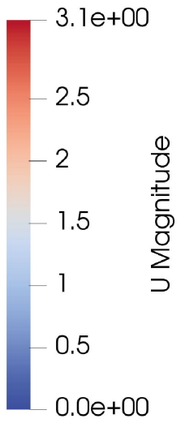


HORIZONTALLY CONVERGING VOID DECKS

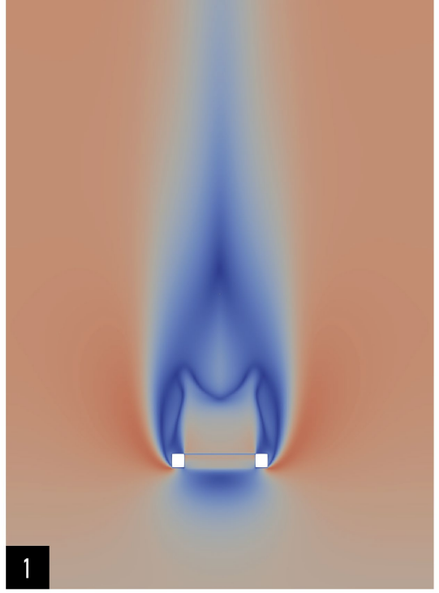


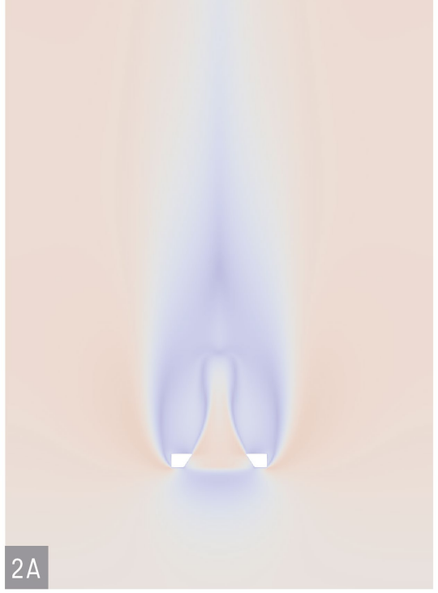


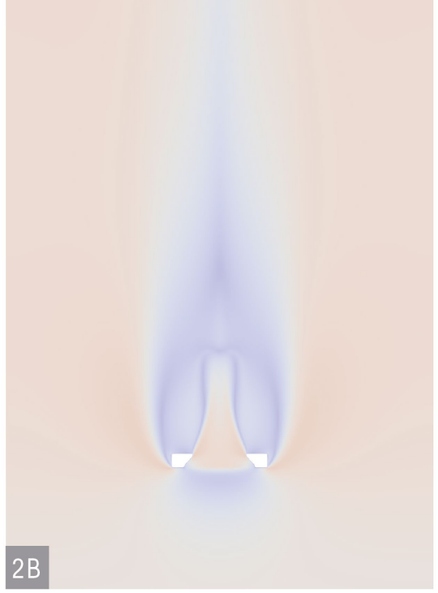


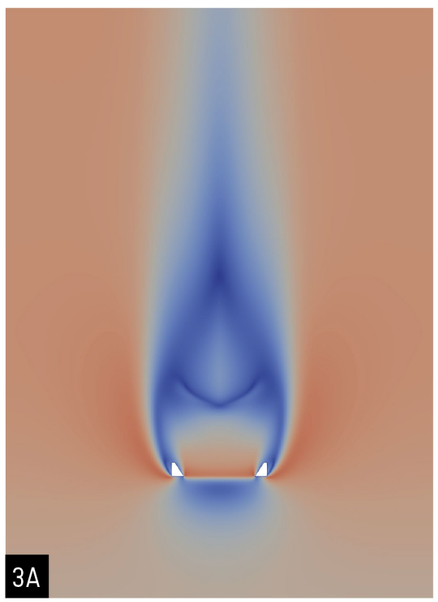


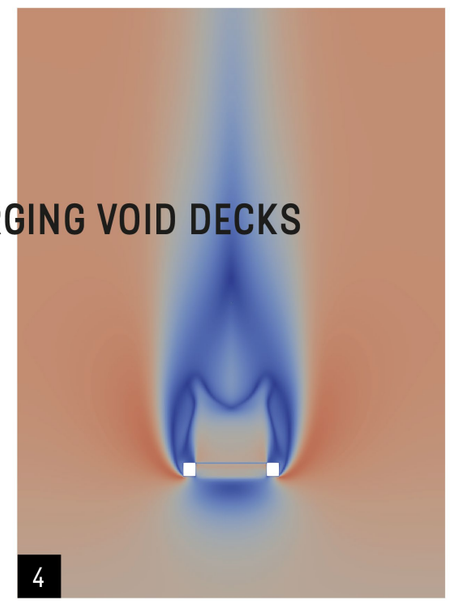
HORIZONTALLY DIVERGING VOID DECKS

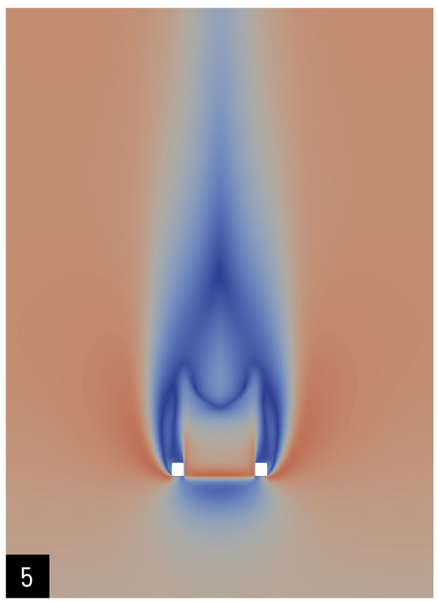


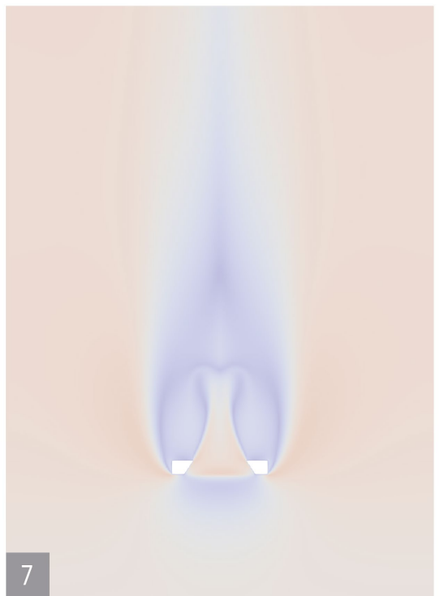


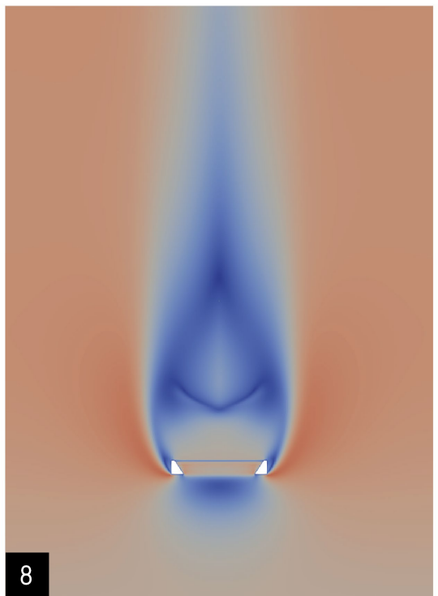


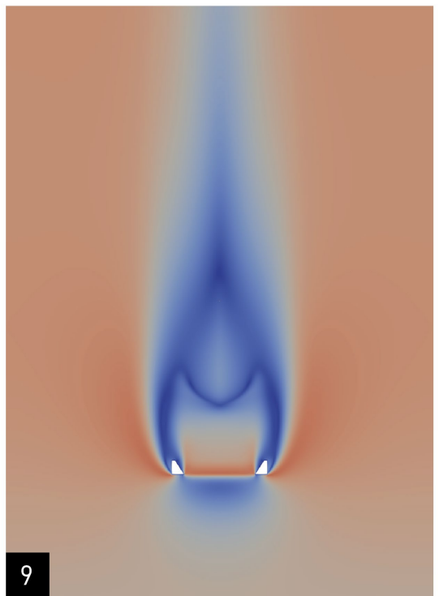




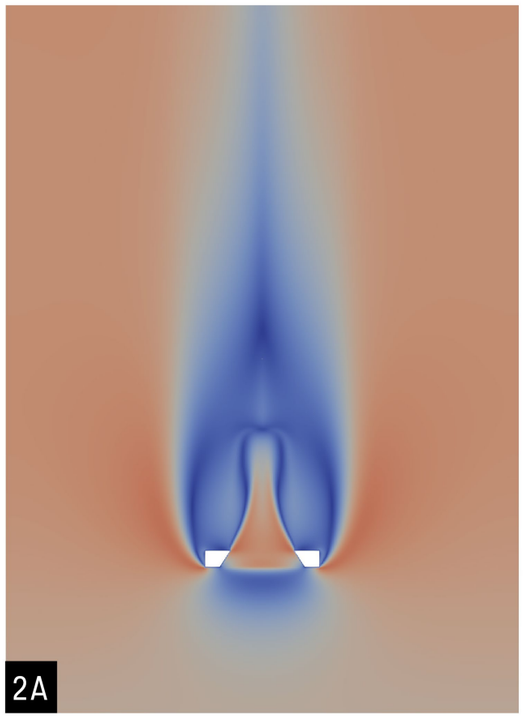




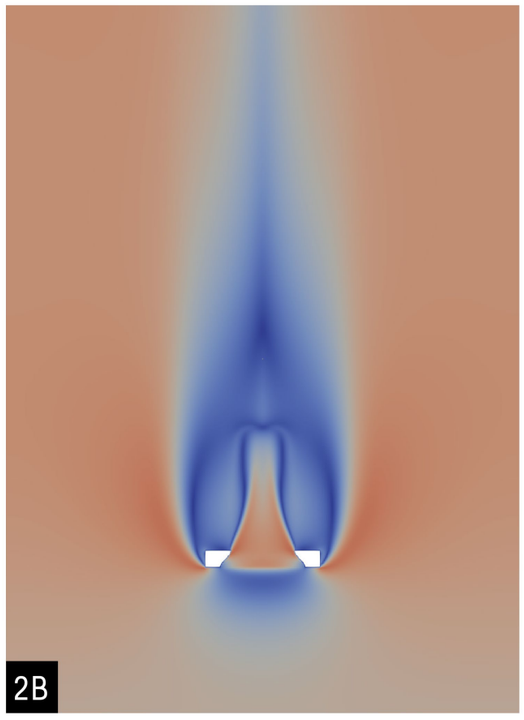




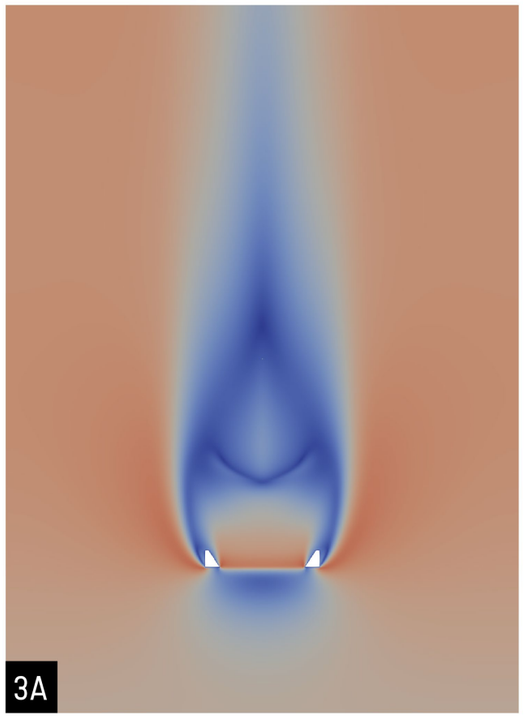
STRAIGHT VS. CURVED WALLS



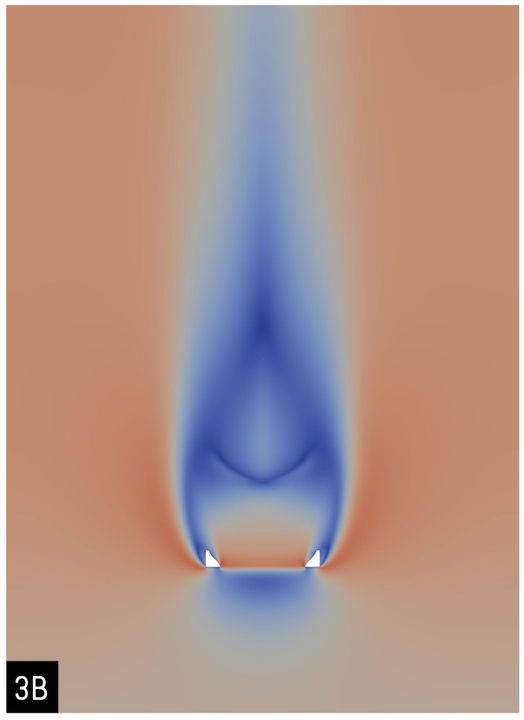
HORIZONTALLY CONVERGING VOID
STRAIGHT TAPER



HORIZONTALLY CONVERGING VOID
CURVED TAPER



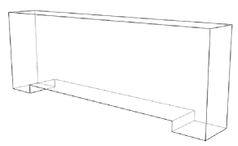
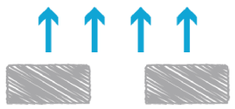
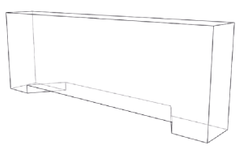
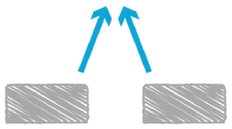
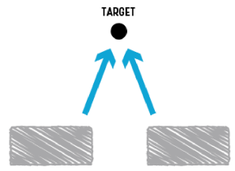
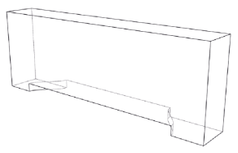
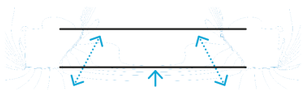
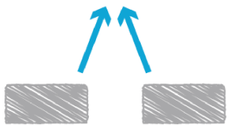
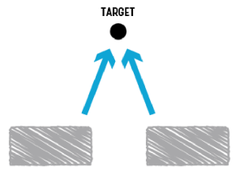
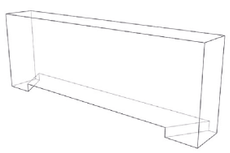
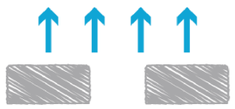
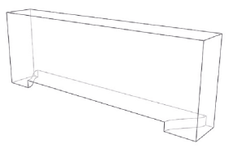
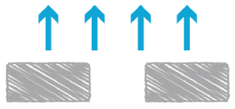
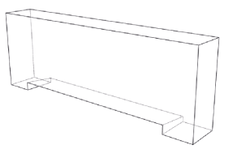
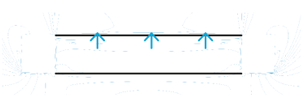
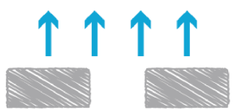
HORIZONTALLY DIVERGING VOID
STRAIGHT TAPER

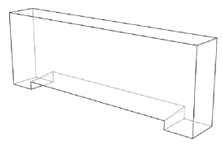
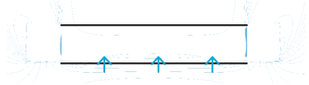
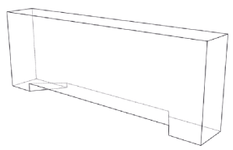
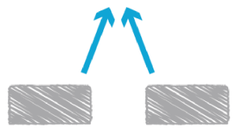
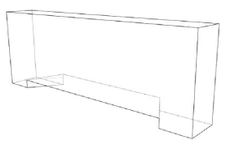
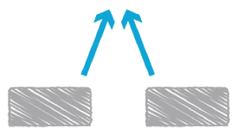
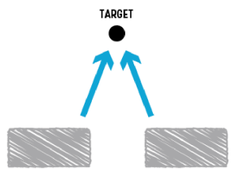
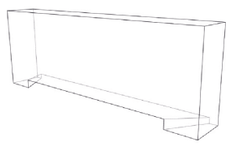
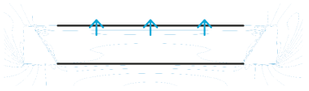
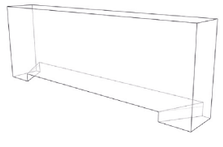
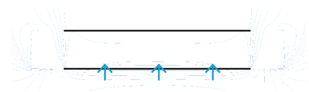
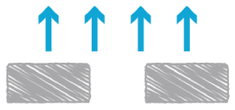


HORIZONTALLY DIVERGING VOID
CURVED TAPER

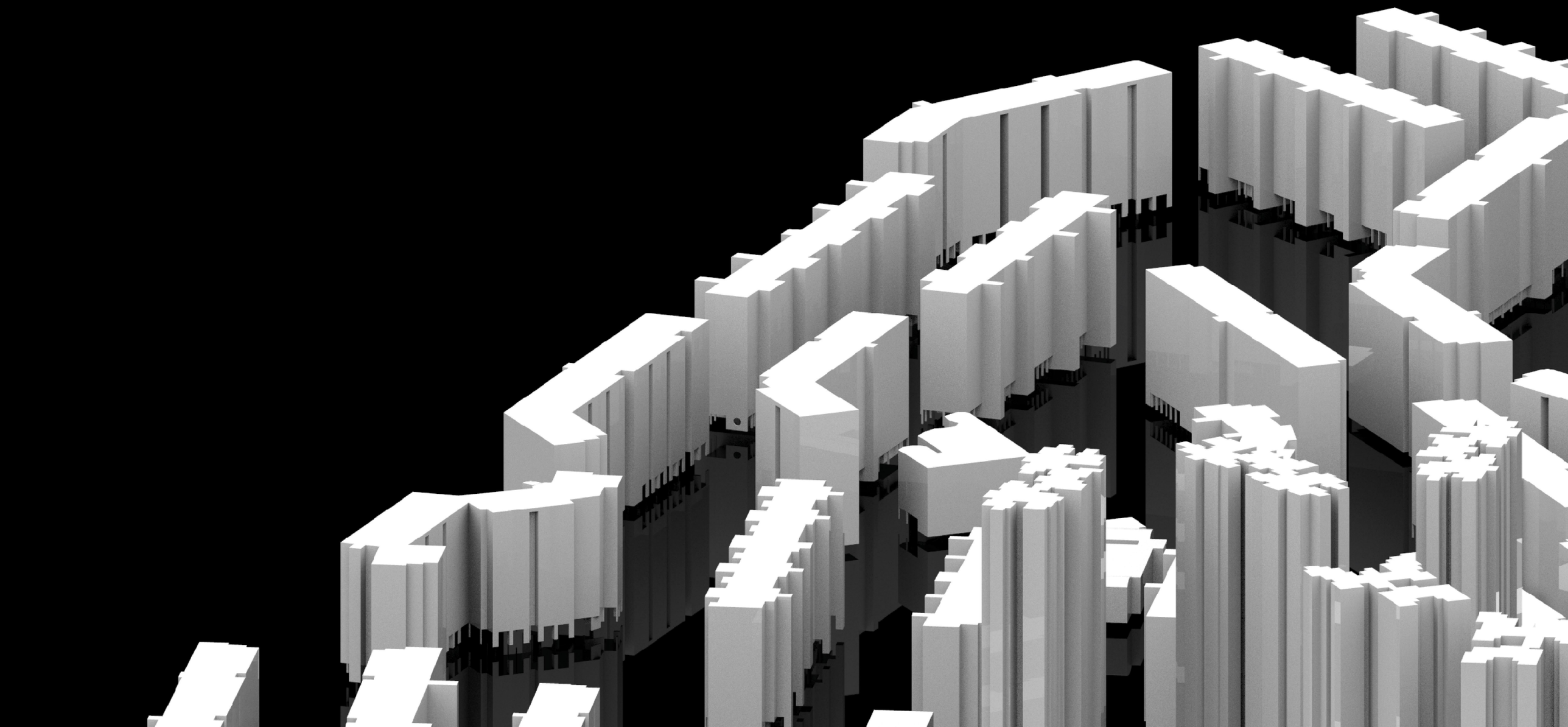
IMPLICATIONS

DESCRIPTION OF FLOW PATTERN

VARIANT	INSIDE VOID DECK	DOWNSTREAM OF VOID DECK	AMPLIFICATION FACTOR AT CENTRE OF VOID DECK	SUGGESTIONS WITH REGARD TO URBAN PLANNING
1 	 no significant velocity gradients inside void deck (steep gradient right before entry of void deck)	 even spread of accelerated flow along length	 K › 1 => urban ventilation ↑ due to presence of building with void deck	 adjacent walking route along building
2A 	 steepest velocity gradient at middle of void deck (entry); more gradual change along edges of void deck walls	 funnel-shaped area of accelerated flow	 K › 1 => urban ventilation ↑ due to presence of building with void deck	 direct accelerated flow towards target
2B 	 steepest velocity gradient at middle of void deck (entry); more gradual change along edges of void deck walls	 funnel-shaped area of accelerated flow	 K › 1 => urban ventilation ↑ due to presence of building with void deck	 direct accelerated flow towards target
3A 	 largest velocity gradients at edges of void deck walls (also steep gradient right before entry of void deck)	 even spread of accelerated flow along length	 K › 1 => urban ventilation ↑ due to presence of building with void deck	 adjacent walking route along building
3B 	 largest velocity gradients at edges of void deck walls (also steep gradient right before entry of void deck)	 even spread of accelerated flow along length	 K › 1 => urban ventilation ↑ due to presence of building with void deck	 adjacent walking route along building
4 	 steepest velocity gradient upon flow exit from void deck	 even spread of accelerated flow along length	 K ‹ 1 => urban ventilation ↓ due to presence of building with void deck	 not suitable for microclimate enhancement inside void deck

5		 steepest velocity gradient upon flow entry in void deck	 even spread of accelerated flow along length	 K › 1 => urban ventilation ↑ due to presence of building with void deck	 adjacent walking route along building
6		 steepest velocity gradients at entry and along edges of void deck walls	 funnel-shaped area of accelerated flow	 K ‹ 1 => urban ventilation ↓ due to presence of building with void deck	 not suitable for microclimate enhancement inside void deck
7		 steepest velocity gradient right before entry; inside void deck steepest along edges of void deck walls	 funnel-shaped area of accelerated flow	 K › 1 => urban ventilation ↑ due to presence of building with void deck	 direct accelerated flow towards target
8		 steepest velocity gradient upon flow exit from void deck; smaller gradient inside void deck	 even spread of accelerated flow along length	 K ‹ 1 => urban ventilation ↓ due to presence of building with void deck	 not suitable for microclimate enhancement inside void deck
9		 steepest velocity gradient upon flow entry in void deck	 even spread of accelerated flow along length	 K › 1 => urban ventilation ↑ due to presence of building with void deck	 adjacent walking route along building

FROM BUILDING TO URBAN SCALE



CURRENT ACTIVITY PATTERN

1

2

3

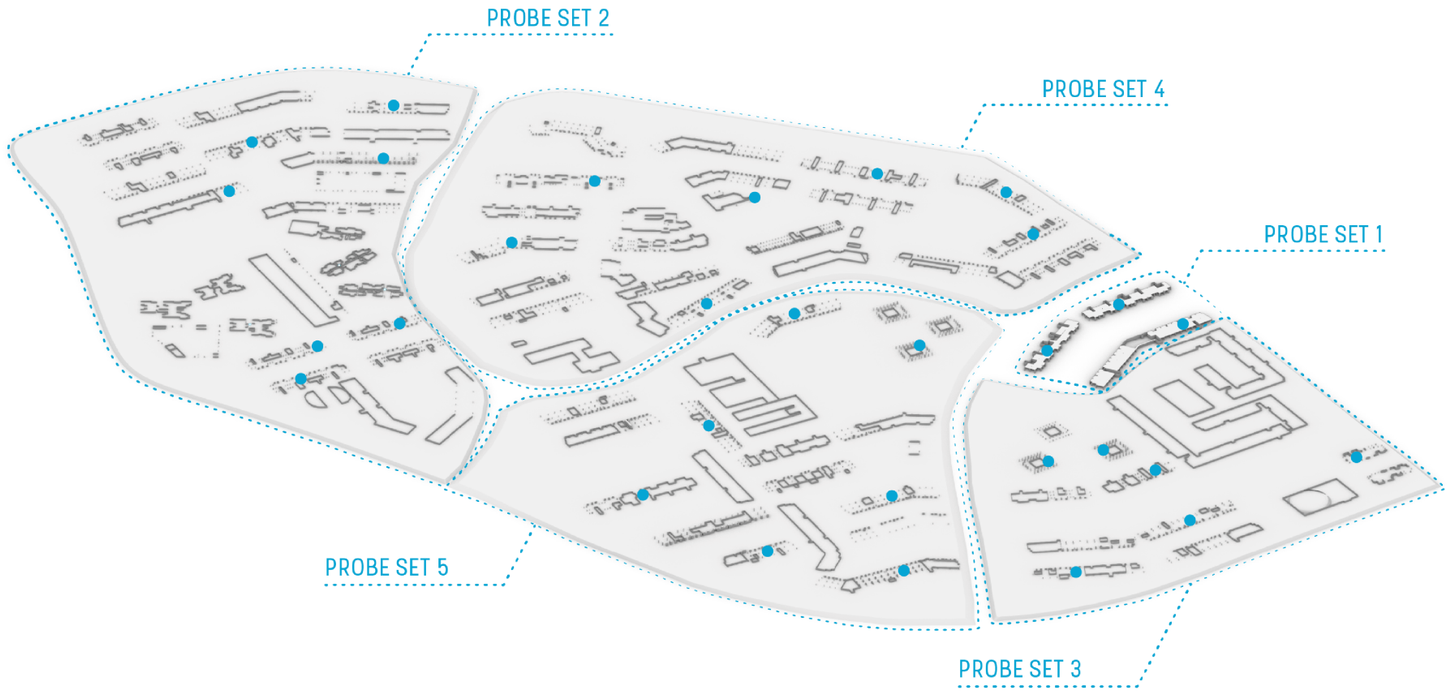
cutting plane: h = 1.75m

- running & cycling trail
- sports field / outdoor gym
- playground
- frequent outdoor seating area (restaurant / café)
- occasional outdoor seating area (void deck)
- B — bus stop
- MRT — MRT station

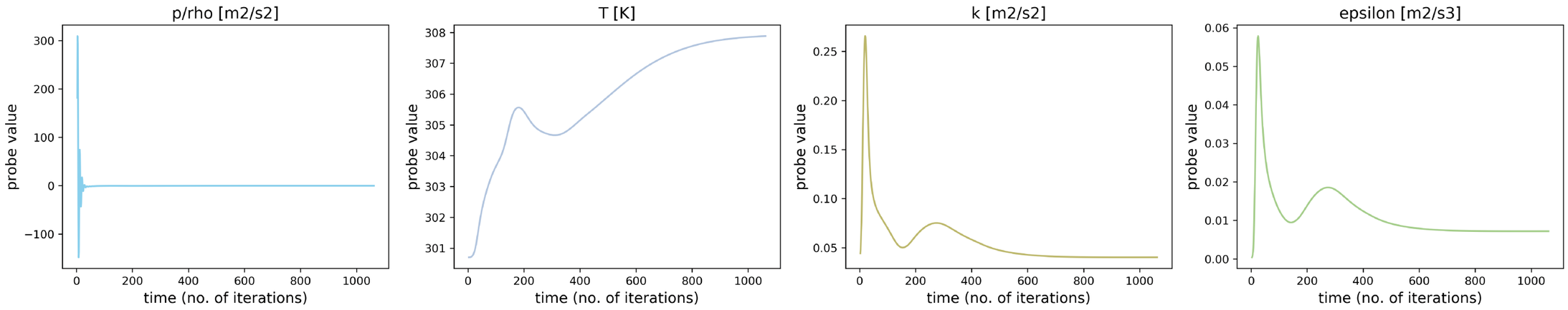
4

5

MONITORING PROBES IN VOID DECKS



example: convergence at probe 13 (probe set 3)



LCZ 5
open mid-rise

LCZ 5
open mid-rise

LCZ 2
compact mid-rise

LCZ 8
large low-rise

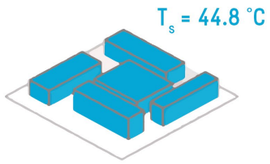
building majority: LCZ 4
open high-rise

roads land cover: LCZ E
bare rock or paved

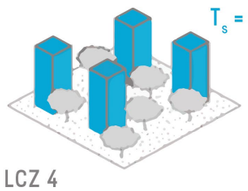
terrain land cover: LCZ B
scattered trees

LCZ 6
open low-rise

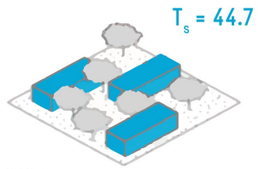
LOCAL CLIMATE ZONES IN STUDY AREA



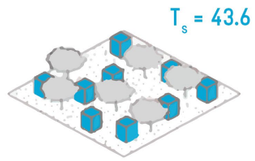
LCZ 2
compact mid-rise



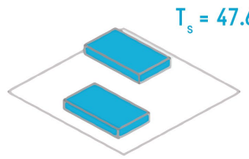
LCZ 4
open high-rise



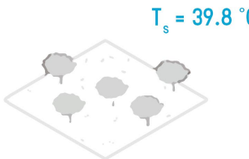
LCZ 5
open mid-rise



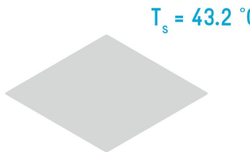
LCZ 6
open low-rise



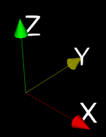
LCZ 8
large low-rise



LCZ B
scattered trees



LCZ E
bare rock or paved


Z
Y
X

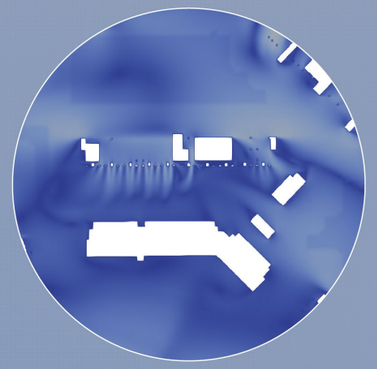
NORTHEAST MONSOON: PREVAILING WIND FROM N

U RESULTS AT PEDESTRIAN HEIGHT

CLEMENTI

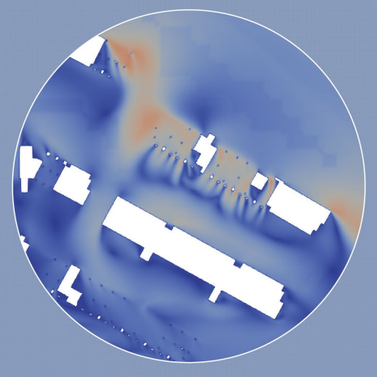
NORTHEAST MONSOON: PREVAILING WIND FROM N

INFLUENCE OF VOID DECKS
ON MAGNITUDE OF U



narrow streams of
increased velocity

INFLUENCE OF VOID DECKS
ON DIRECTION OF U

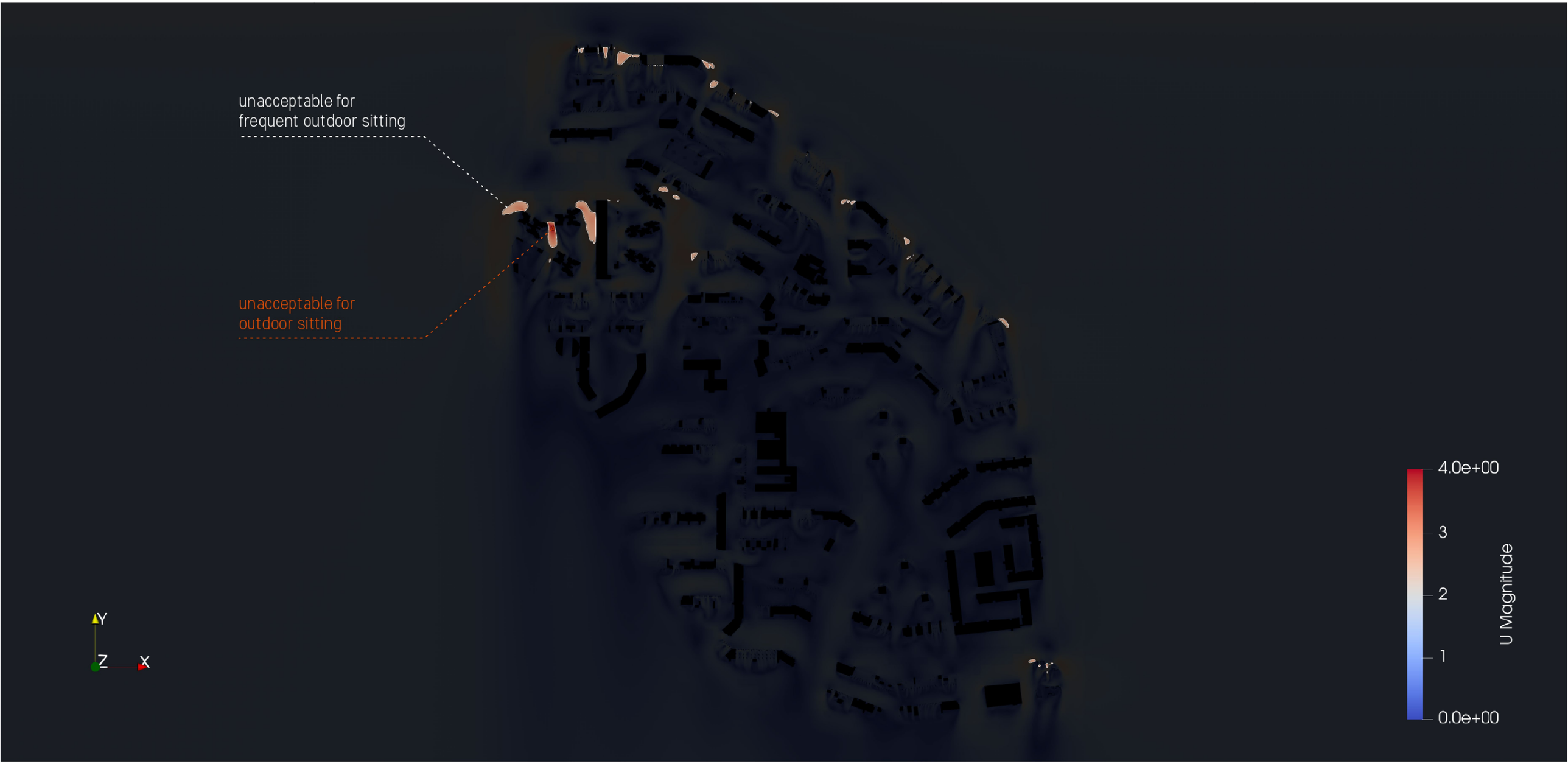


flow guided in
particular direction

U RESULTS AT PEDESTRIAN HEIGHT

CLEMENTI

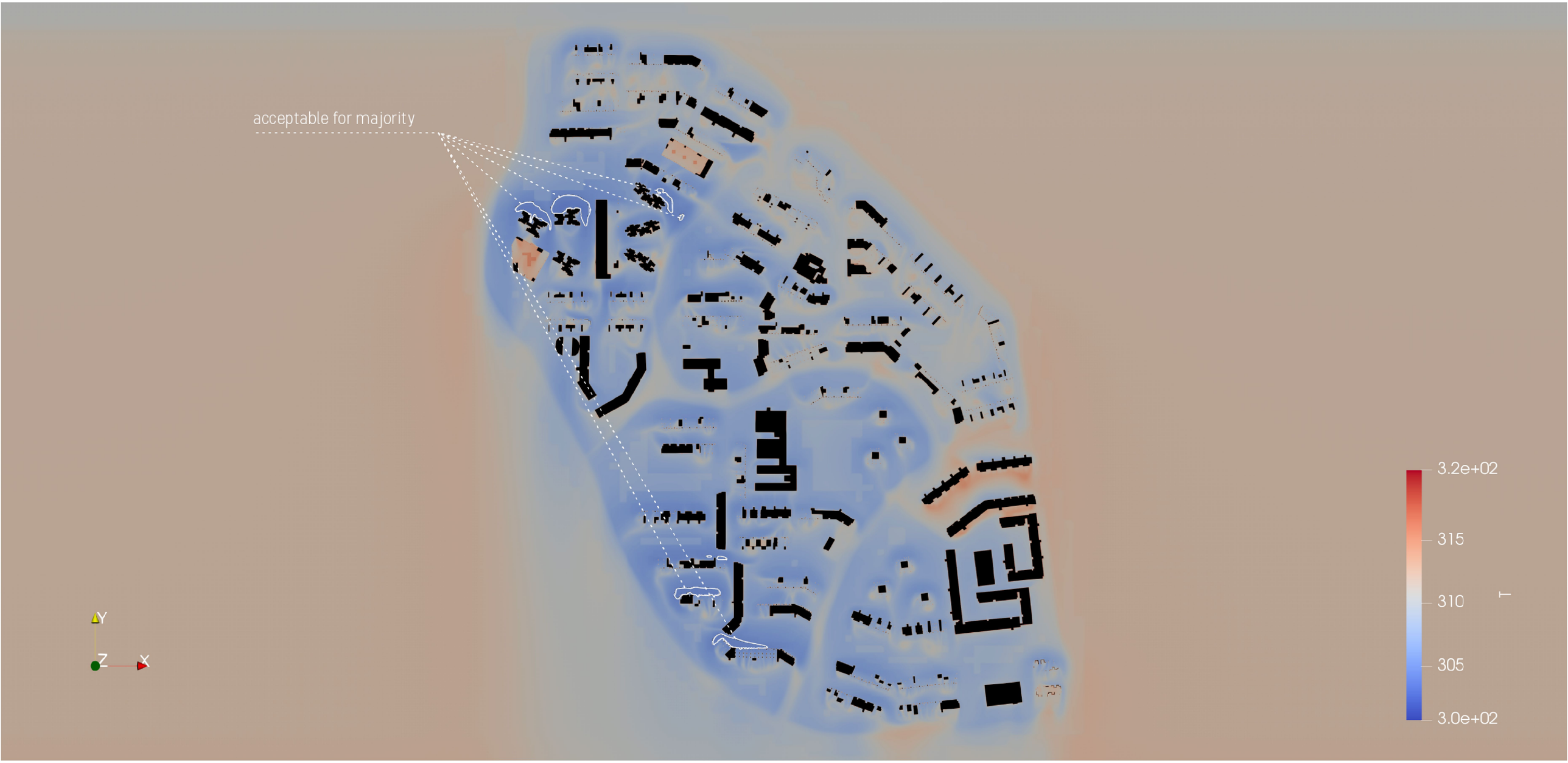
NORTHEAST MONSOON: PREVAILING WIND FROM N



PEDESTRIAN WIND COMFORT: UNACCEPTABLE AREAS FOR FREQUENT & OCCASIONAL OUTDOOR SITTING
[2.5 m/s ‹ U ≤ 4.0 m/s] and [4.0 m/s ‹ U ≤ 6.0 m/s]

CLEMENTI

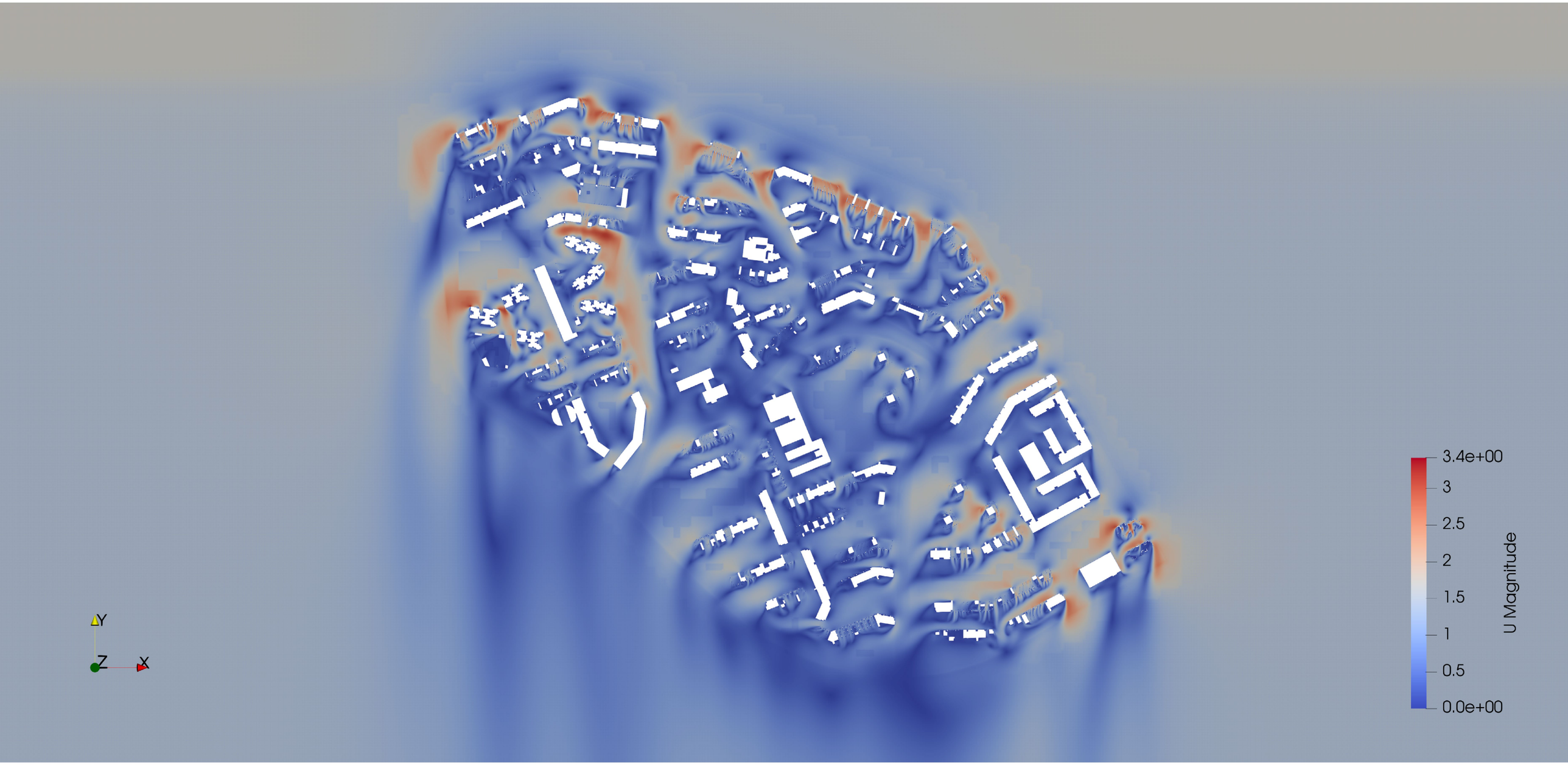
NORTHEAST MONSOON: PREVAILING WIND FROM N



OUTDOOR THERMAL COMFORT: THERMALLY ACCEPTABLE & UNCOMFORTABLY HOT AREAS
[24 °C ‹ THI ≤ 31 °C] and [THI › 31 °C]

CLEMENTI

NORTHEAST MONSOON: PREVAILING WIND FROM NNE



U RESULTS AT PEDESTRIAN HEIGHT

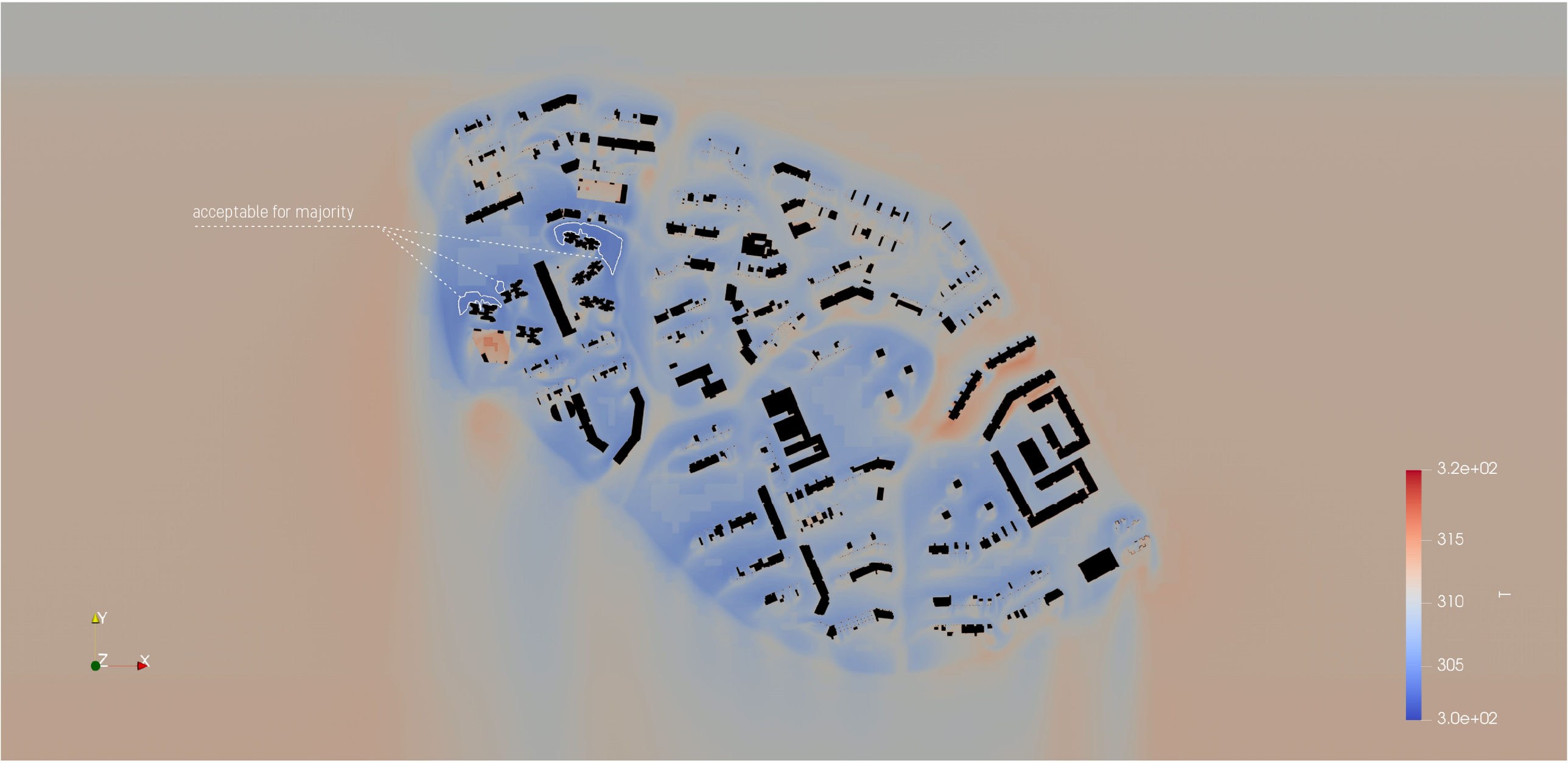
CLEMENTI

NORTHEAST MONSOON: PREVAILING WIND FROM NNE

PEDESTRIAN WIND COMFORT: UNACCEPTABLE AREAS FOR FREQUENT OUTDOOR SITTING
[2.5 m/s < U ≤ 4.0 m/s]

CLEMENTI

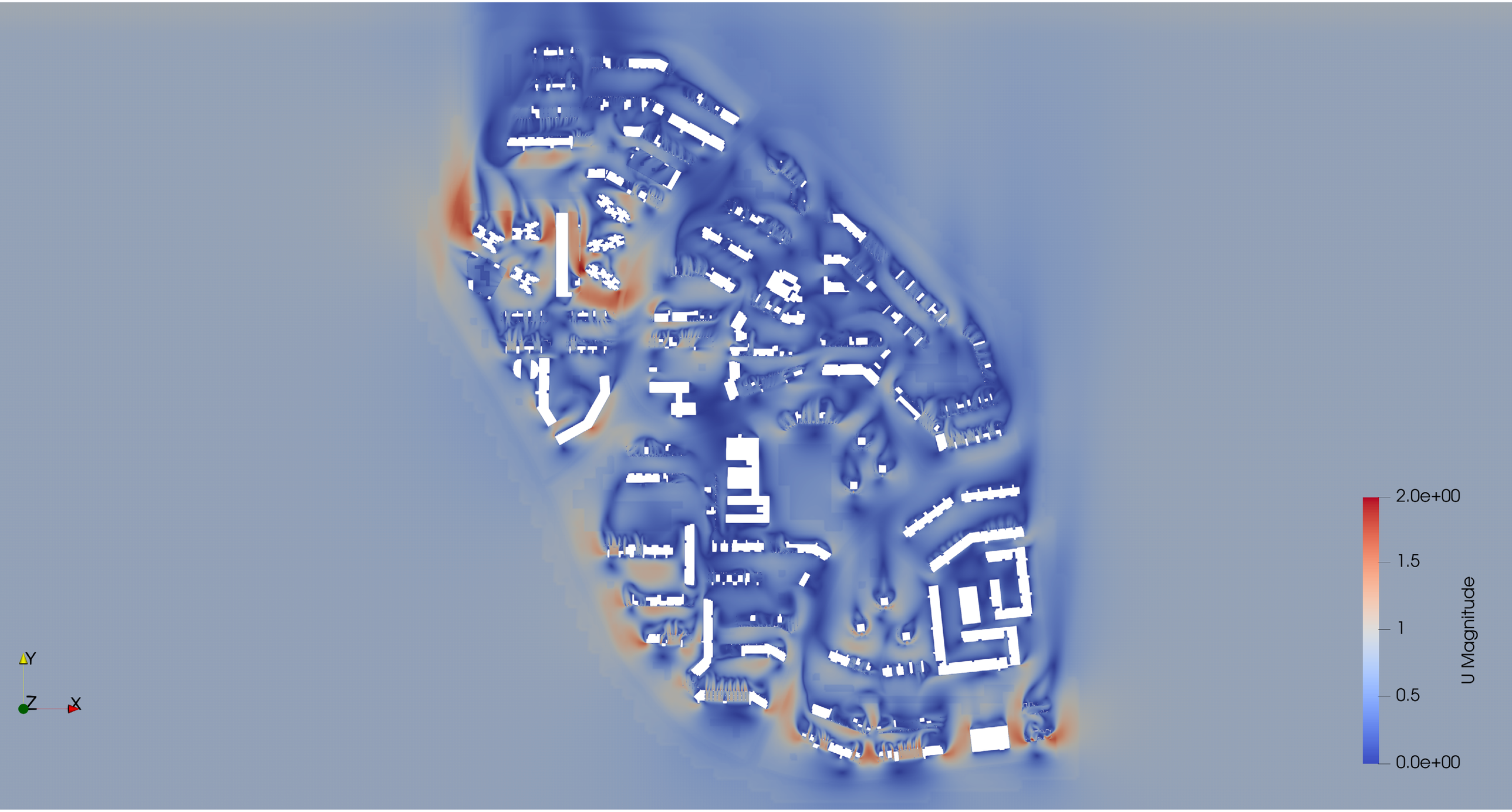
NORTHEAST MONSOON: PREVAILING WIND FROM NNE



OUTDOOR THERMAL COMFORT: THERMALLY ACCEPTABLE & UNCOMFORTABLY HOT AREAS
[24 °C ‹ THI ≤ 31 °C] and [THI › 31 °C]

CLEMENTI

SOUTHWEST MONSOON: PREVAILING WIND FROM S

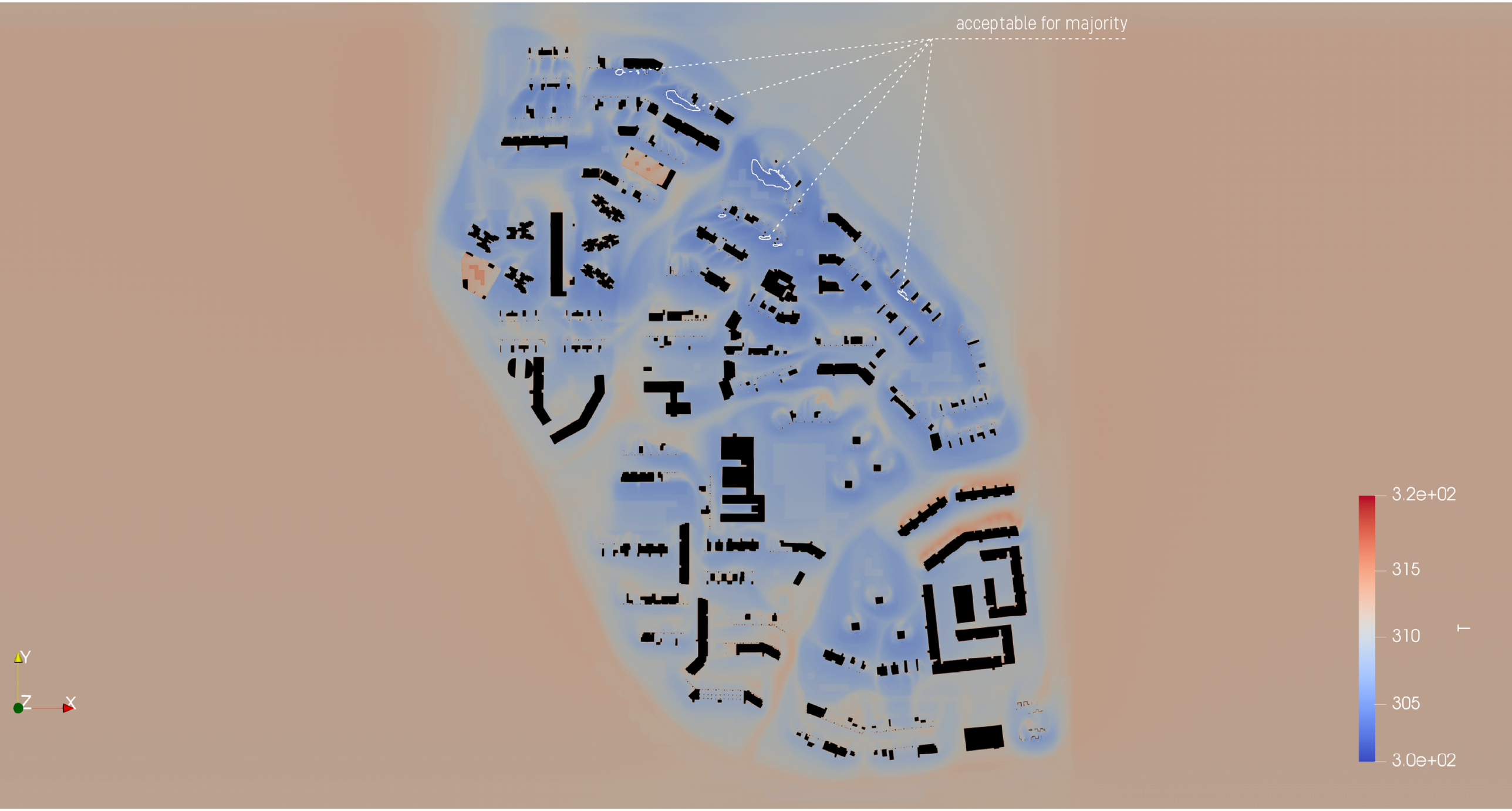


U RESULTS AT PEDESTRIAN HEIGHT

PEDESTRIAN WIND COMFORT: ACCEPTABLE FOR ALL ASSESSED OUTDOOR ACTIVITIES

CLEMENTI

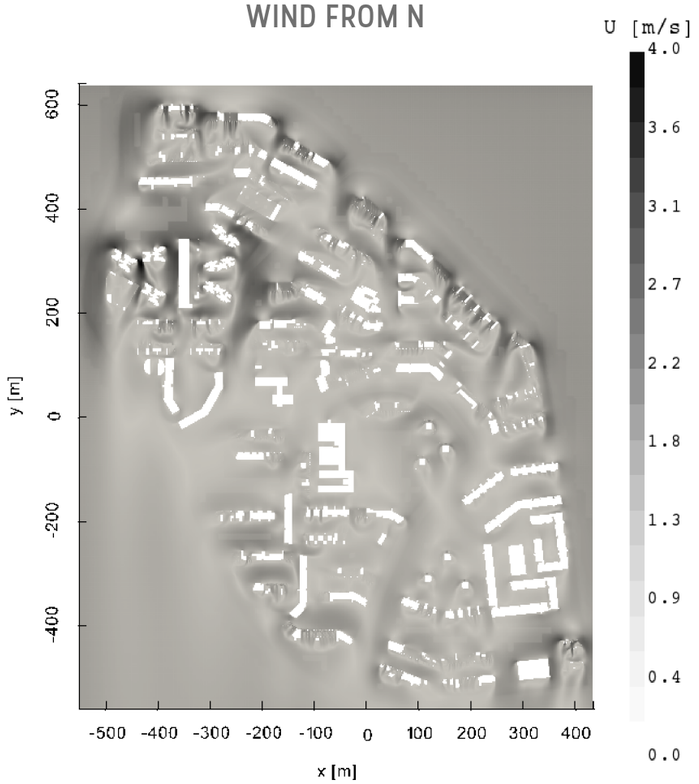
SOUTHWEST MONSOON: PREVAILING WIND FROM S

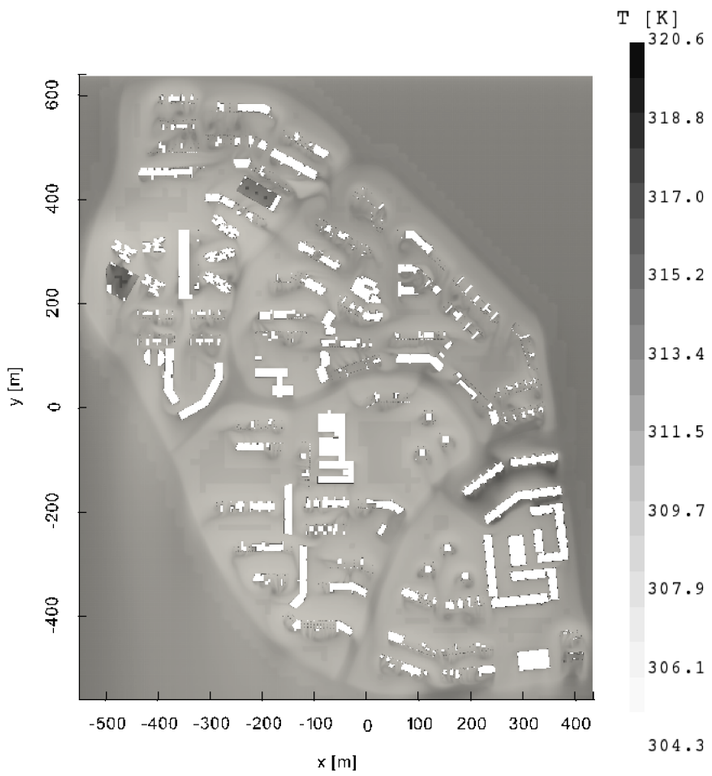


OUTDOOR THERMAL COMFORT: THERMALLY ACCEPTABLE & UNCOMFORTABLY HOT AREAS
[24 °C ‹ THI ≤ 31 °C] and [THI › 31 °C]

CLEMENTI

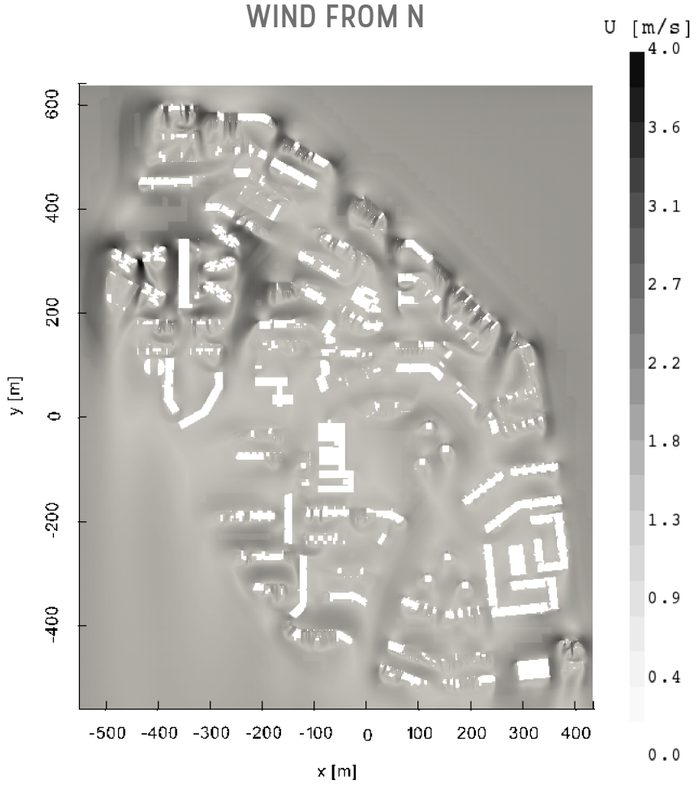
WIND FROM N



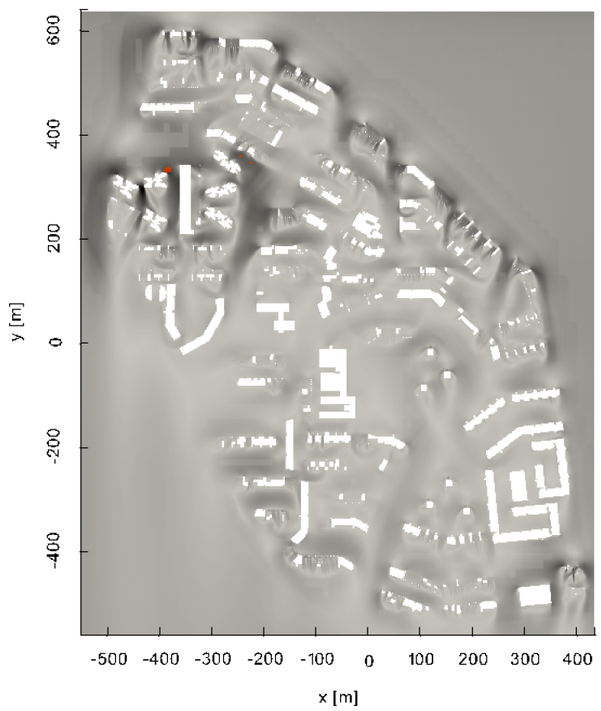


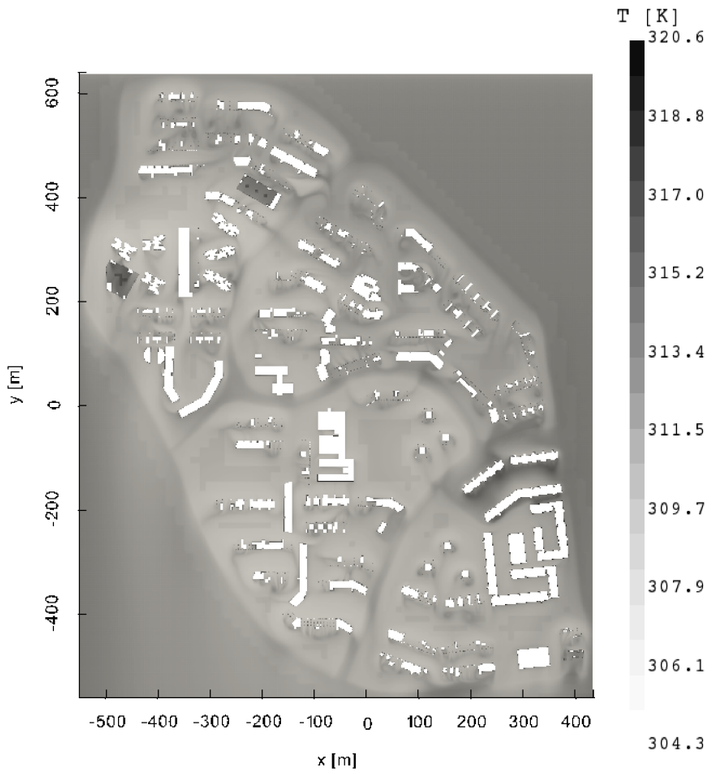
CLEMENTI

WIND FROM N

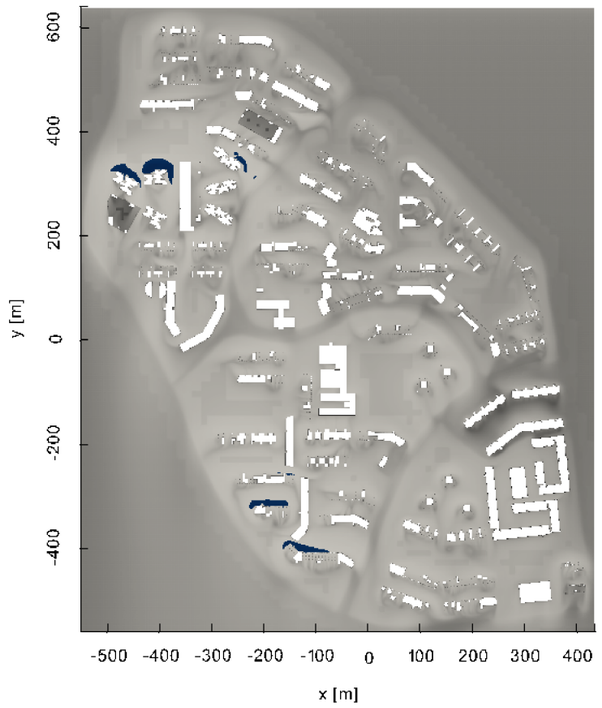


PEDESTRIAN WIND DISCOMFORT



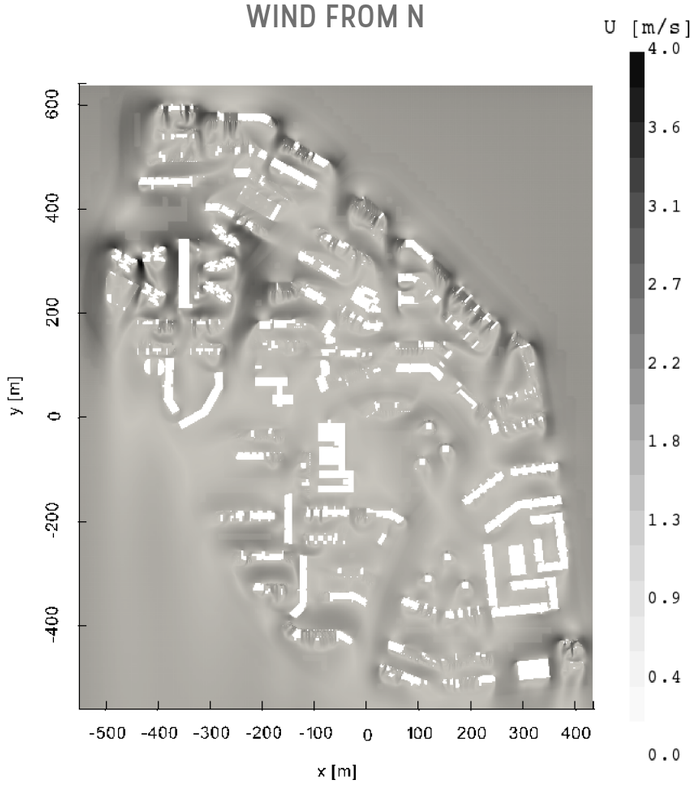


ACCEPTABLE THERMAL COMFORT

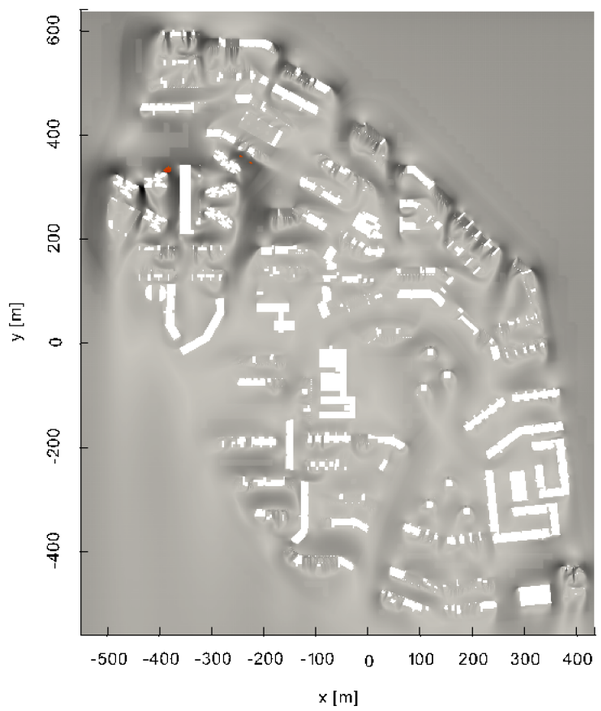


CLEMENTI

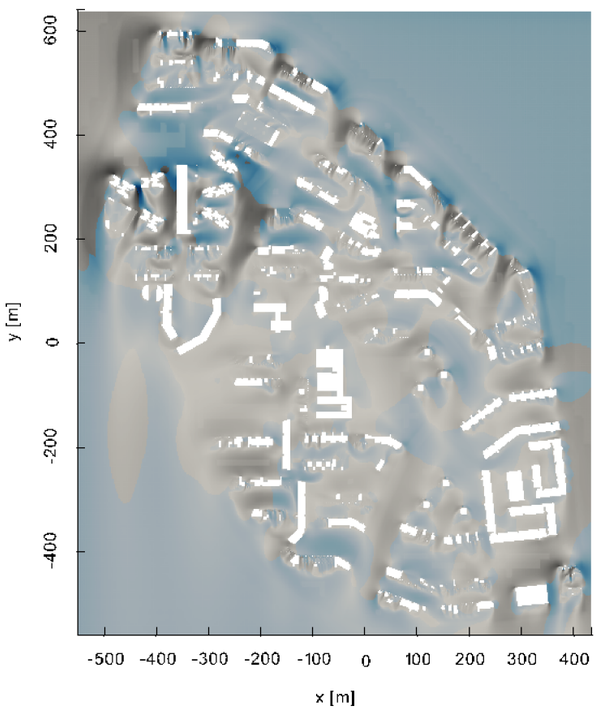
WIND FROM N

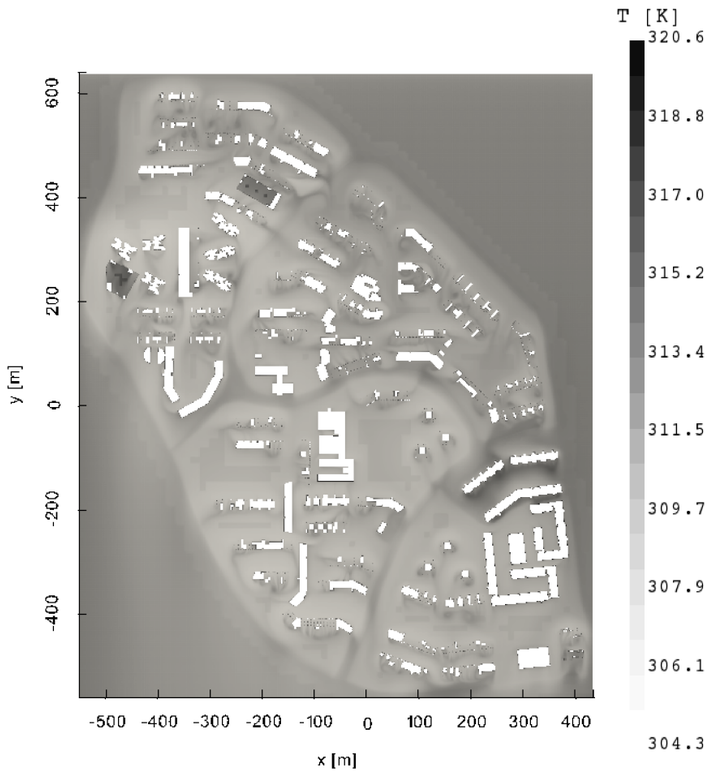


PEDESTRIAN WIND DISCOMFORT

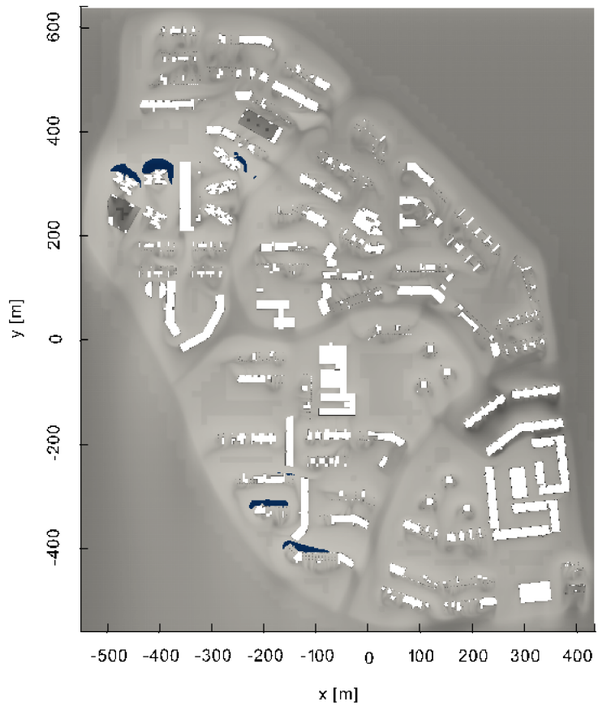


PEDESTRIAN WIND COMFORT

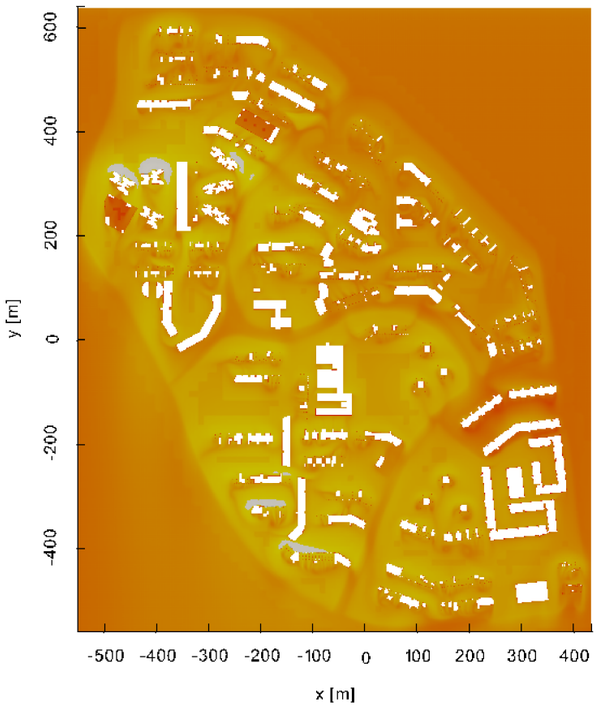




ACCEPTABLE THERMAL COMFORT

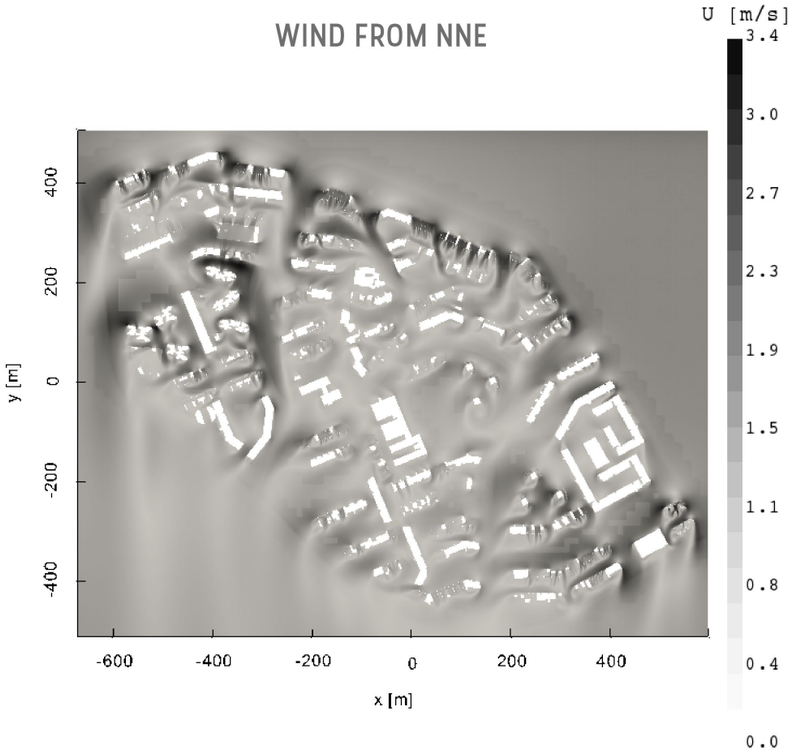


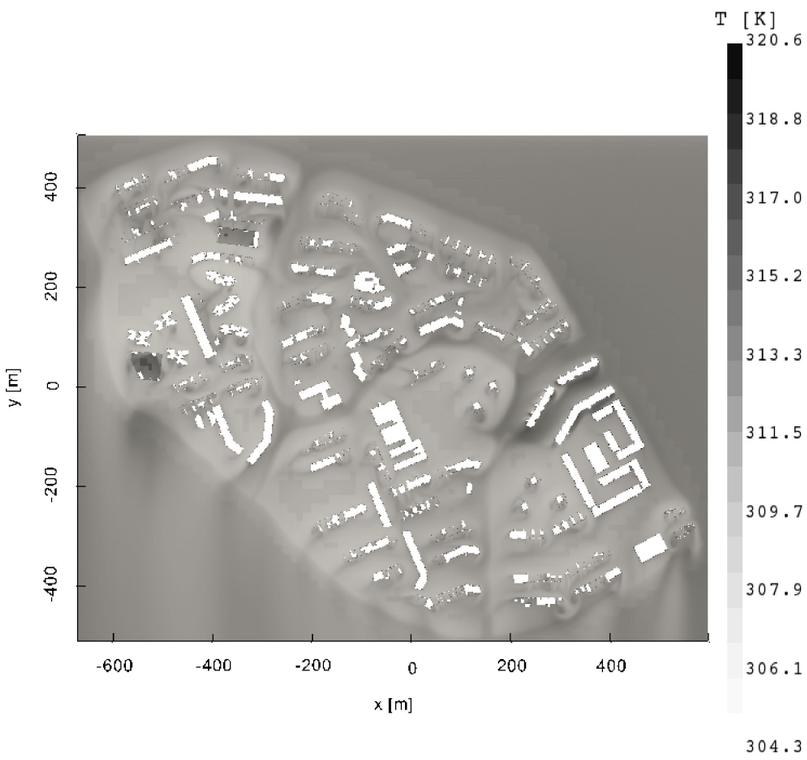
THERMAL DISCOMFORT



CLEMENTI

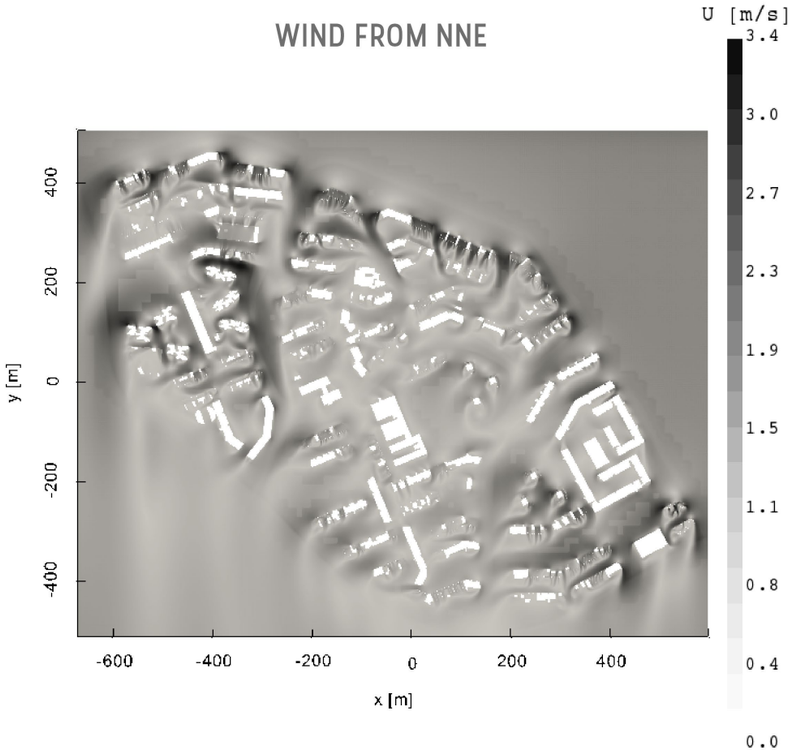
WIND FROM NNE



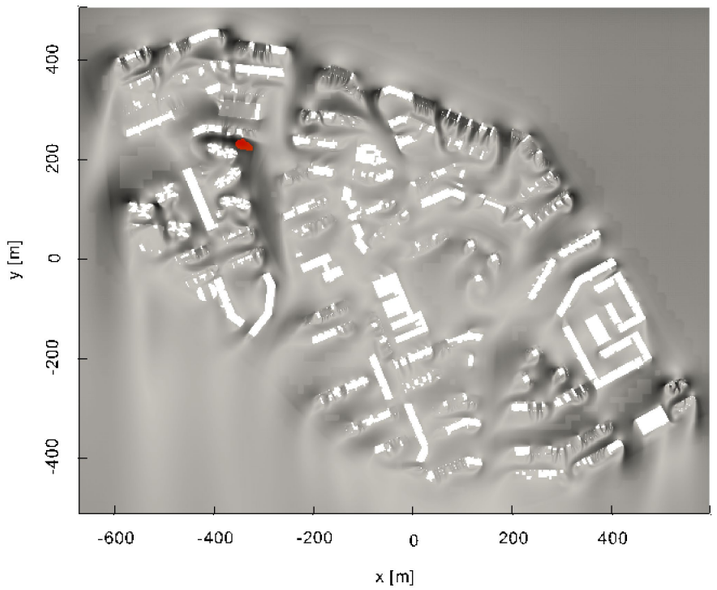


CLEMENTI

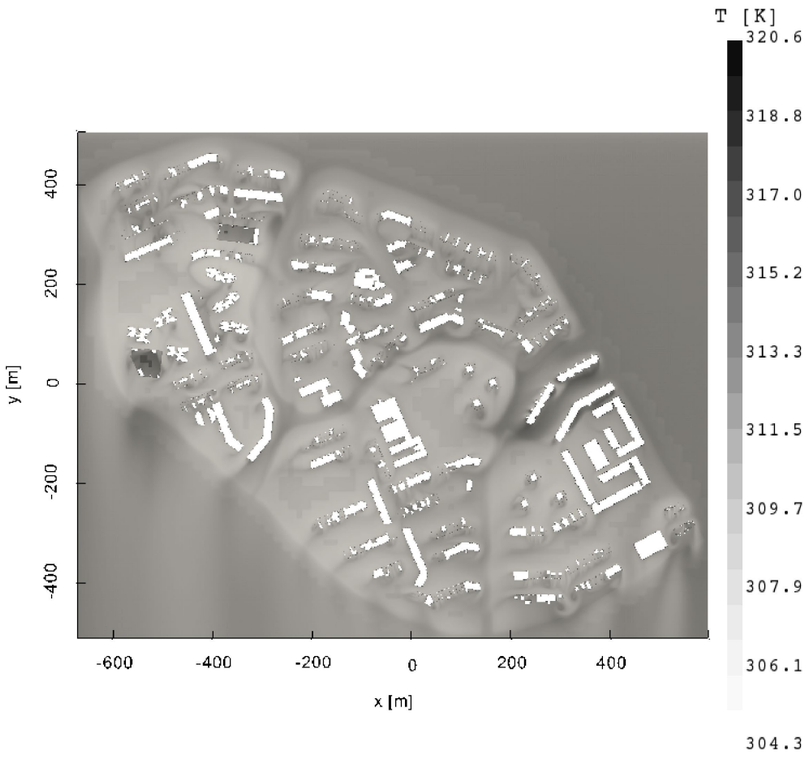
WIND FROM NNE

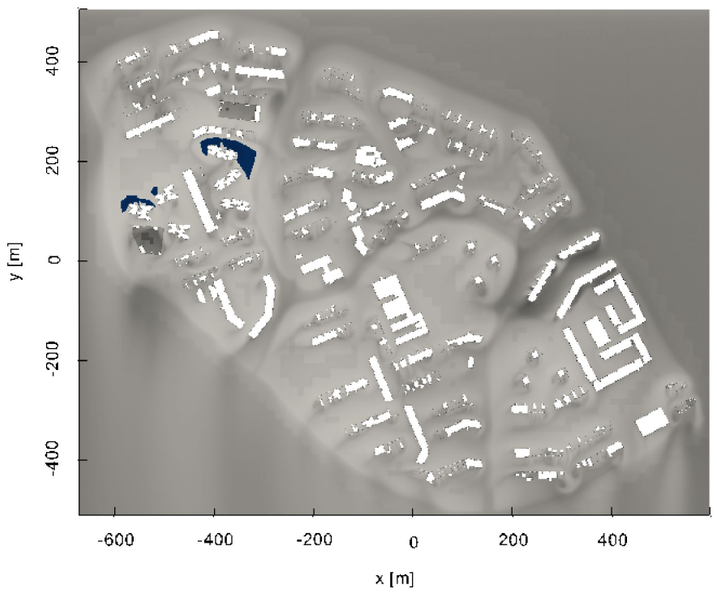


PEDESTRIAN WIND DISCOMFORT



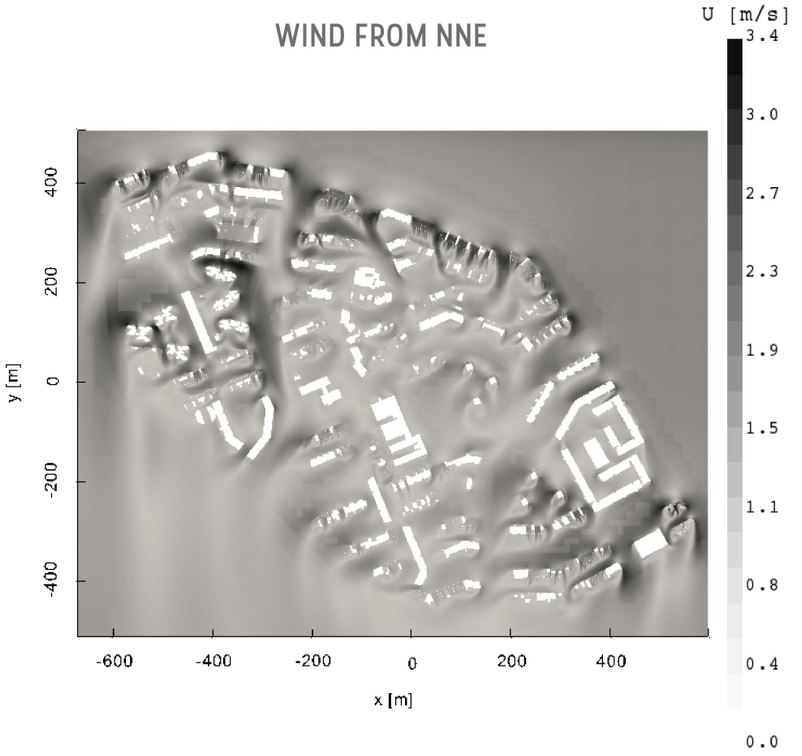
ACCEPTABLE THERMAL COMFORT



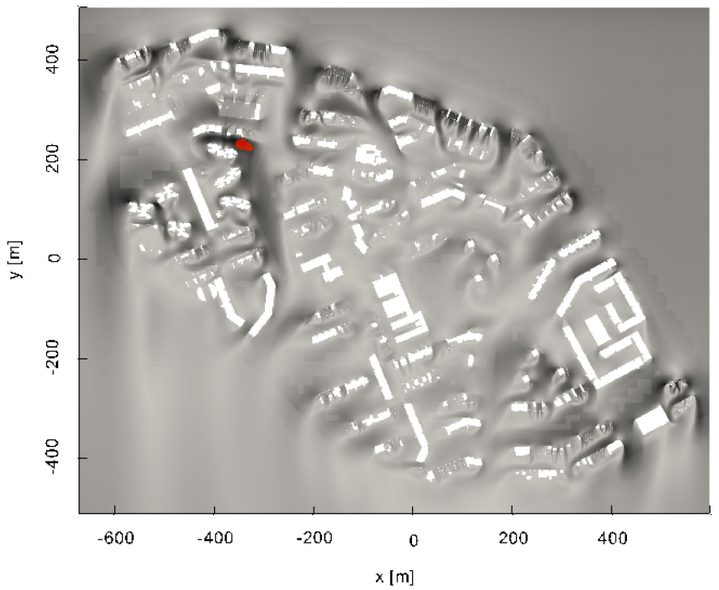


CLEMENTI

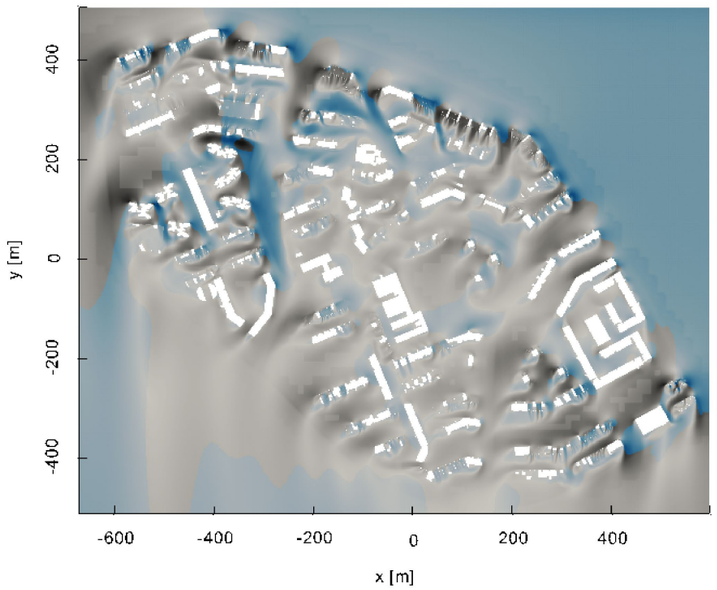
WIND FROM NNE

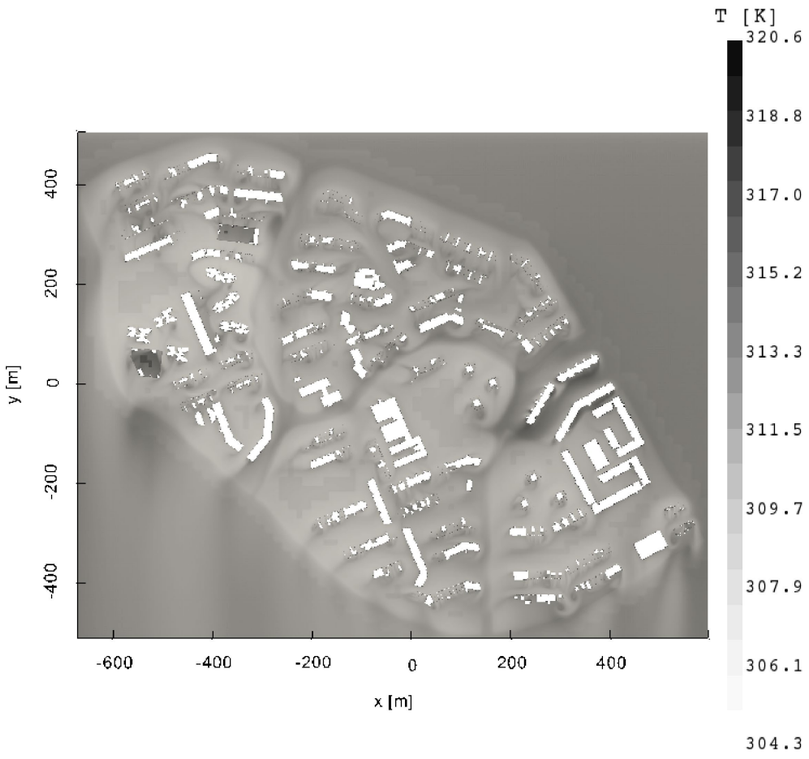


PEDESTRIAN WIND DISCOMFORT

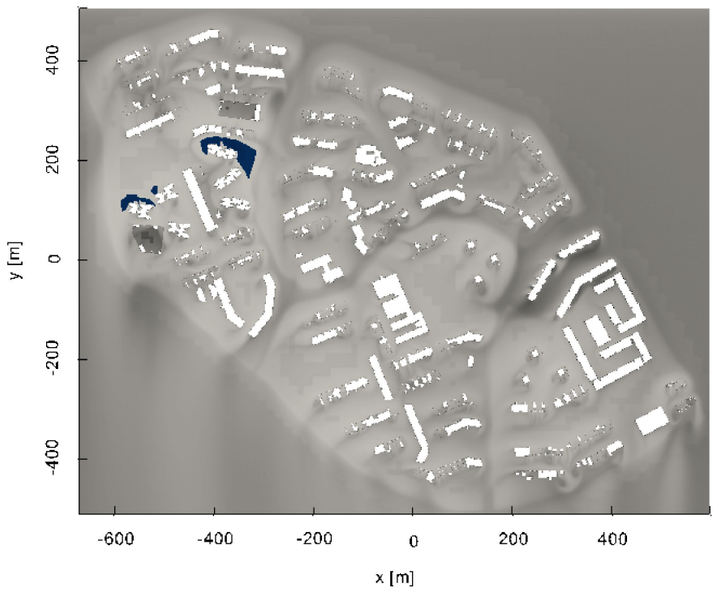


PEDESTRIAN WIND COMFORT

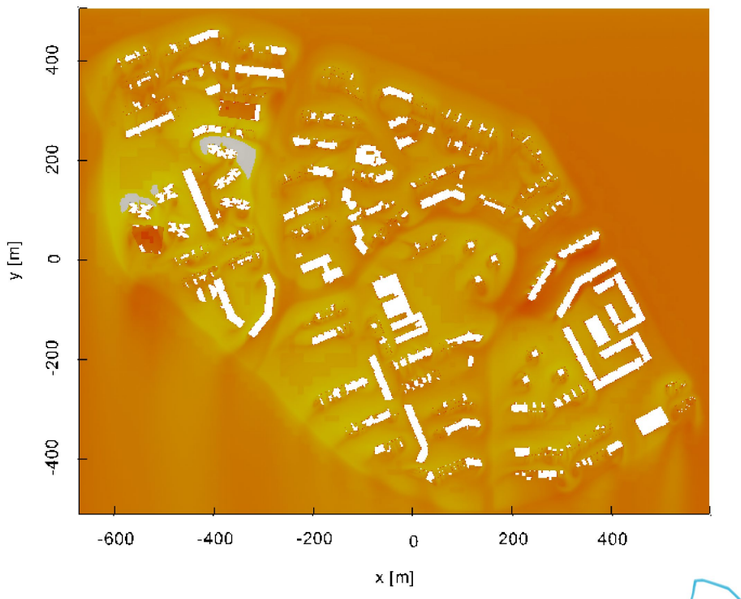




ACCEPTABLE THERMAL COMFORT

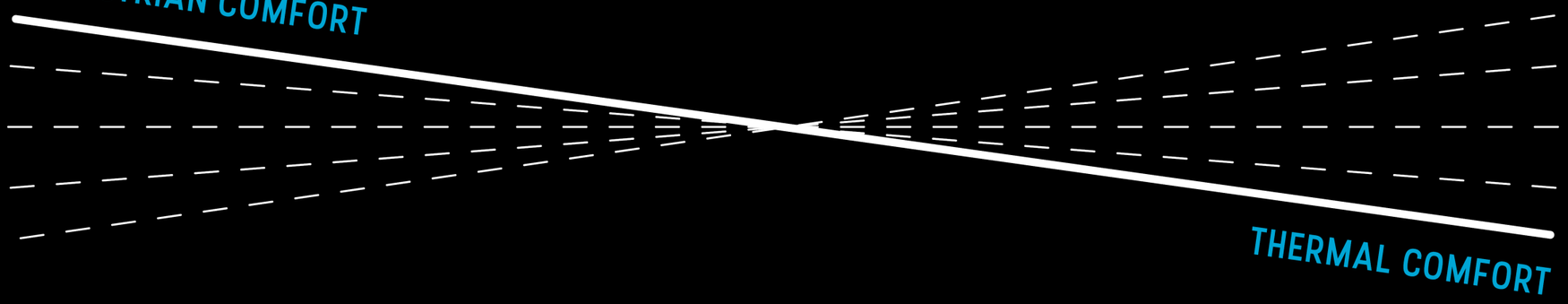


THERMAL DISCOMFORT

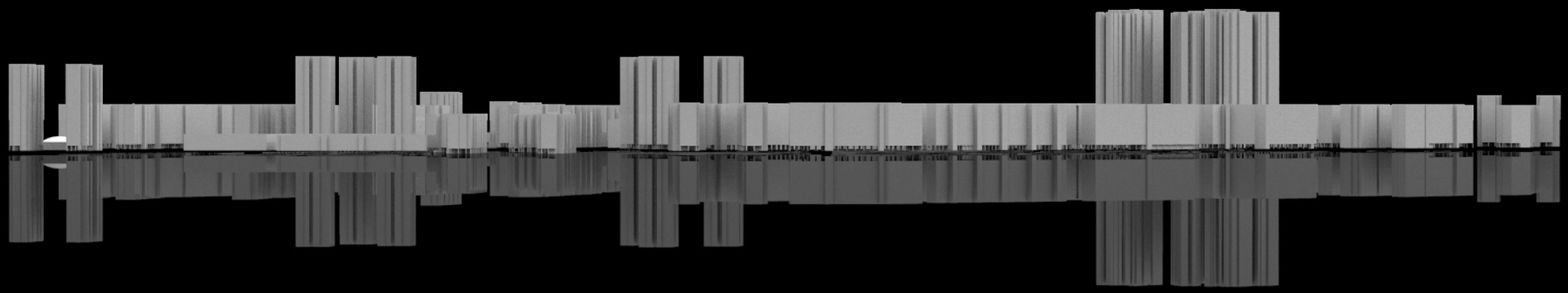


CLEMENTI

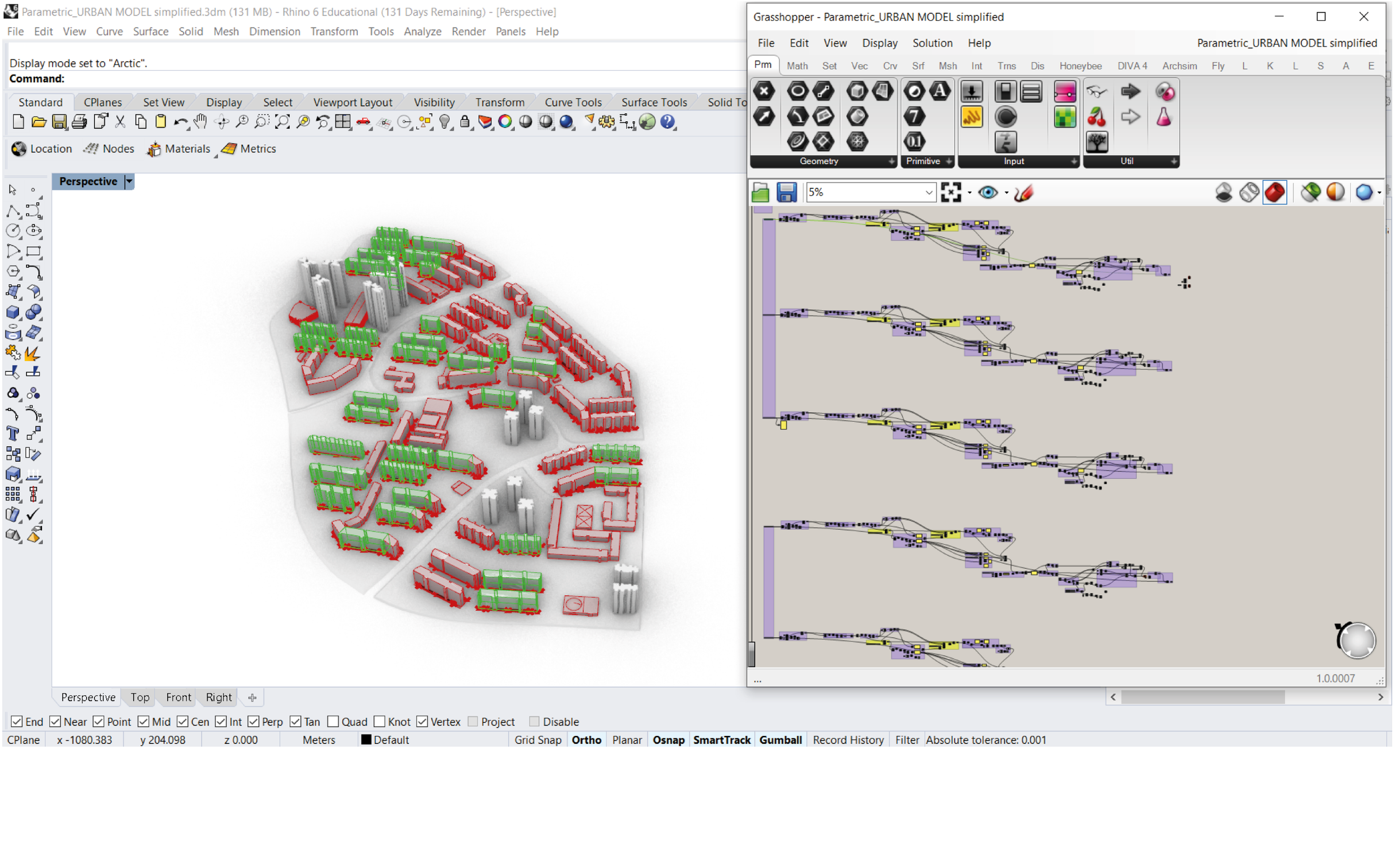
STRONG IMBALANCE



INTERVENTION



PARAMETRIC VOID DECK MODEL – URBAN SCALE



URBAN-SCALE VOID DECK GEOMETRY INTERVENTION

BUILDING GROUPS

BUILDING GROUP 1: buildings perpendicular to wind from N/S

BUILDING GROUP 2: buildings perpendicular to wind from NNE/NE (long blocks)

BUILDING GROUP 5: buildings perpendicular to wind from NW/SE

BUILDING GROUP 3: buildings perpendicular to wind from NNE/NE (short blocks)

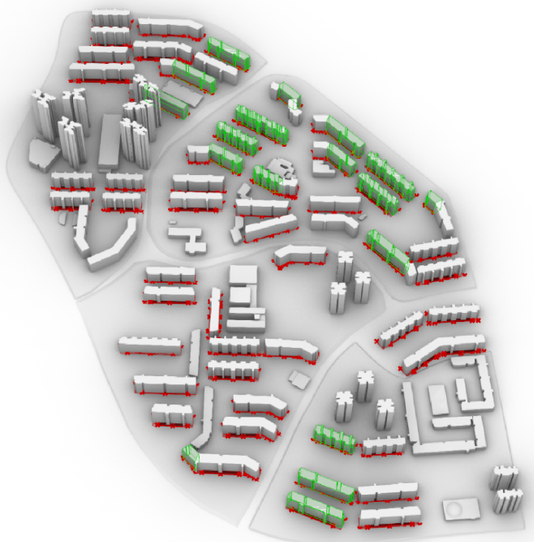
BUILDING GROUP 4: buildings perpendicular to wind from E/W

CLEMENTI

URBAN-SCALE VOID DECK GEOMETRY INTERVENTION

FOCUS BUILDING GROUPS

BUILDING GROUP 1: buildings perpendicular to wind from N/S



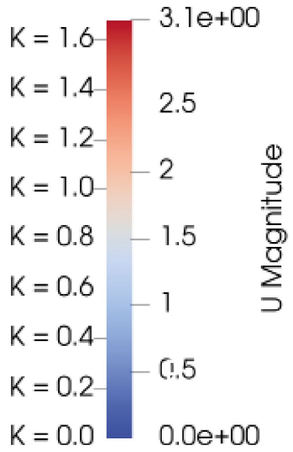
BUILDING GROUP 2: buildings perpendicular to wind from NNE/NE (long blocks)

BUILDING GROUP 5: buildings perpendicular to wind from NW/SE

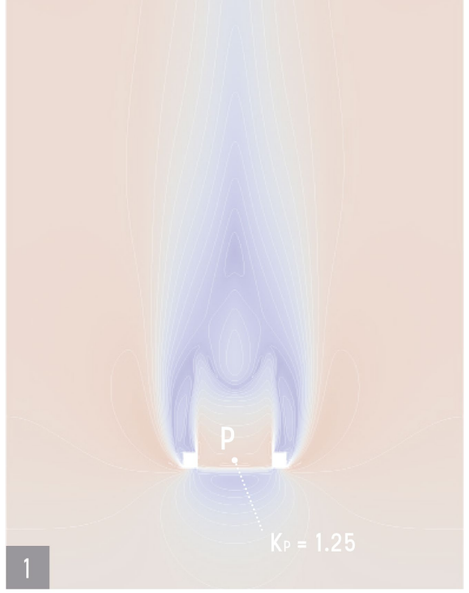
BUILDING GROUP 3: buildings perpendicular to wind from NNE/NE (short blocks)

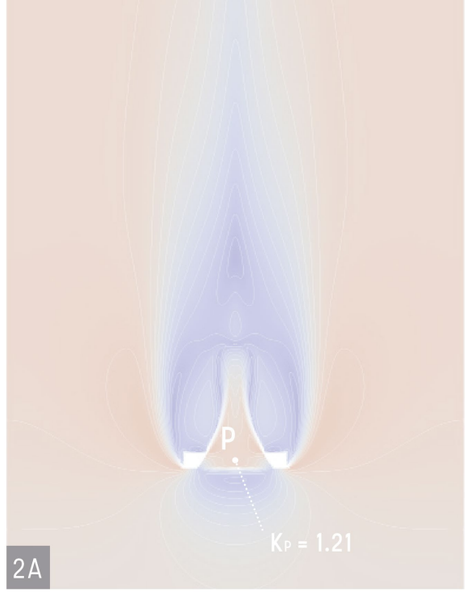
BUILDING GROUP 4: buildings perpendicular to wind from E/W

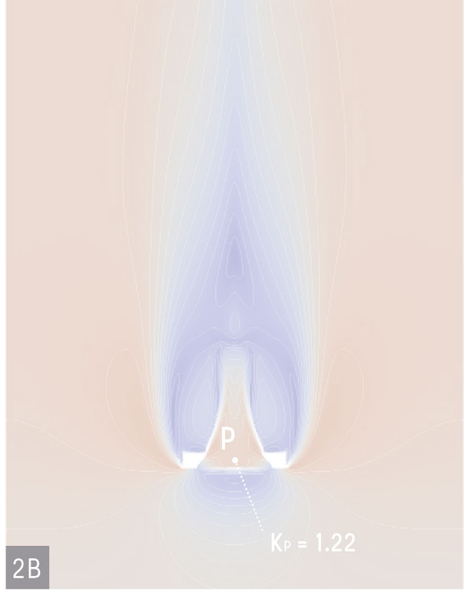
CLEMENTI



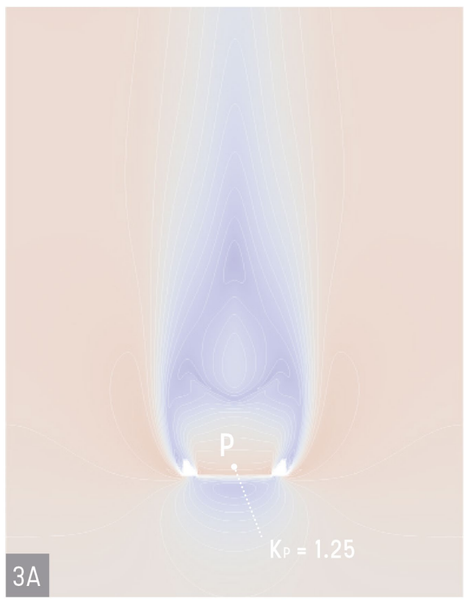
0 AMPLIFICATION FACTOR (plane h=1.75m)

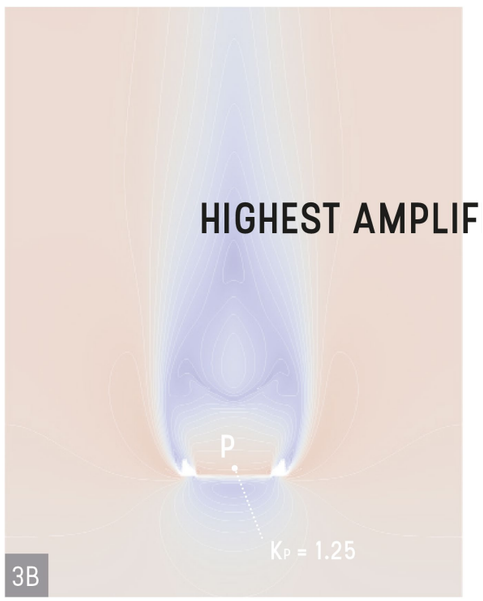


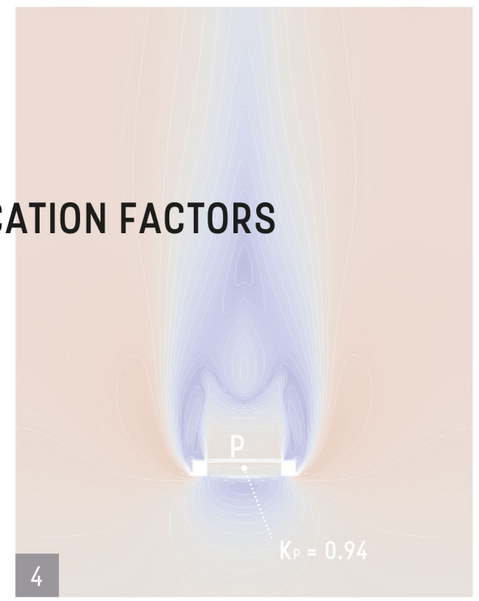


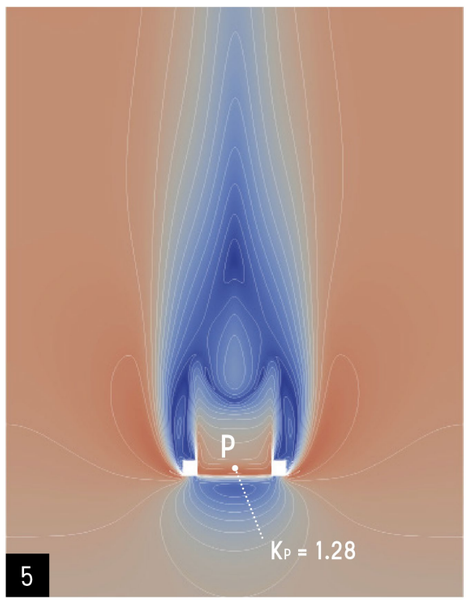


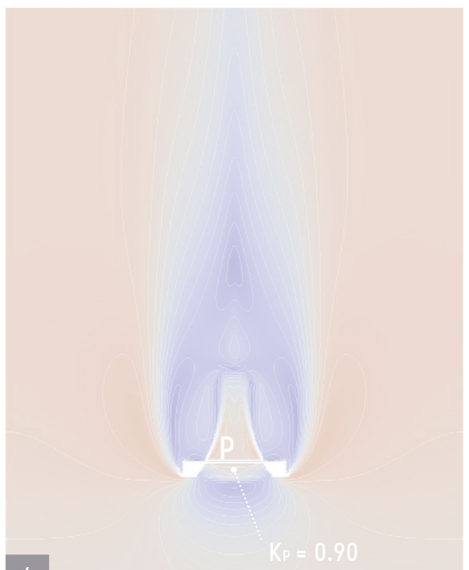
HIGHEST AMPLIFICATION FACTORS

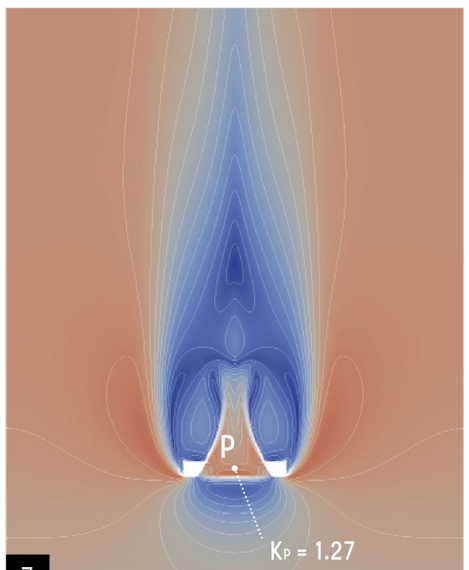


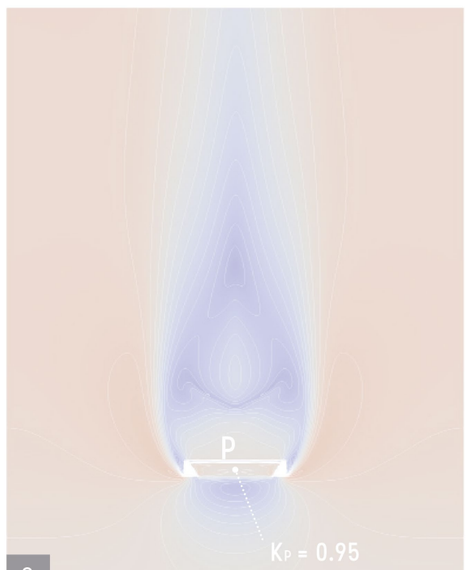


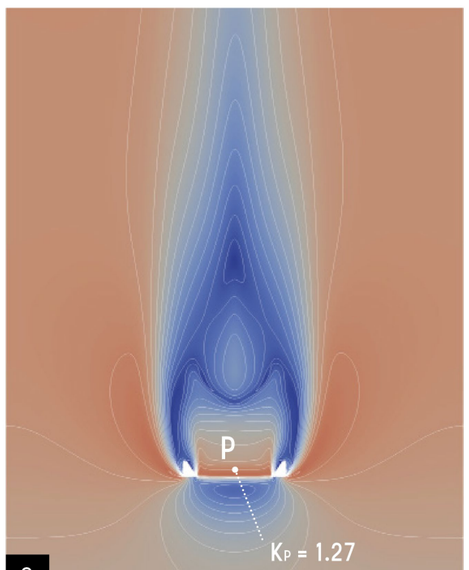


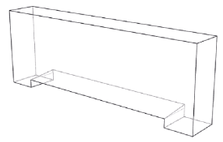
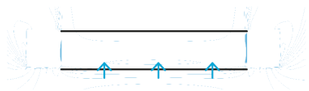
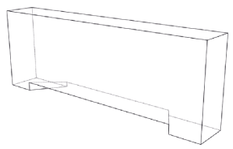
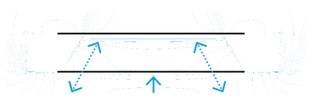
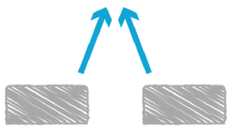
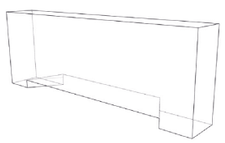
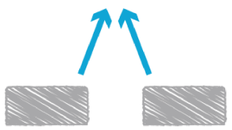
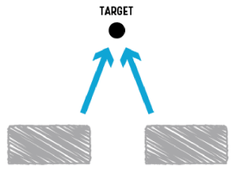
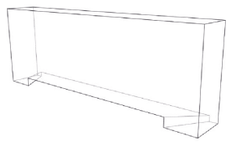
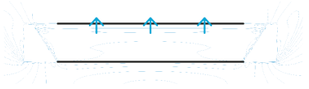
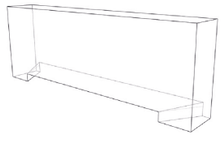
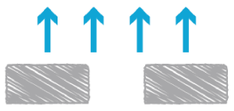




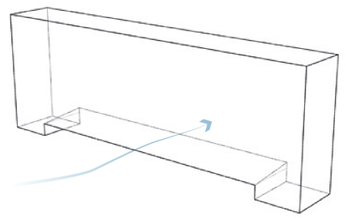




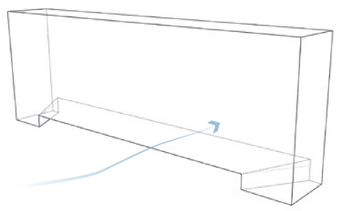


5			steepest velocity gradient upon flow entry in void deck	even spread of accelerated flow along length		K › 1 => urban ventilation ↑ due to presence of building with void deck		adjacent walking route along building
6			steepest velocity gradients at entry and along edges of void deck walls		funnel-shaped area of accelerated flow		K ‹ 1 => urban ventilation ↓ due to presence of building with void deck		not suitable for microclimate enhancement inside void deck
7			steepest velocity gradient right before entry; inside void deck steepest along edges of void deck walls		funnel-shaped area of accelerated flow		K › 1 => urban ventilation ↑ due to presence of building with void deck		direct accelerated flow towards target
8			steepest velocity gradient upon flow exit from void deck; smaller gradient inside void deck		even spread of accelerated flow along length		K ‹ 1 => urban ventilation ↓ due to presence of building with void deck		not suitable for microclimate enhancement inside void deck
9			steepest velocity gradient upon flow entry in void deck		even spread of accelerated flow along length		K › 1 => urban ventilation ↑ due to presence of building with void deck		adjacent walking route along building

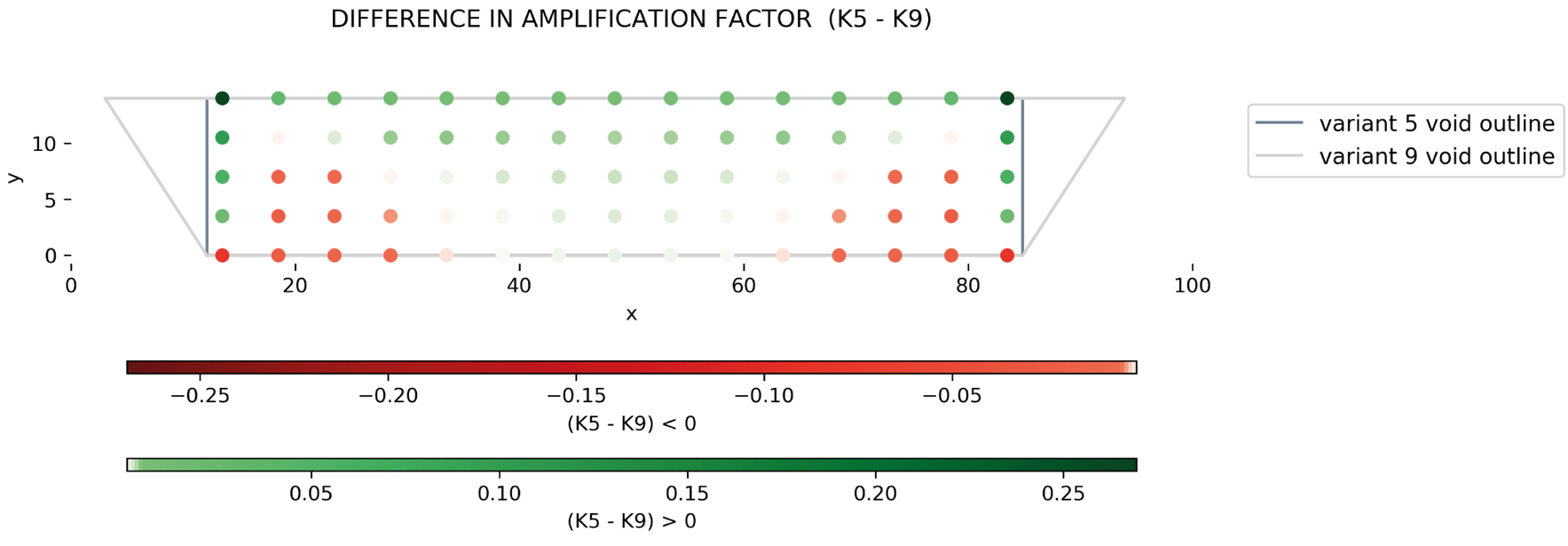
GEOMETRY FOR INTERVENTION



5 vertically diverging void

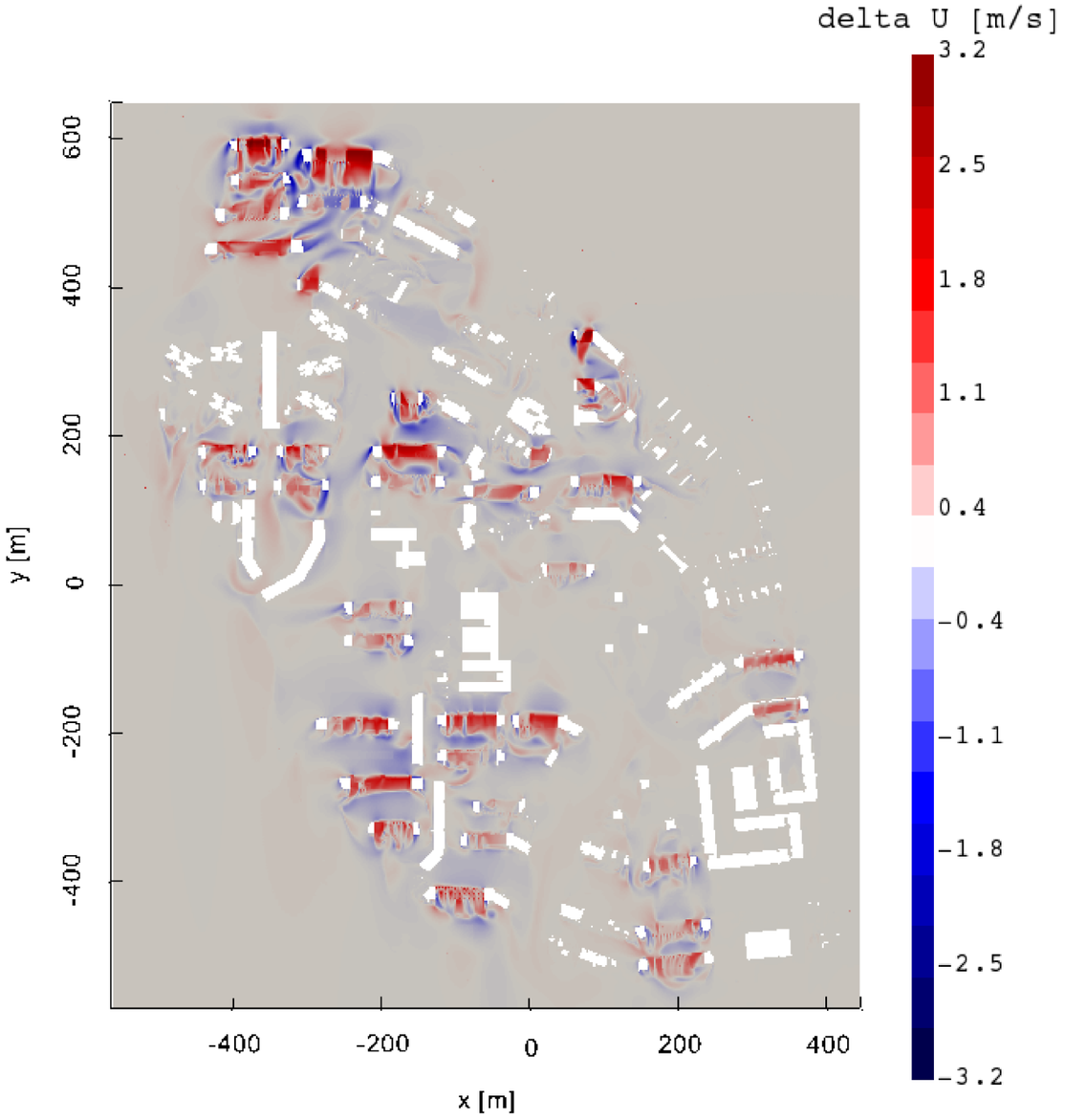


9 horizontally & vertically diverging void

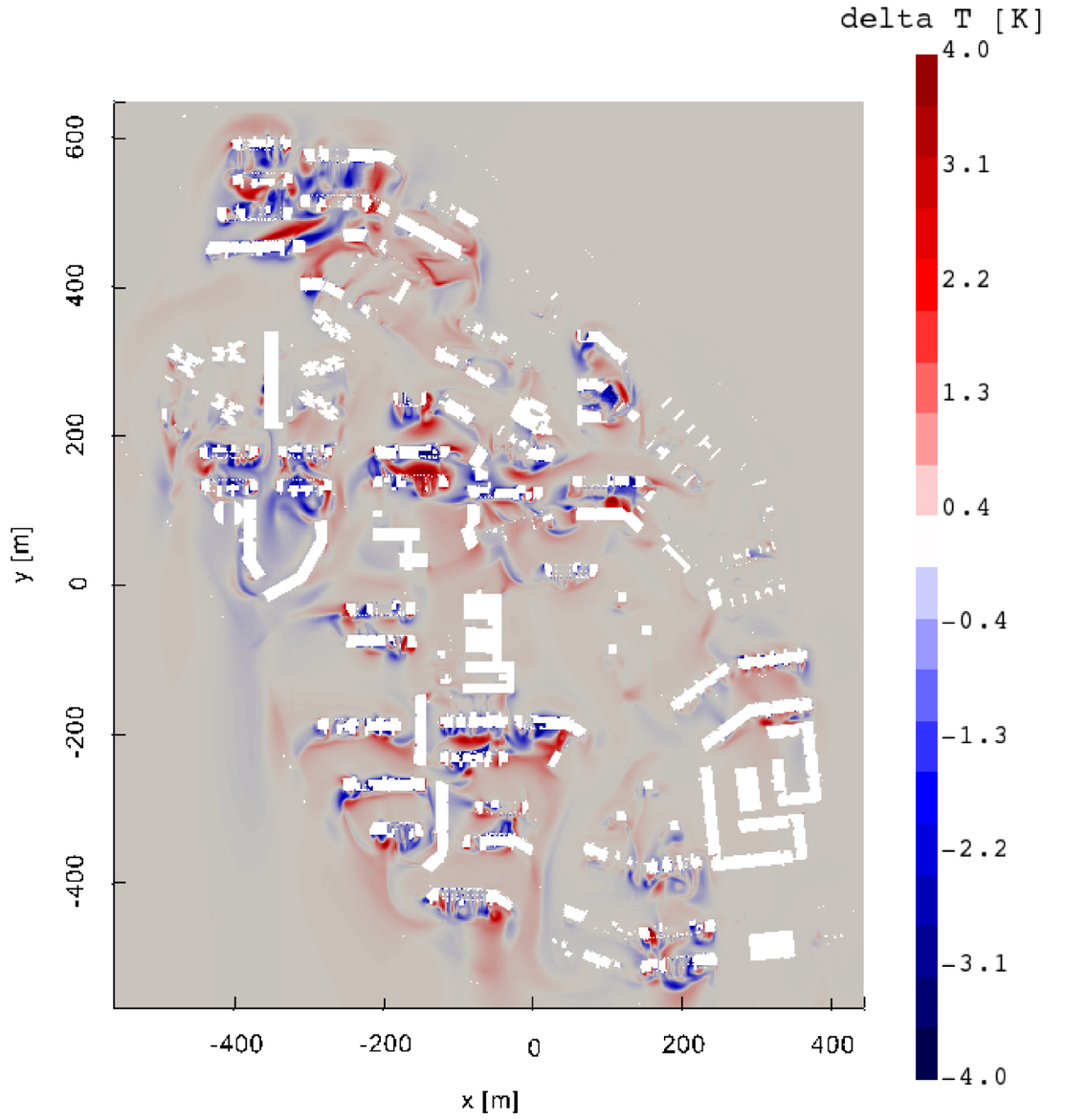


URBAN-SCALE VOID DECK GEOMETRY INTERVENTION

EFFECT ON VELOCITY

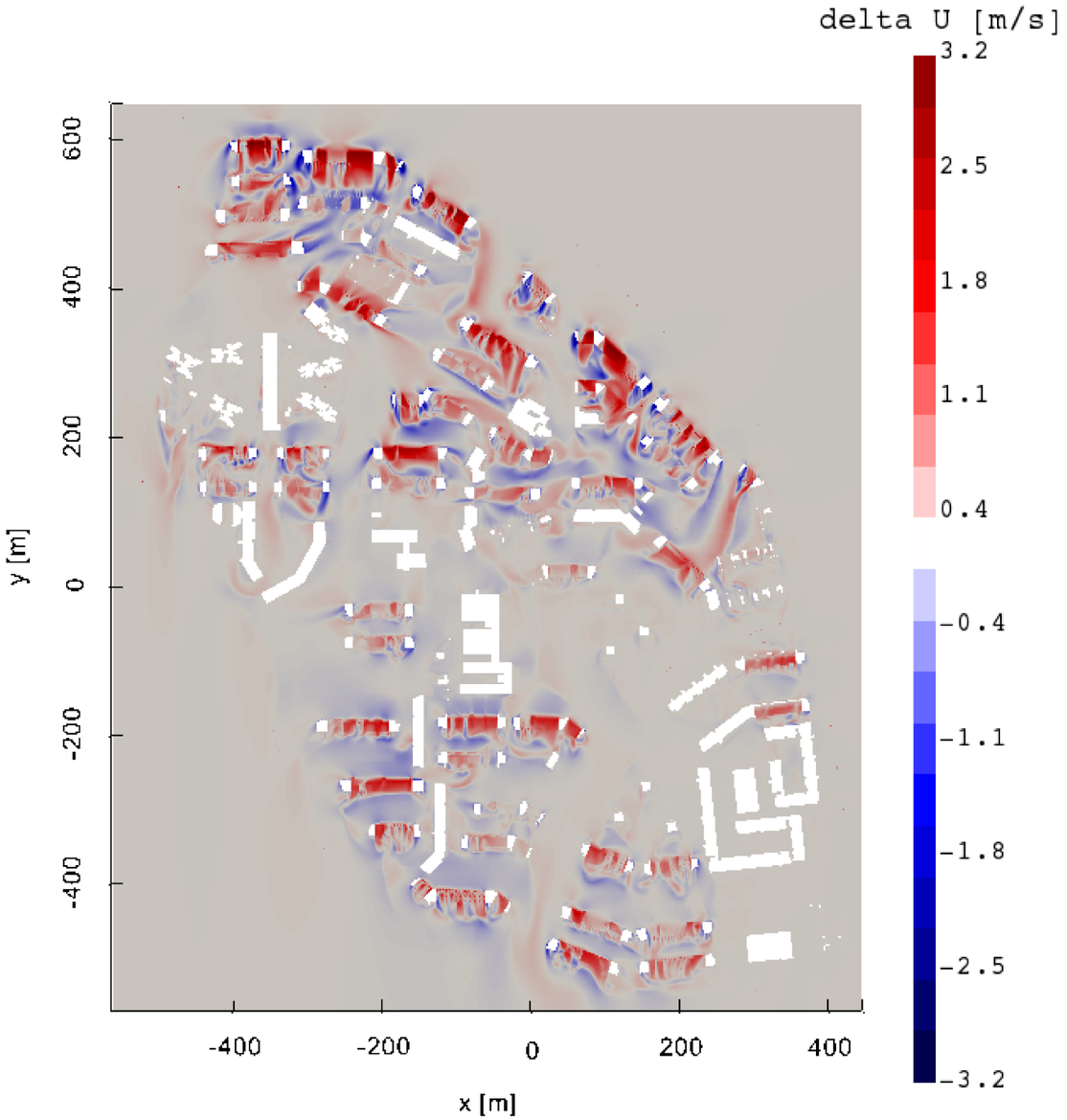


EFFECT ON TEMPERATURE

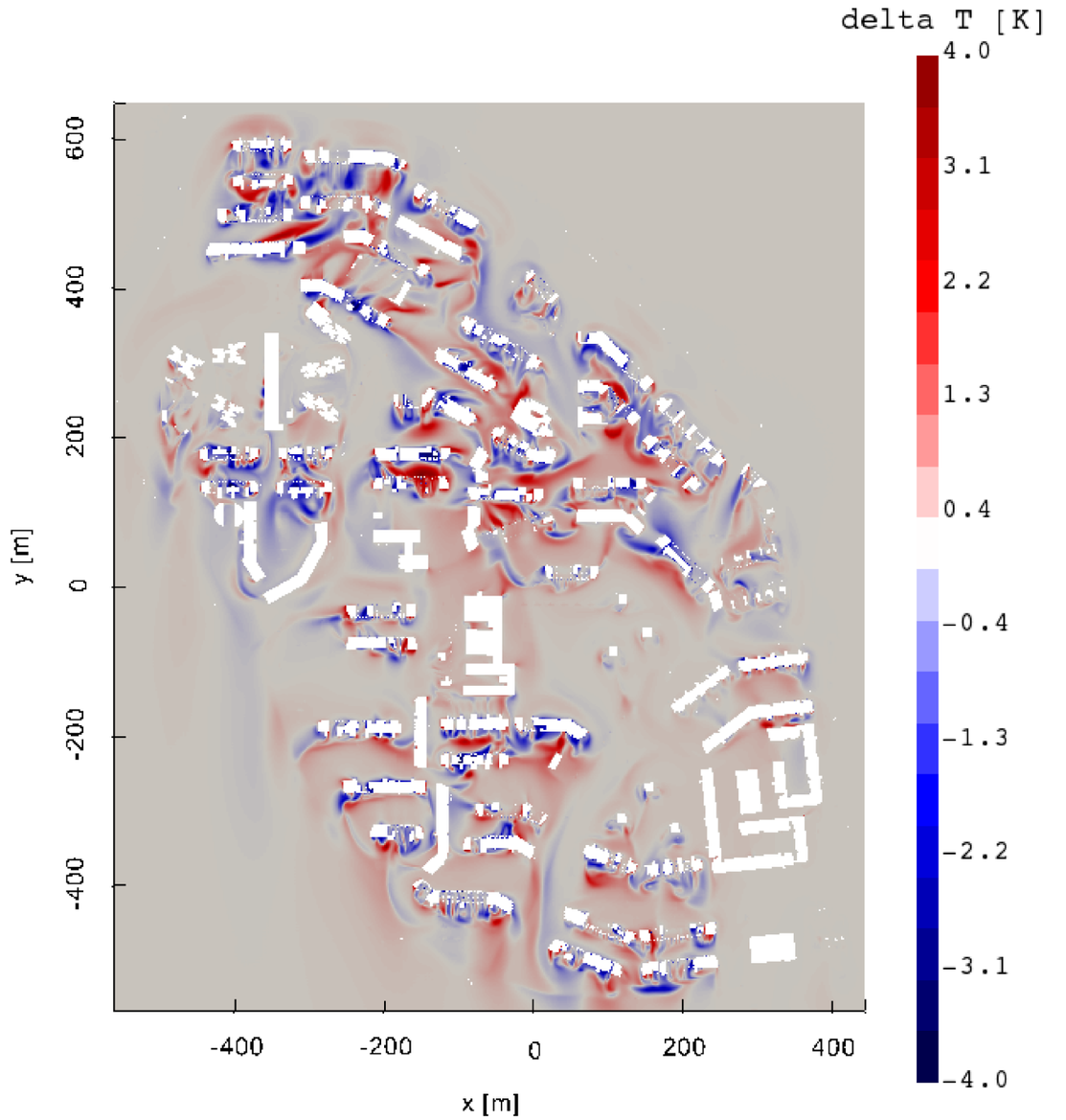


URBAN-SCALE VOID DECK GEOMETRY INTERVENTION

EFFECT ON VELOCITY



EFFECT ON TEMPERATURE



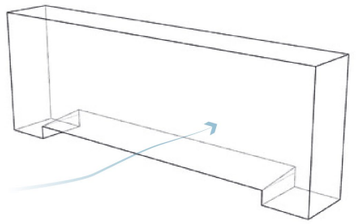
MAIN RESEARCH QUESTION:

How can the geometry design of void decks be optimized to enhance urban ventilation for outdoor thermal comfort in Singapore while ensuring good pedestrian comfort?

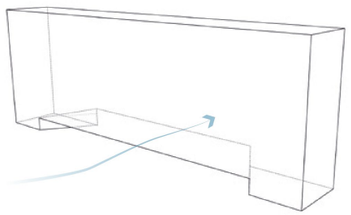
Void decks affect flow pattern, magnitude and direction of wind velocity
=› also temperature distribution
(locally inside void decks & in between buildings)

We can optimize geometry of void decks to amplify wind speed as desired
(all tested geometries except vertically converging void decks showed K › 1
=› good potential for wind speed – and thus convective surface heat transfer – enhancement)

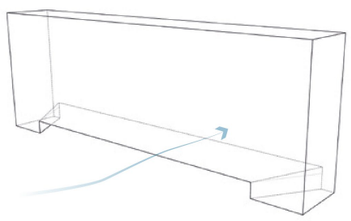
HOW?



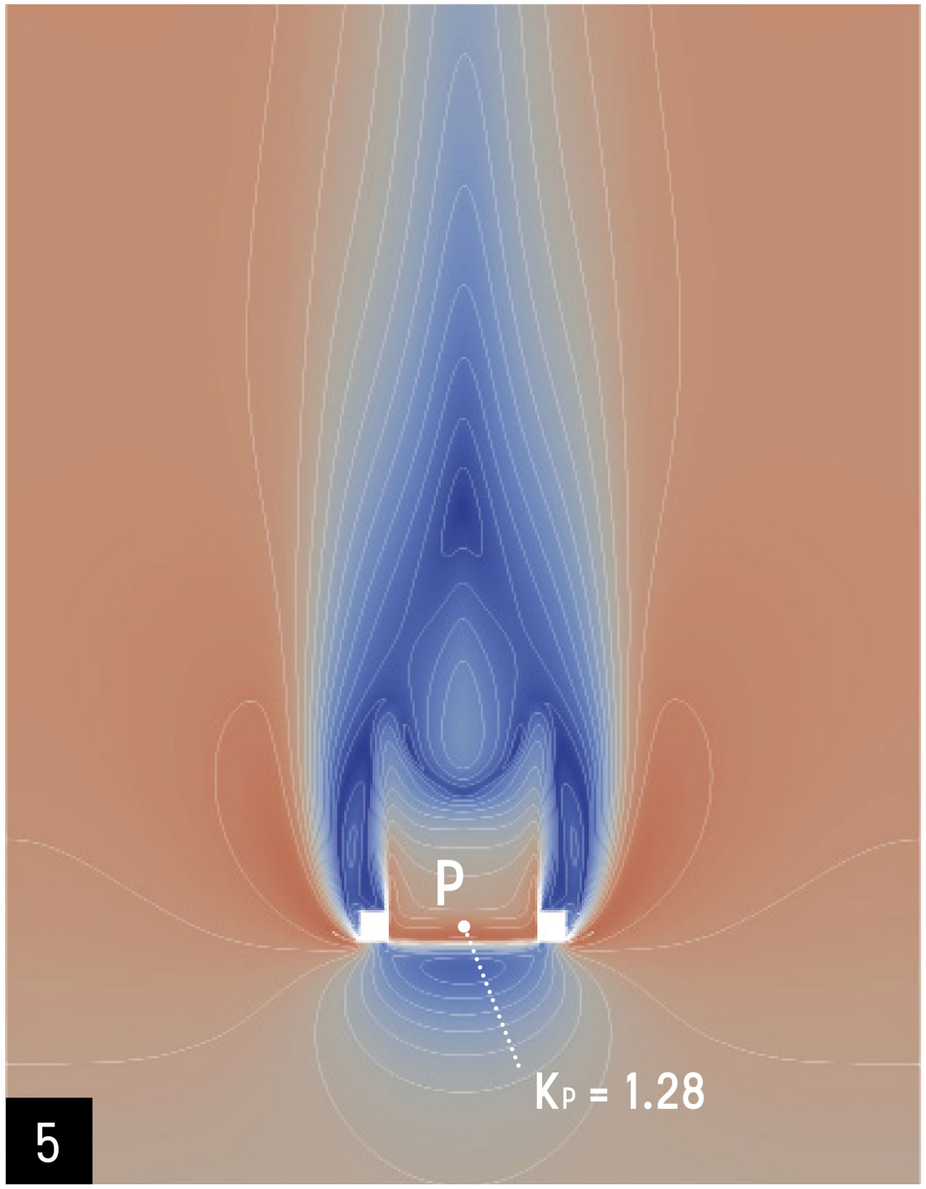
5 vertically diverging void



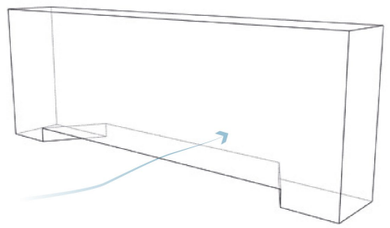
7 horizontally converging & vertically diverging void



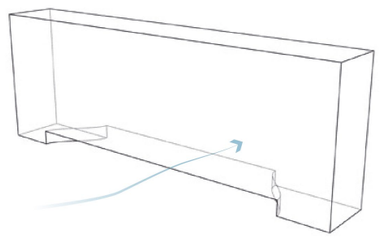
9 horizontally & vertically diverging void



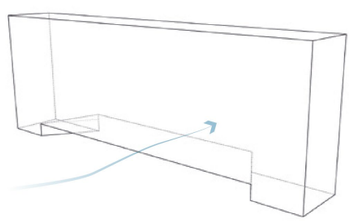
Apply vertically diverging geometry for highest amplification effect in void deck



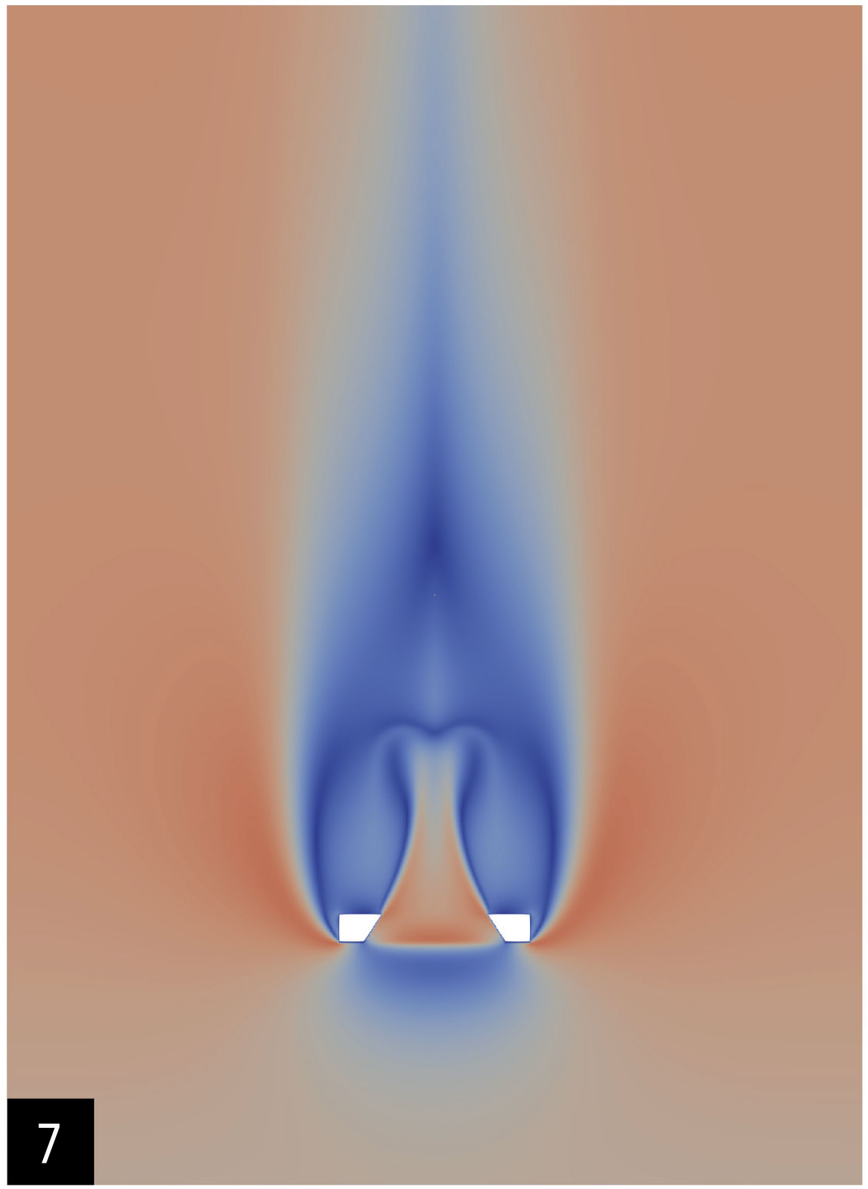
2A horizontally converging void (straight taper)



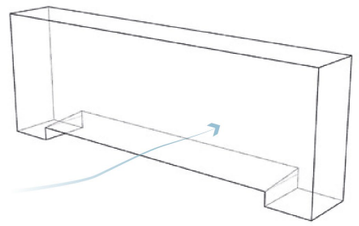
2B horizontally converging void (curved taper)



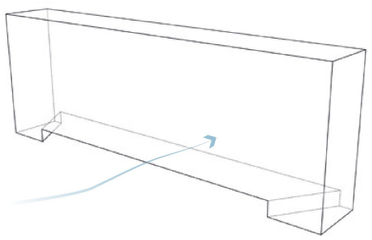
7 horizontally converging & vertically diverging void



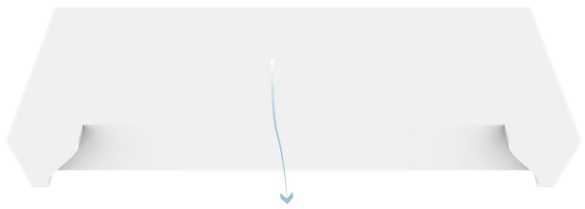
Apply horizontally converging geometry and/or small void deck elements to direct flow towards location with high ventilation demand (e.g. sports field)

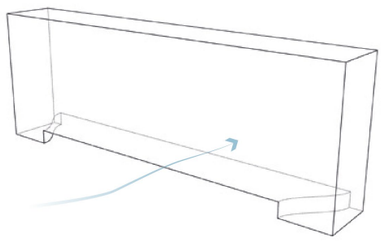


5 vertically diverging void

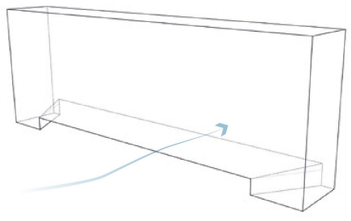


3A horizontally diverging void (straight taper)

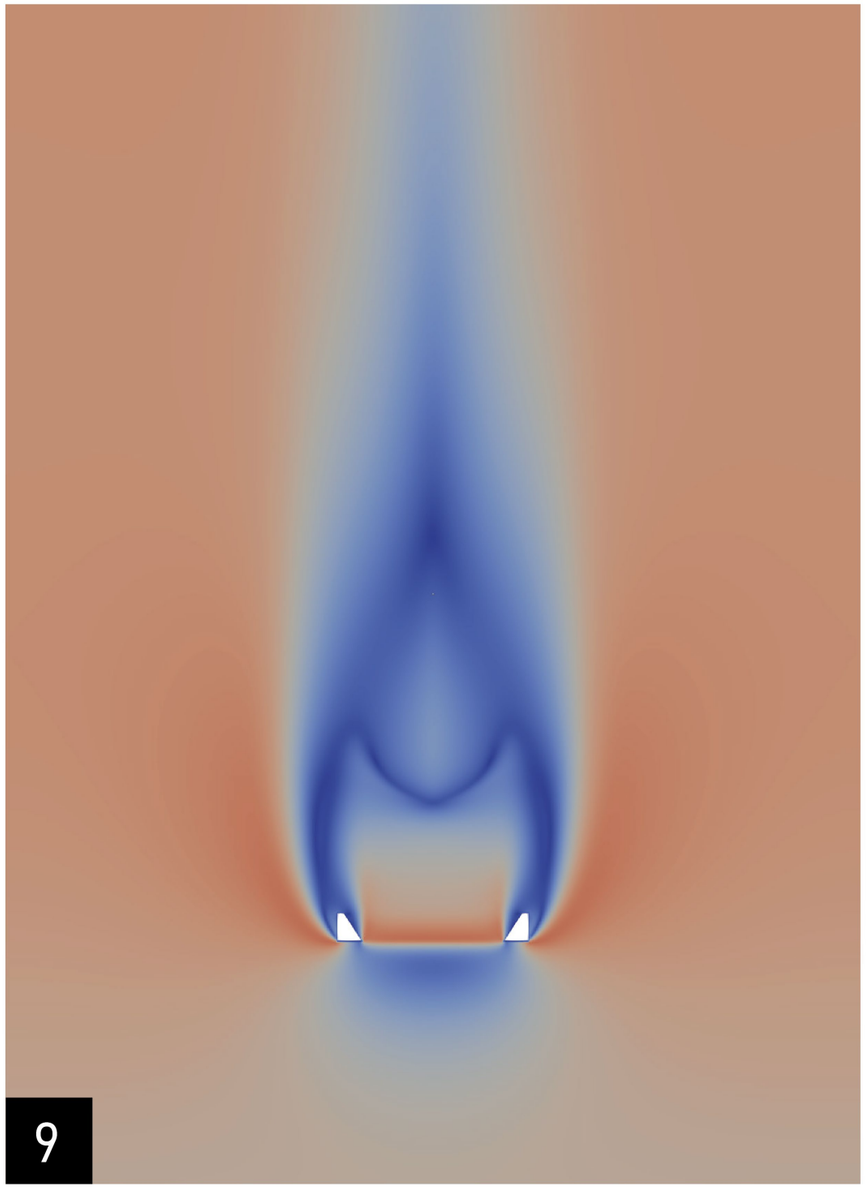




3B horizontally diverging void (curved taper)



9 horizontally & vertically diverging void



Apply horizontally diverging geometry for more evenly spread region of accelerated flow along void length (e.g. adjacent walking routes)

- Apply wind speed–amplifying void deck geometries in combination with other urban cooling strategies to enhance outdoor thermal comfort in SG
(e.g. tall buildings' downdraught effect, evaporative cooling, high-SRI materials)

- Use workflow based on combination of parametric design & CFD simulation tools to test variants and make better wind-informed design decisions

COMPUTATIONAL DESIGN & SIMULATION WORKFLOW FOR URBAN WIND MICROCLIMATE ENHANCEMENT

1

PARAMETRIC SMALL-SCALE TESTS

Perform simple CFD-tests on
parametric single-building model

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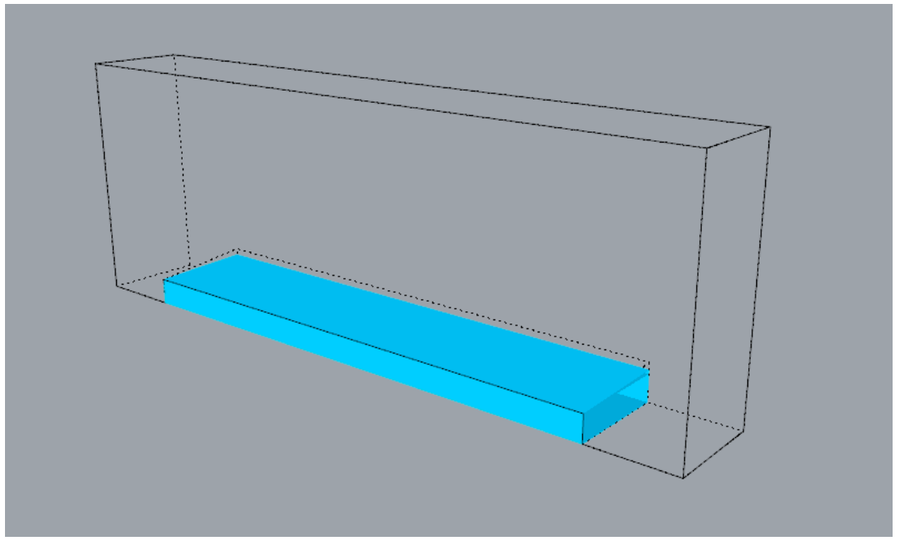

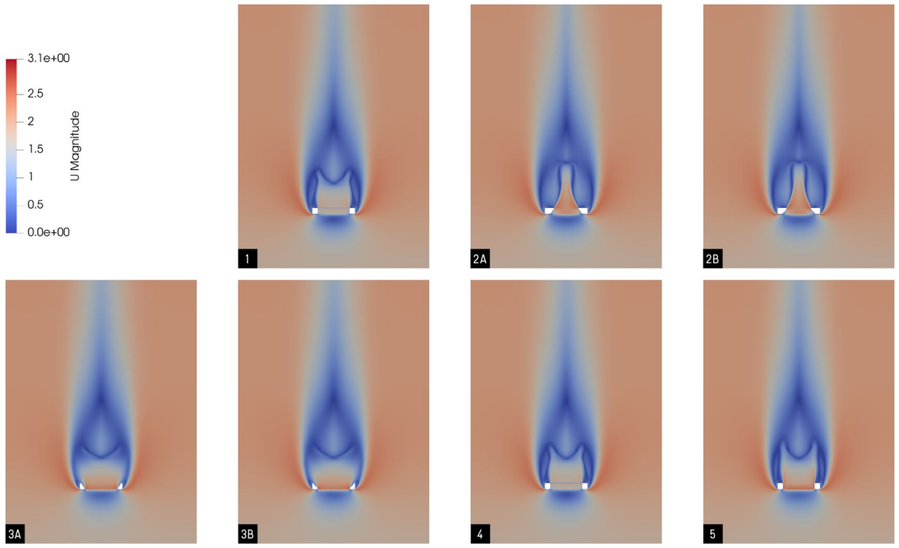

DESCRIPTION OF FLOW PATTERN

	VARIANT	INSIDE VOID DECK	DOWNSTREAM OF VOID DECK	AMPLIFICATION FACTOR AT CENTRE OF VOID DECK	SUGGESTIONS WITH REGARD TO URBAN PLANNING
4		steepest velocity gradient upon flow exit from void deck	even spread of accelerated flow along length	K < 1 => urban ventilation ↓ due to presence of building with void deck	not suitable for microclimate enhancement inside void deck
5		steepest velocity gradient upon flow entry in void deck	even spread of accelerated flow along length	K > 1 => urban ventilation ↑ due to presence of building with void deck	adjacent walking route along building
6		steepest velocity gradients at entry and along edges of void deck walls	funnel-shaped area of accelerated flow	K < 1 => urban ventilation ↓ due to presence of building with void deck	not suitable for microclimate enhancement inside void deck
7		steepest velocity gradient right before entry; inside void deck steepest along edges of void deck walls	funnel-shaped area of accelerated flow	K > 1 => urban ventilation ↑ due to presence of building with void deck	TARGET direct accelerated flow towards target
8		steepest velocity gradient upon flow exit from void deck; smaller gradient inside void deck	even spread of accelerated flow along length	K < 1 => urban ventilation ↓ due to presence of building with void deck	not suitable for microclimate enhancement inside void deck

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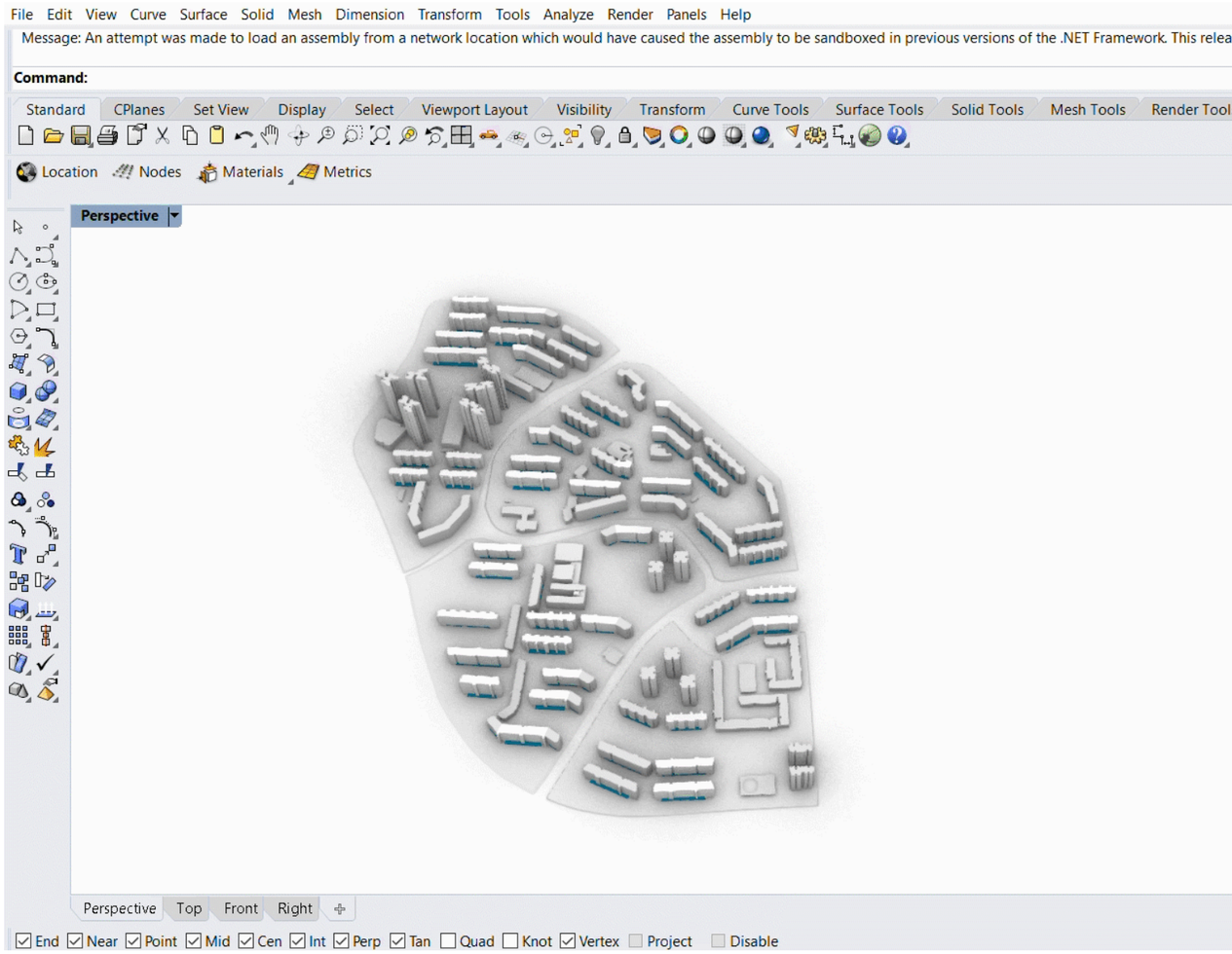
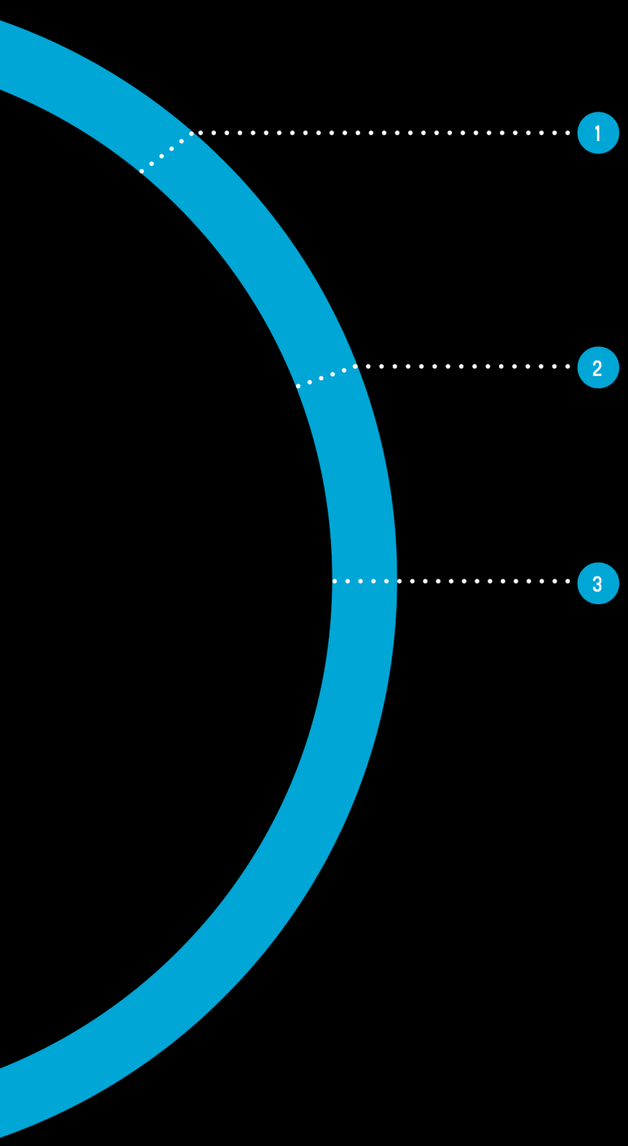


COMPUTATIONAL DESIGN & SIMULATION WORKFLOW FOR URBAN WIND MICROCLIMATE ENHANCEMENT



1

PARAMETRIC SMALL-SCALE TESTS

Perform simple CFD-tests on parametric single-building model

2

PARAMETRIC LARGE-SCALE INTERVENTION

Apply modifications to building groups in parametric urban model

3

URBAN INTERVENTION CFD-SIMULATION

Perform urban intervention CFD-simulation and analyze results

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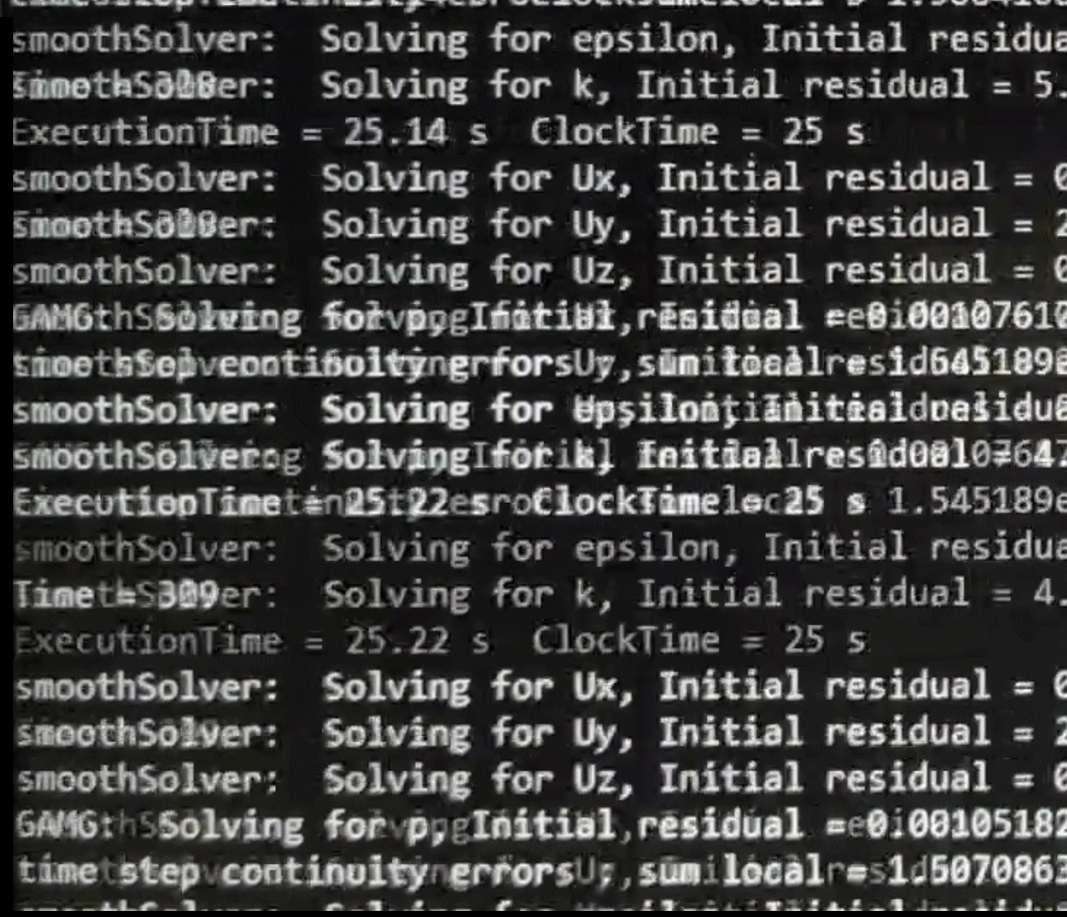

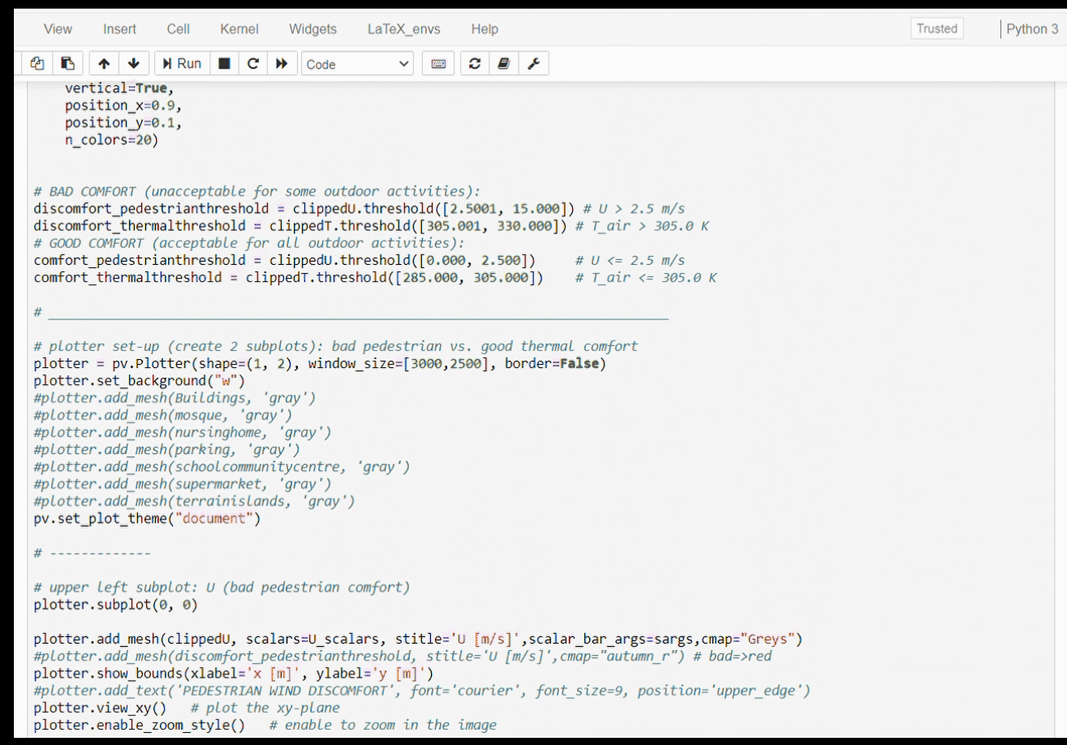

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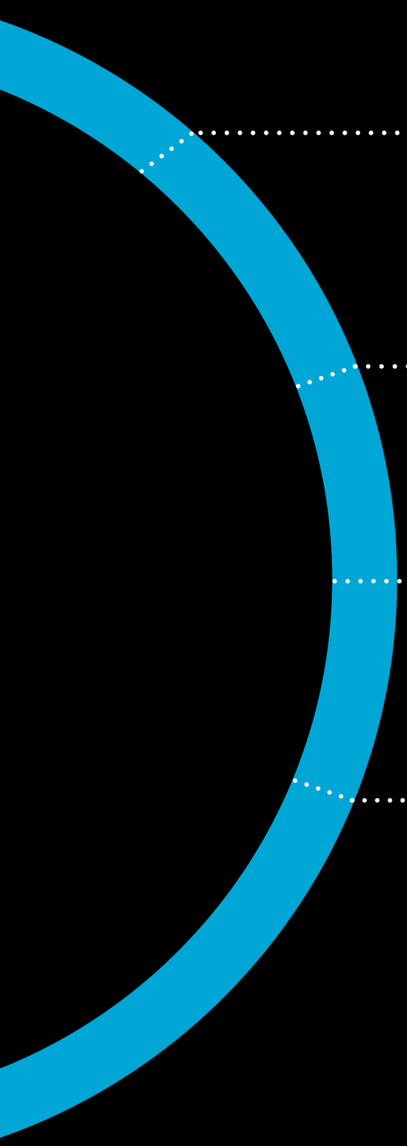

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NON-PARAMETRIC LOCAL INTERVENTION

Apply (non-parametric) modification at particular location based on results from small-scale tests and specific activity comfort requirements

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CURRENT ACTIVITY PATTERN

DESCRIPTION OF FLOW PATTERN

VARIANT	INSIDE VOID DECK	DOWNSTREAM OF VOID DECK	AMPLIFICATION FACTOR AT CENTRE OF VOID DECK	SUGGESTIONS WITH REGARD TO URBAN PLANNING
4	steepest velocity gradient upon flow exit from void deck	even spread of accelerated flow along length	K < 1 => urban ventilation ↓ due to presence of building with void deck	not suitable for microclimate enhancement inside void deck
5	steepest velocity gradient upon flow entry in void deck	even spread of accelerated flow along length	K > 1 => urban ventilation ↑ due to presence of building with void deck	adjacent walking route along building
6	steepest velocity gradients at entry and along edges of void deck walls	funnel-shaped area of accelerated flow	K < 1 => urban ventilation ↓ due to presence of building with void deck	not suitable for microclimate enhancement inside void deck
7	steepest velocity gradient right before entry; inside void deck steepest along edges of void deck walls	funnel-shaped area of accelerated flow	K > 1 => urban ventilation ↑ due to presence of building with void deck	direct accelerated flow towards target
8	steepest velocity gradient upon flow exit from void deck; smaller gradient inside void deck	even spread of accelerated flow along length	K < 1 => urban ventilation ↓ due to presence of building with void deck	not suitable for microclimate enhancement inside void deck

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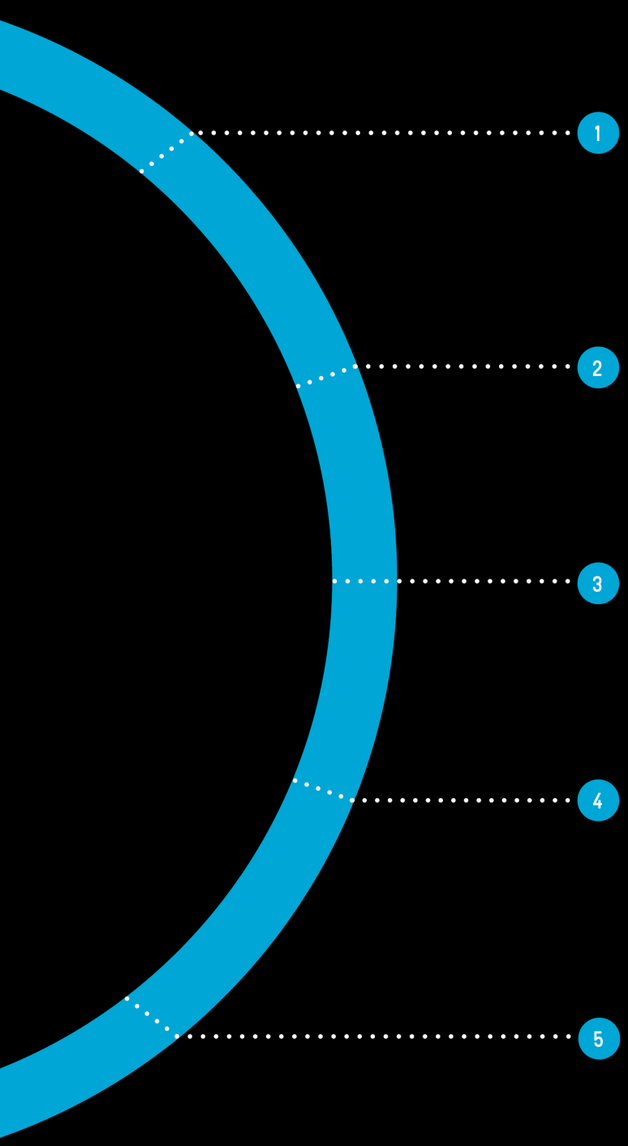

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LOCAL INTERVENTION CFD-SIMULATION

Perform local intervention CFD-simulation and evaluate

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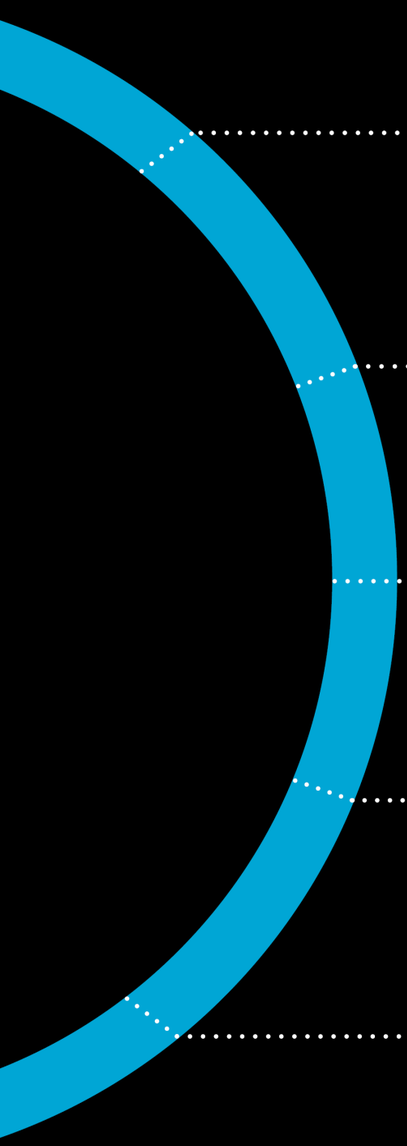

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Demonstrated workflow also applicable in optimization process of other building features that may affect the urban wind microclimate (e.g. canopies, building podia)