GEOB 401 - Project 3E:

Modelling Turbulence in a Street Canyon

[redacted]

Problem Statement

"To investigate the effect of canyon aspect ratio of an idealized canyon on flow patterns using ENVI-met software"

- Qualitatively manipulate street canyon aspect ratios to examine flow regimes relating to empirical turbulent models
- Effects and implications of pollution dispersion in the context of canyon turbulence

Outline

1. Background of ENVI-met software
2. Turbulence in the Urban Canopy Layer
3. Predictions
4. Our model
5. Results & Discussion
6. Applications of urban canyon modelling
7. Problems and limitations of ENVI-met
8. Conclusions
9. References

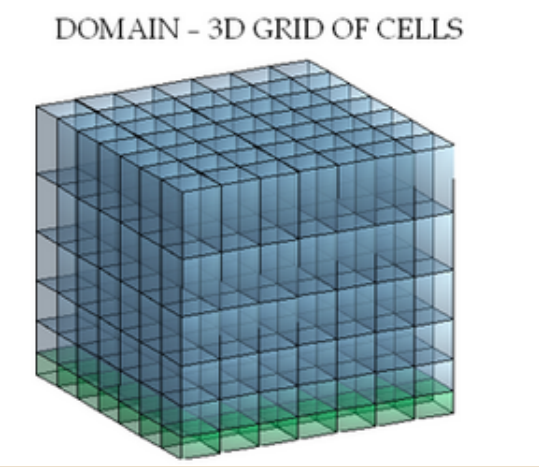
1.What is ENVI-met?

Program Background

- Developed in 1993 by Dr. Michael Bruse
- ENVI-met provides services for investors, businesses, urban planners, architects and scientists
- Used worldwide in over 147 countries with over 4000 simulations runs

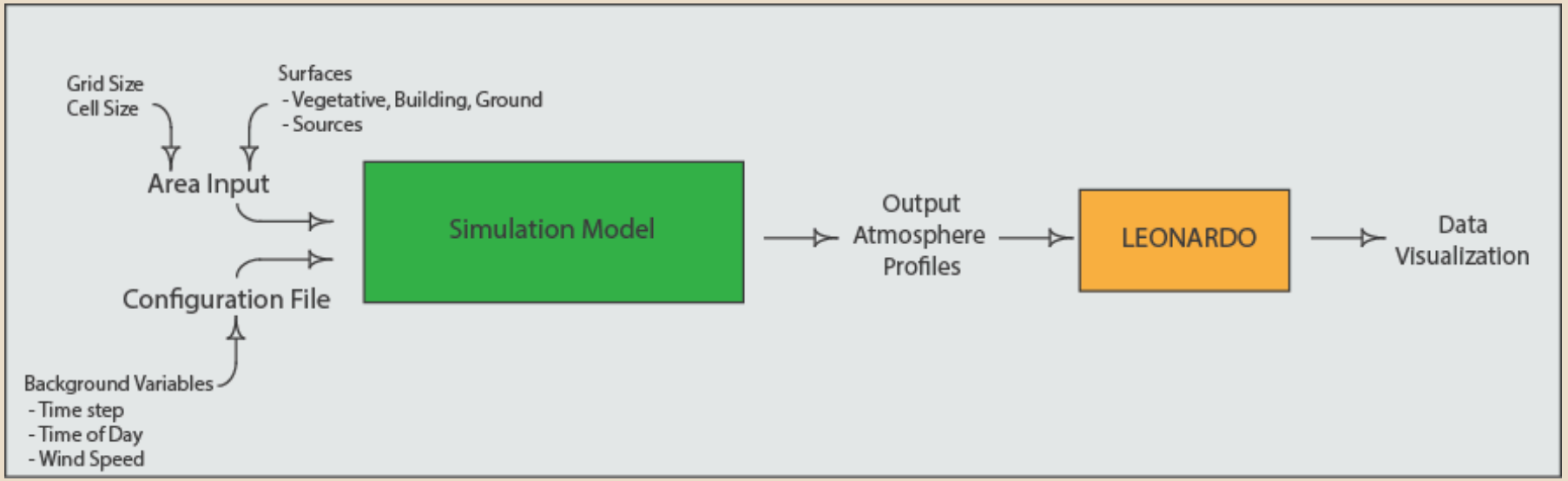
Numerical Model

- Computational model solving differential equations for a given domain over a defined time period
- Allows theoretical modeling of scenarios that can be visualized in 2D or 3D pictorial form



Source: Boštjan Grašič, Primož Mlakar and Marija Zlata Božnar (2011).

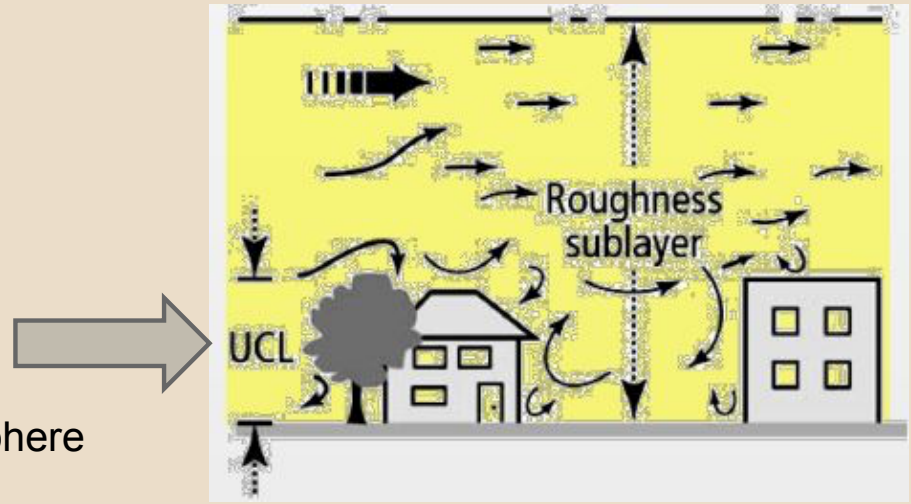
ENVI-met Data Flow - Flowchart



- Simulation
  - Data resolution limited by grid basis
  - Iterative time interval selected
- Leonardo - data visualization

2. Turbulent Processes in the UCL

- Surface to mean building height
- Includes urban street canyons
- Affected by mean wind (pressure gradient) and roughness elements



Source: Christen, *Lecture 3*: Urban Atmosphere

Turbulence in the UCL

- Turbulent production
  - Mostly mechanical in UCL
  - Caused by pressure/velocity differences (form drag)
  - Mechanical energy converted into turbulence through eddy formation (sweeps and ejections)

- Turbulent Intensity
  - Kinetic energy used for turbulent exchange
  - Related to average deviation of all components from main flow

Turbulence in the UCL

Mechanical Energy + Pressure Change = Turbulence

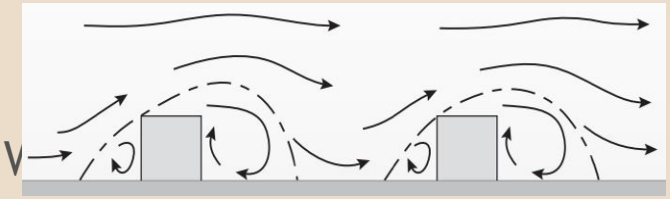
(Mean Flow) (Roughness Elements)

(Eddying)

3. Prediction of Flow Regimes

Canyon Aspect Ratio should affect flow regime of turbulence...

- Isolated Roughness Flow



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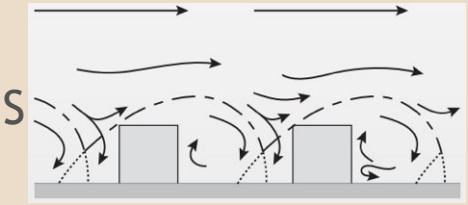

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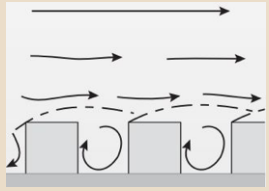
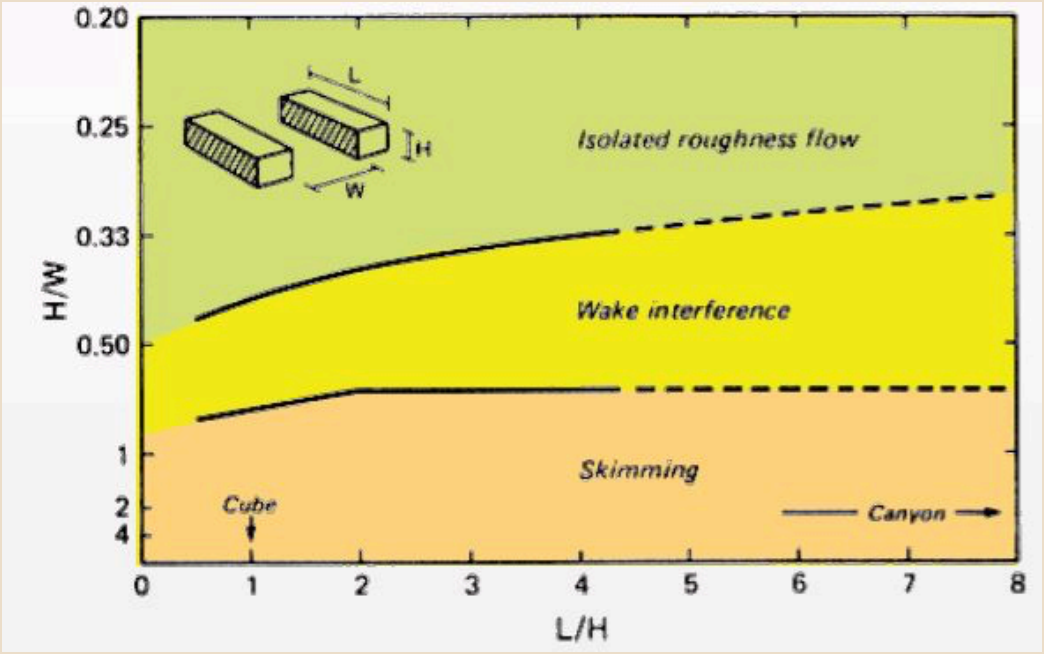


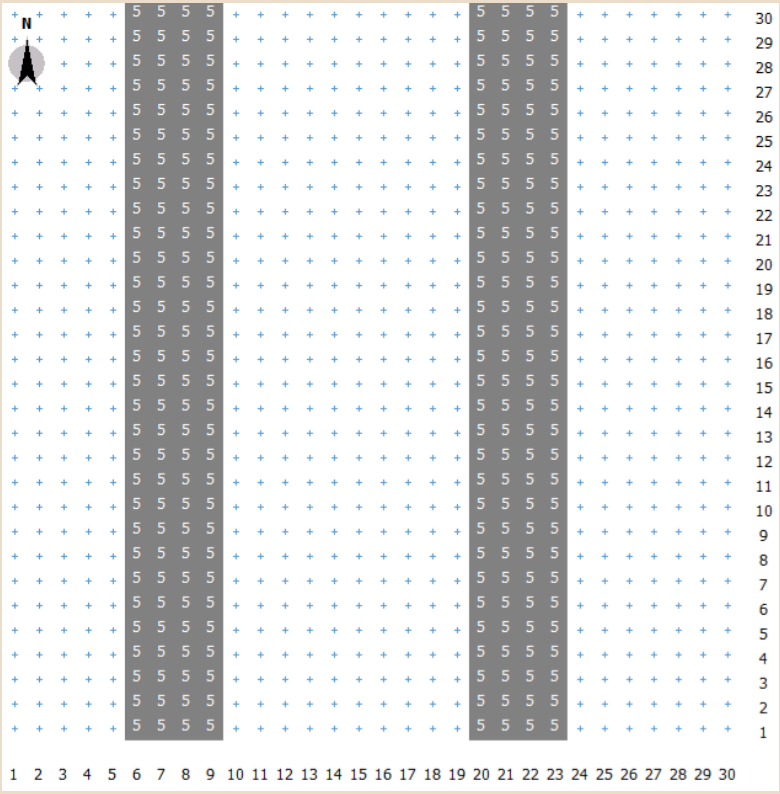


Source: Christen, *Lecture 12:* Flow around buildings and in the urban canopy

4. Our Model

Configuration:

- Simplified cross-canyon flow
- Demonstrate basic principles of canyon turbulence and flow regimes
- Only considers local effects, rather than in large urban context
- Steady state model - all variables are controlled except building width (canyon aspect ratio)



Input Characterization

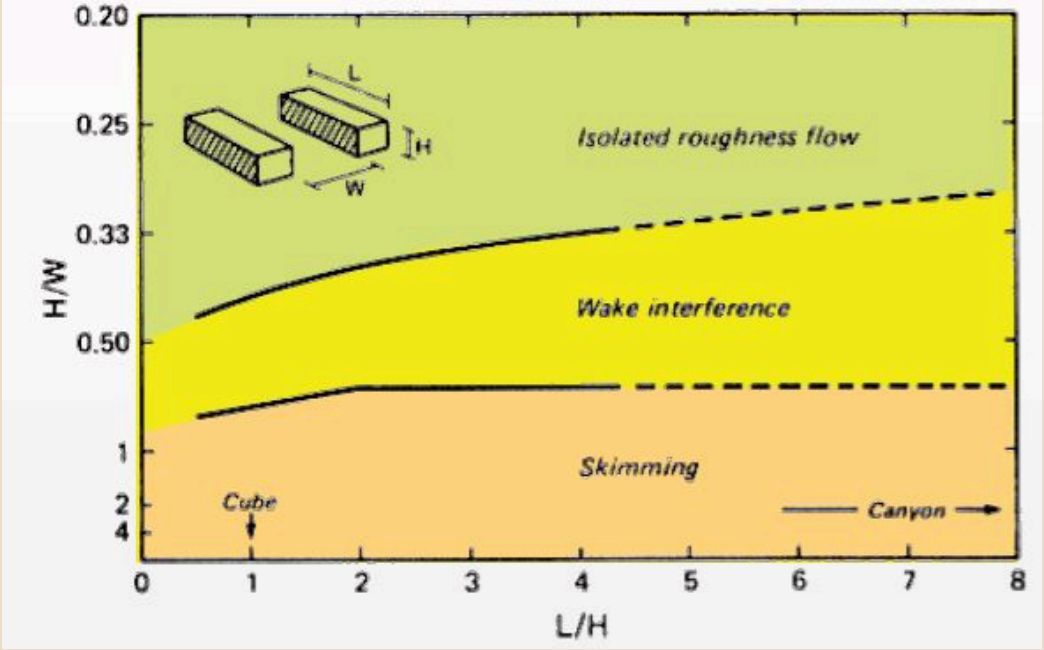
Simulation	Building Height (m)	Building Length (m)	Building Width (m)	H/W	L/H	Grid Size	Cell Size, dxdydz (m^3)
1	5	30	20	0.25	6	50x30x20	1x1x1
2	5	30	10	0.5	6	50x30x20	1x1x1
3	5	30	5	1	6	50x30x20	1x1x1

Location: Vancouver
Time Step: 1h
Start Time: 12 pm

Background Wind: 3 m/s
Wind Direction: 270° (from the West)
Ground: Loamy Soil

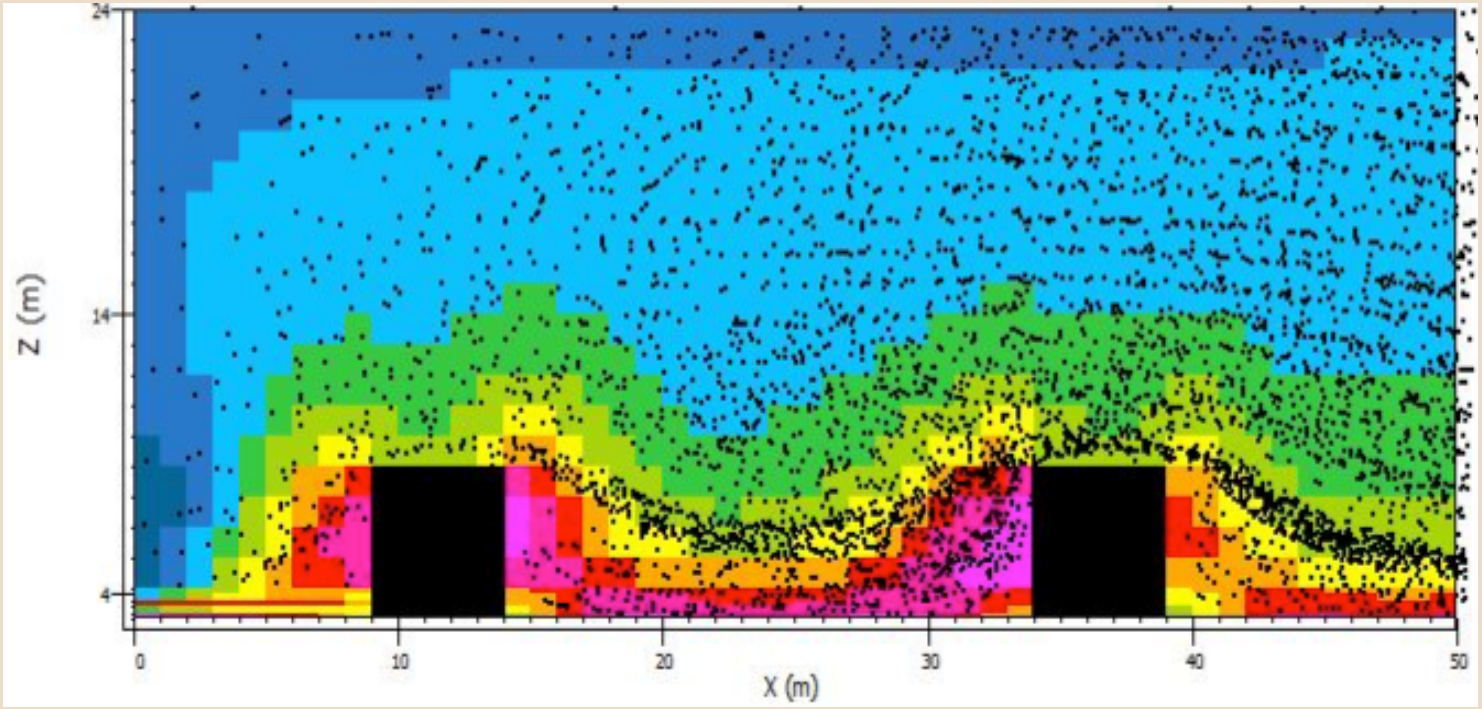
Input Characterization

Simulation	H/W	L/H	Expected Flow Regime
1	0.25	6.0	Isolated
2	0.50	6.0	Wake Interference
3	1.00	6.0	Skimming

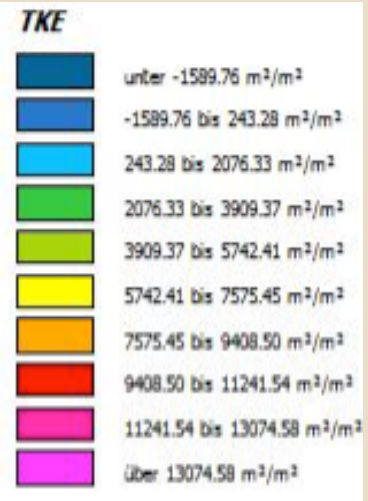


Source: Christen, *Lecture 12:* Flow around buildings and in the urban canopy

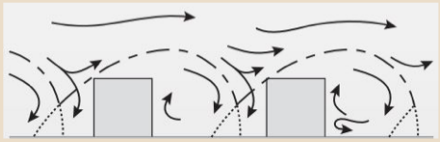
5. Results – Simulation 1

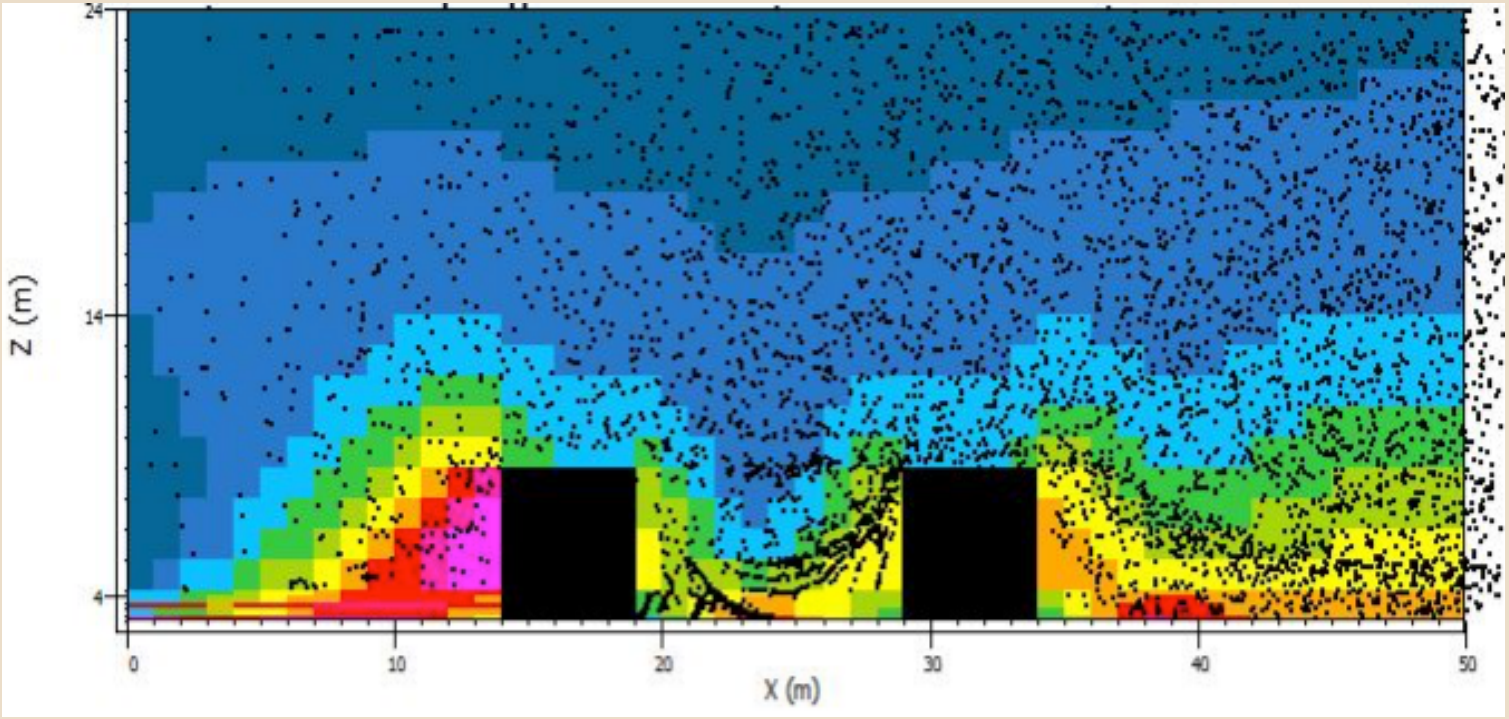


Aspect Ratio: 0.25
Observed: Isolated Flow



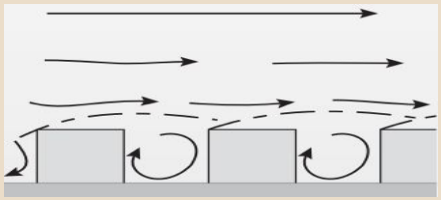
Results - Simulation 2



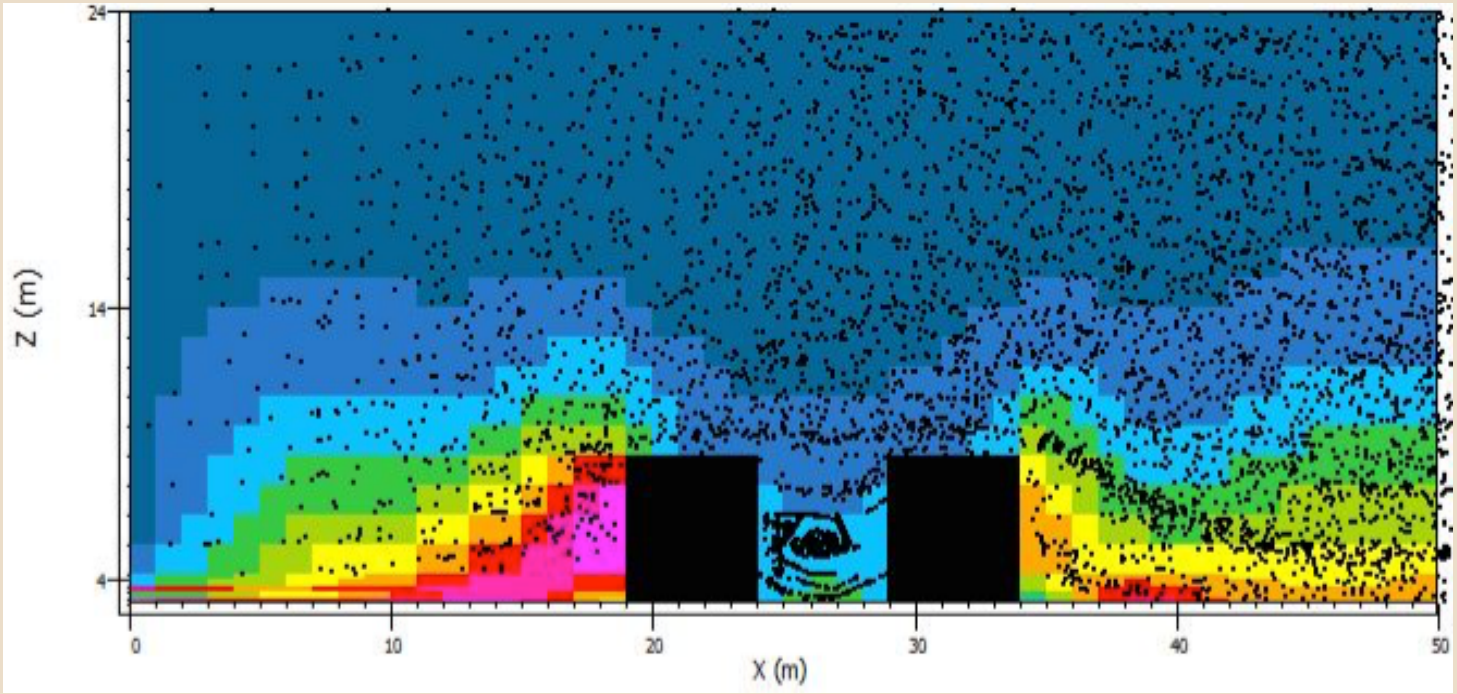


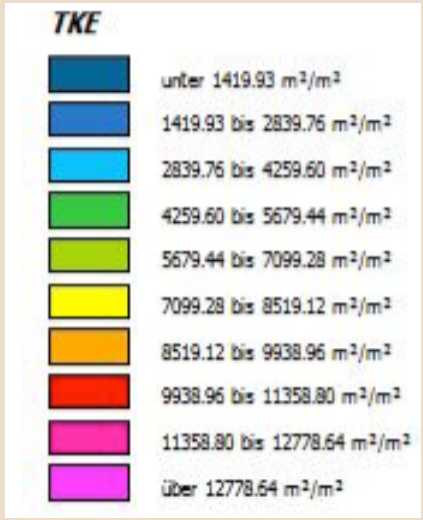
Aspect Ratio: 0.50
Observed: Wake Interference Flow

Results - Simulation 3



Aspect Ratio: 1.0
Observed:
Skimming Flow





Compiled Results

Simulation	H/W	L/H	Expected Flow Regime	Observed Flow Regime
1	0.25	6.0	Isolated	Isolated
2	0.50	6.0	Wake Interference	Wake Interference
3	1.00	6.0	Skimming	Skimming

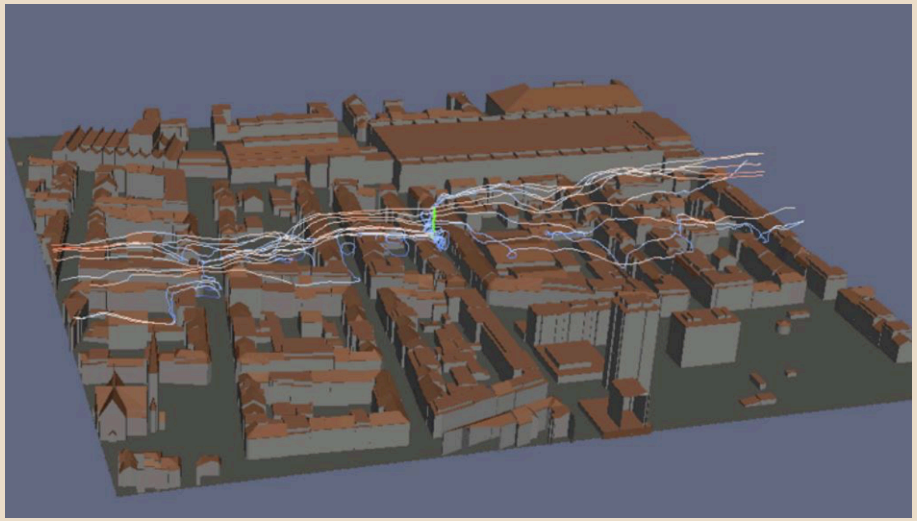
As canyon aspect ratio increases, TKE within canyon decreases

- causes vortex trapping within canyon

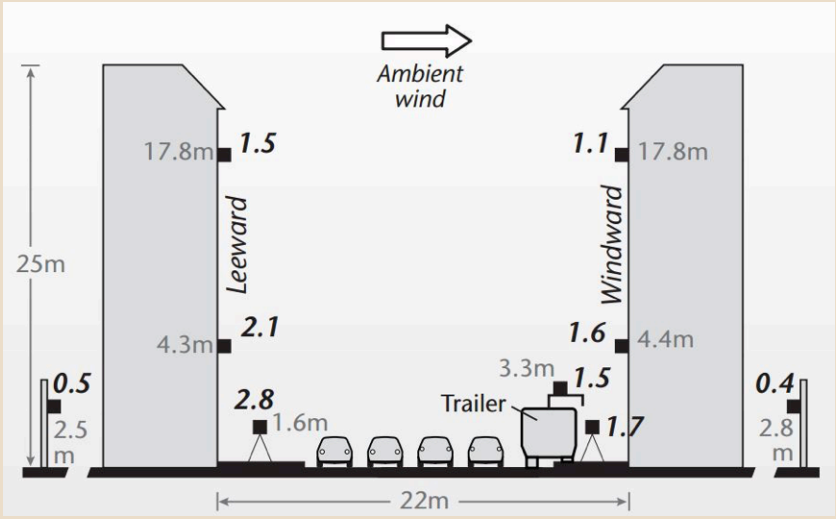
6. Applications to Pollution Dispersion

- **Implications for Pollution**

Dispersion within street canyons from outside sources

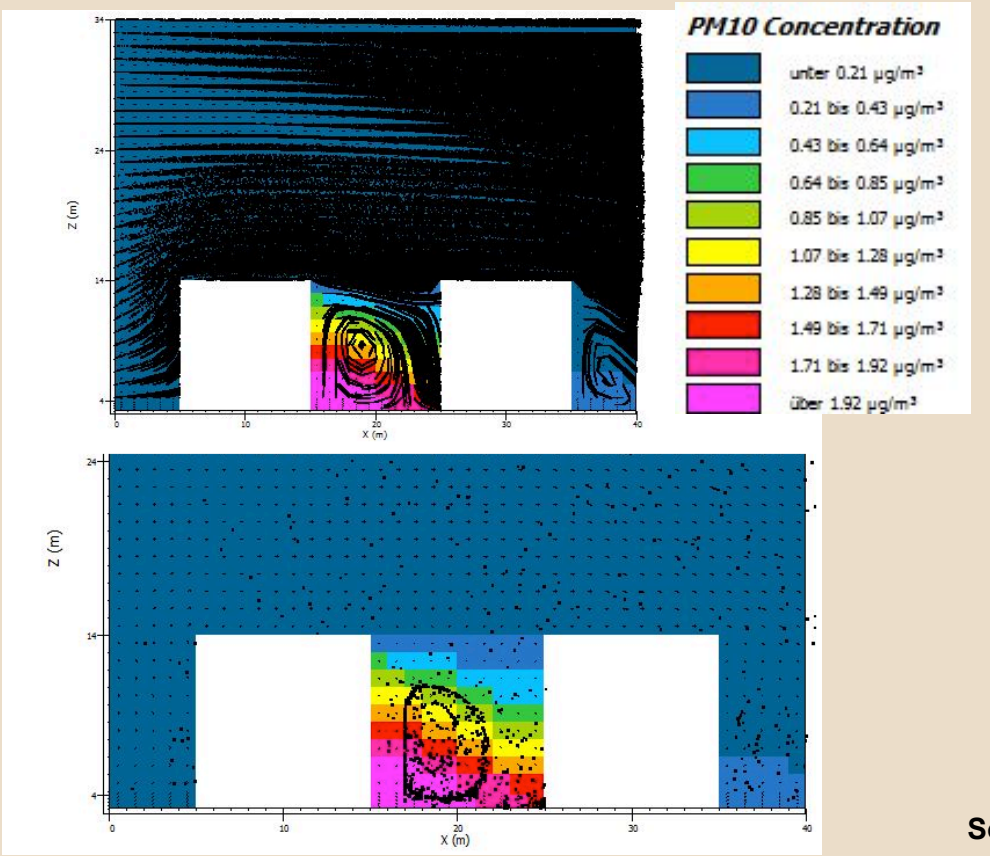


Circulation of pollution within street canyons

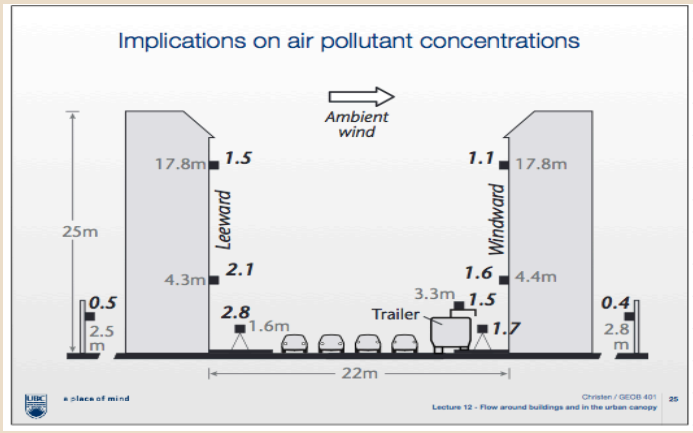


Source: Christen, *Lecture 12:* Flow around buildings and in the urban canopy

Pollution Data



- Canyon Aspect Ratio = 1
- PM10 Pollutants released in canyon center
- Skimming flow causes turbulent vortex
- Accumulation of pollutants on leeward side (pink area)



Source: Christen, *Lecture 12:* Flow around buildings and in the urban canopy

7. ENVI-met Limitations

Program Limitations

- Grid height must exceed maximum building height by twofold
- Computationally intensive
- Steady-state assumption(parameters do not change with time) - not necessarily true in real world
- Applies only microscale atmospheric models - on spatial and temporal scales

Our Model Limitations

- ENVI-met is only as precise as the information you input into the program
- There is little information to educate you on the use of this program
- Greatly simplified and isolated street canyon
- Complex models require extensive manual setup

8. Conclusion

1. Using Envi-Met software we were able to demonstrate the correlation between aspect ratio and turbulent flow regimes in the urban canopy layer. As the aspect ratio increases, the flow regime changes from isolated to wake-interference to skimming flow.
2. This software can be used for small scale atmospheric simulations such as modelling pollution dispersal within a street canyon
    - Ex. Higher aspect ratio can cause pollutant trapping

8. References

1. Boštjan Grašič, Primož Mlakar and Marija Zlata Božnar (2011). Method for Validation of Lagrangian Particle Air Pollution Dispersion Model Based on Experimental Field Data Set from Complex Terrain, Advanced Air Pollution, Dr. Farhad Nejadkoorki (Ed.), ISBN: 978-953-307-511-2, InTech, DOI: 10.5772/17286. Available from: http://www.intechopen.com/books/advanced-air-pollution/method-for-validation-of-lagrangian-particle-air-pollution-dispersion-model-based-on-experimental-fi
2. Christen, Andreas. *GEOB 401 Urban Meteorology. "Lecture 12:* Flow around buildings and in the urban canopy".Web.April 5, 2015. <http://ibis.geog.ubc.ca/courses/geob401/>
3. Envimet. *Company Information*.Web.April 5, 2015<http://www.envi-met.com/#section/intro>