9th International Conference on Urban Climate (ICUC9)
Toulouse, France, July 20-24, 2015

COUPLING OF NUMERICAL WEATHER PREDICTION MODELS AND PHYSICAL SIMULATIONS FOR URBAN WIND ENVIRONMENT

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Why urban studies matter?

- **>50% of global population lives in cities** (United Nations, 2014)
- **79.3% of the French population lives in cites** (United Nations, 2014)

Toulouse. Source:
http://www.ambafrance-be.org/IMG/jpg/P008356.jpg

Numerical Weather Prediction (NWP) models

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- **Parametrization of the urban environments in the NWP models:**
  1. **Simple variation of the surface parameters – slab models**
  2. **Coupling of urban canopy layer model with NWP model**
     - **Single Layer Models: -> 1st layer of the NWP model**
     - **Multi Layer Models: -> several layers of the NWP model**
  3. **Coupling of microscale CFD model with NWP model**

- **First option is still utilized in most operational NWP models used by national meteorological services**
- **Other two options are used for research and in industry (e.g. urban wind energy, dispersion of pollutants)**

Wind tunnels vs. CFD

- **Both techniques are valid, but both have positives and negatives**
- **Advantages of wind tunnels over CFD:**
  1. **More reliable estimates of peak values**
  2. **Long computational time of CFD models**
  3. **CFD simulations highly sensitive to numerous parameters in the model**
- **Disadvantages of wind tunnels over CFD:**
  1. **Less flexibility of inflow conditions**
  2. **Scaling**
  3. **Convective vs. Buoyancy flows**

WRF-ARW model: Results

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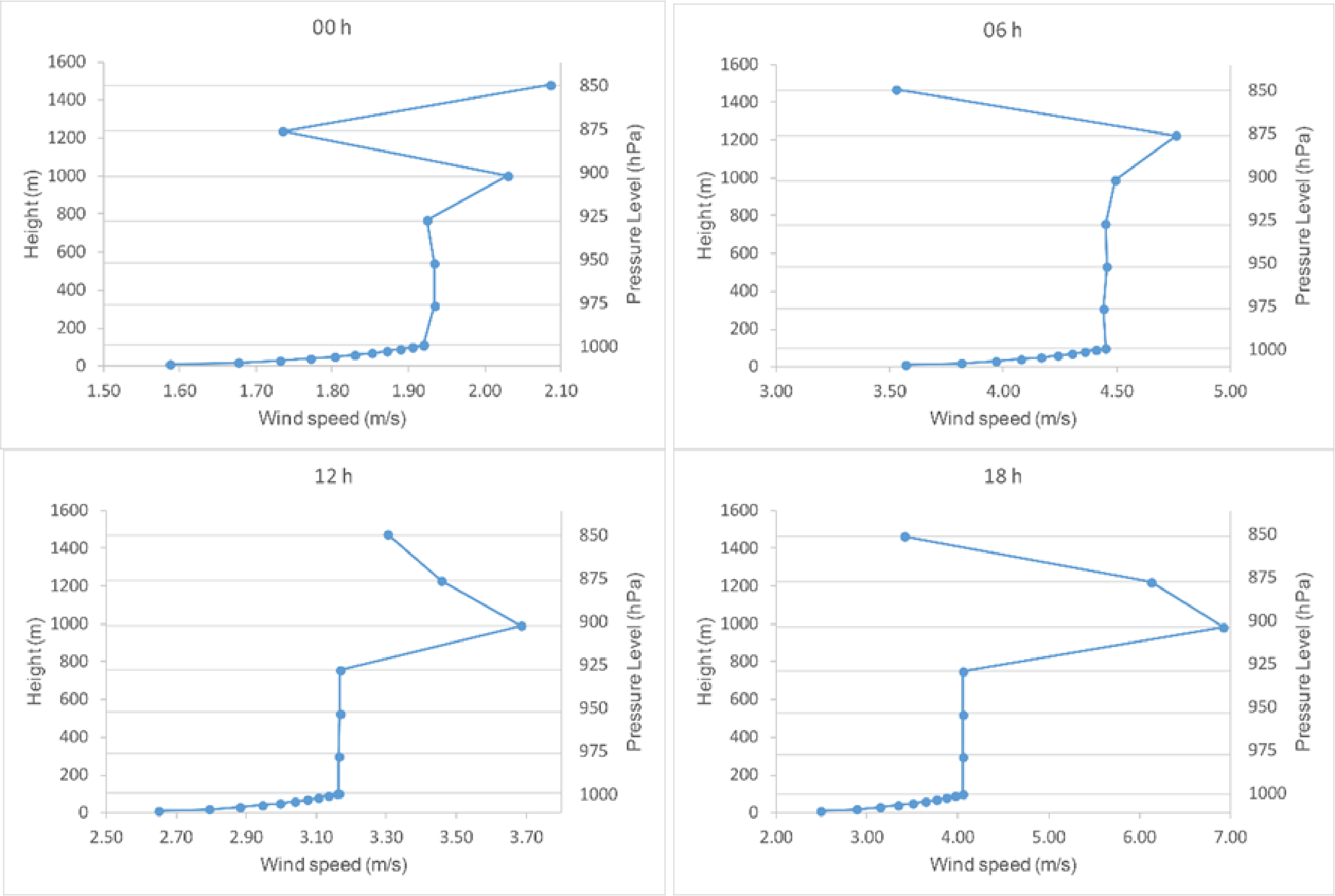
- **Testbed: City of Cacak (central Serbia); July 21, 2014**

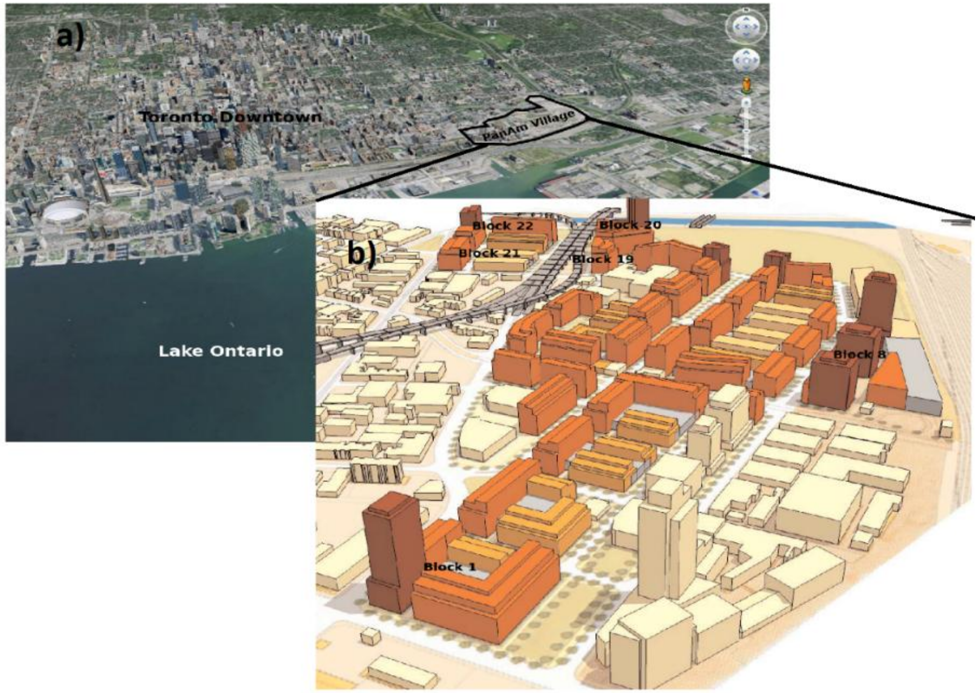


Wind atlas + CFD

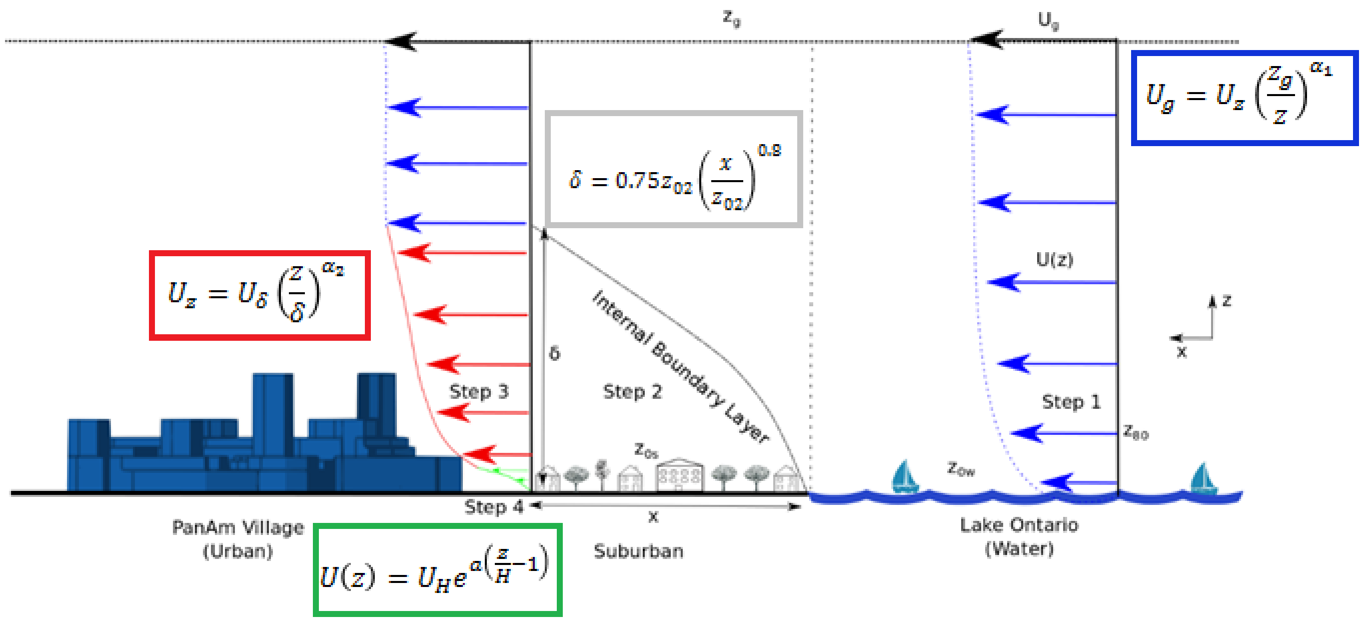
- **PanAm Village site in Toronto**

Source:

Toronto's Condo Blog



Wind atlas + CFD methodology



1. z= 80 m from Canadian Wind Energy Atlas and Vgr based on α_1 =0.1

2. IBL growth

3. ABL at site: α_1 =0.1 above IBL and α_2 =0.34 below

Wind atlas + CFD results: wind field

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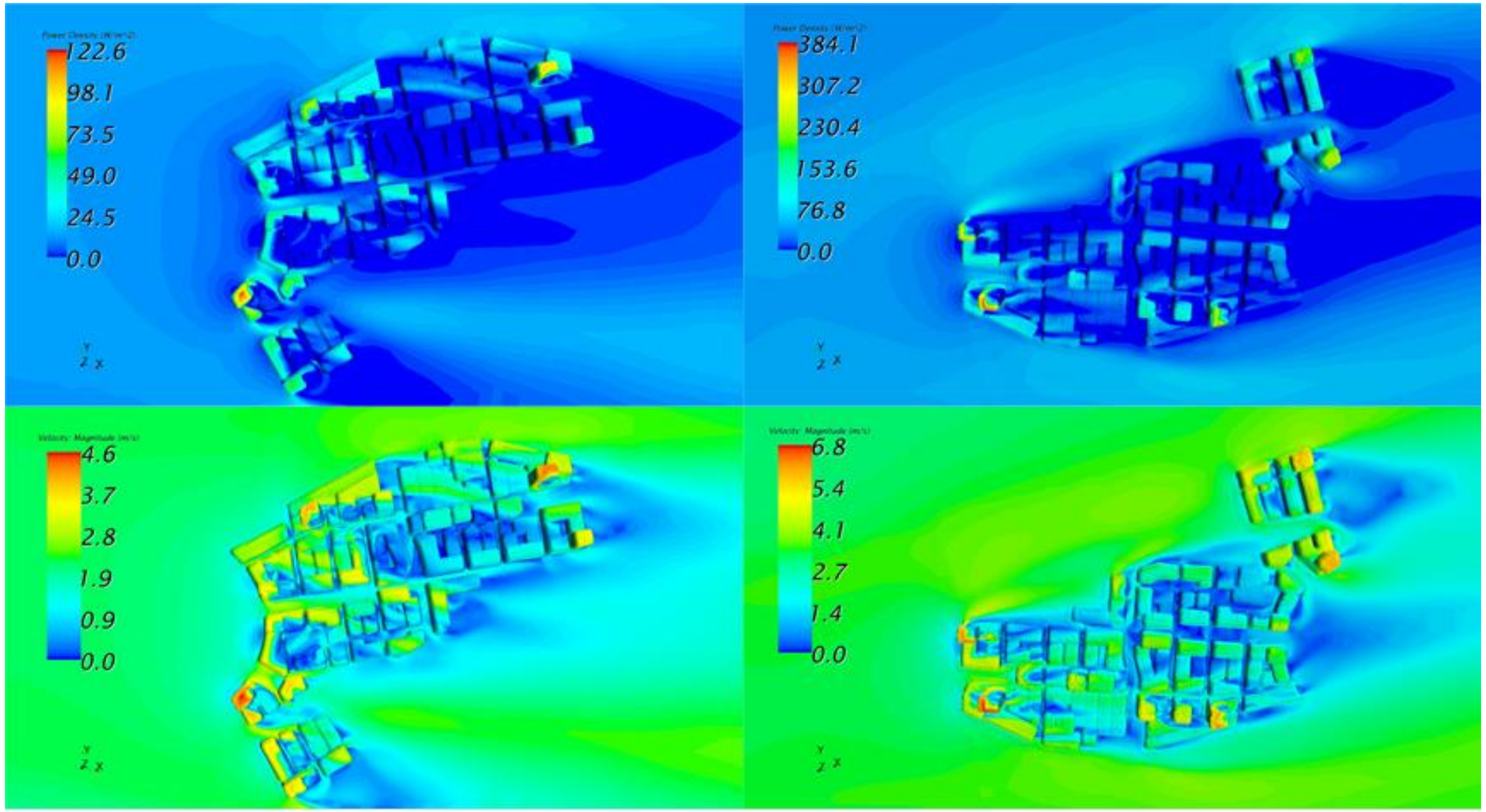
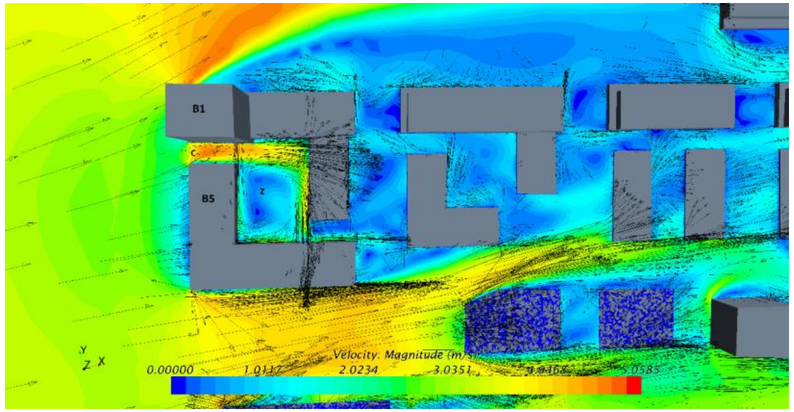
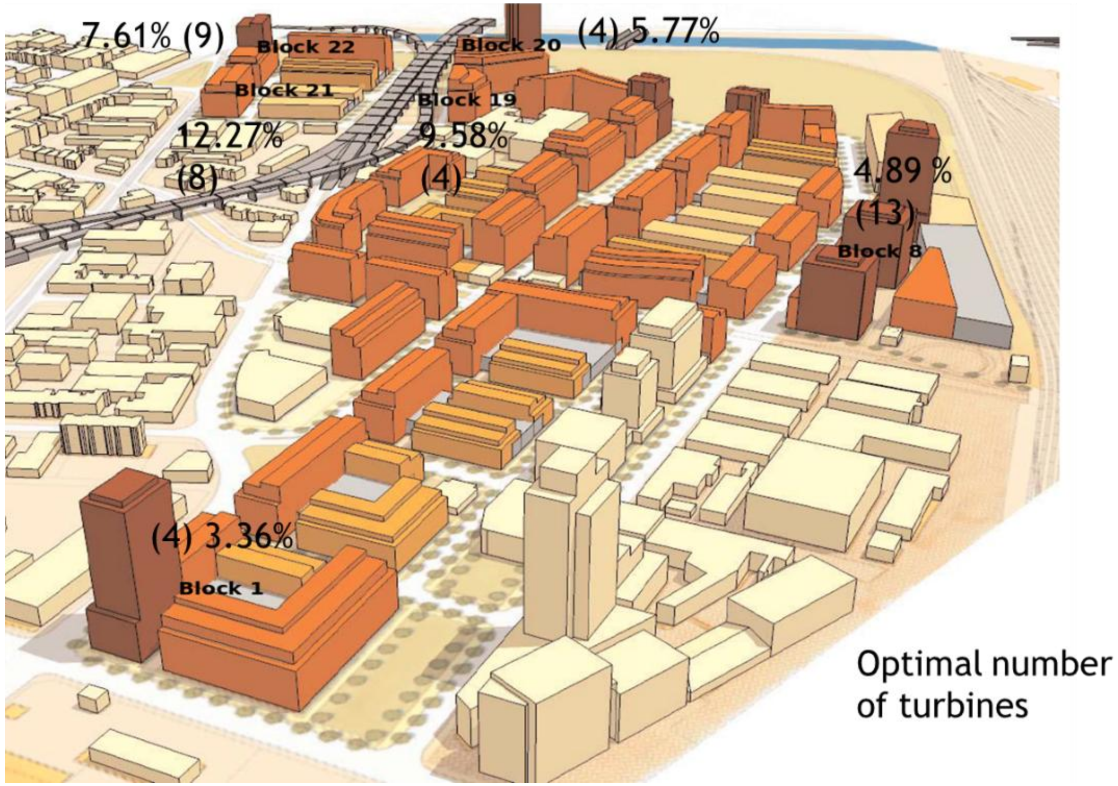
Mean power density (upper panels) and wind speed (lower panels) 8 m above the buildings and ground for 90° direction (left panels) and 240° direction (right panels). Flow direction is along the x-axis.

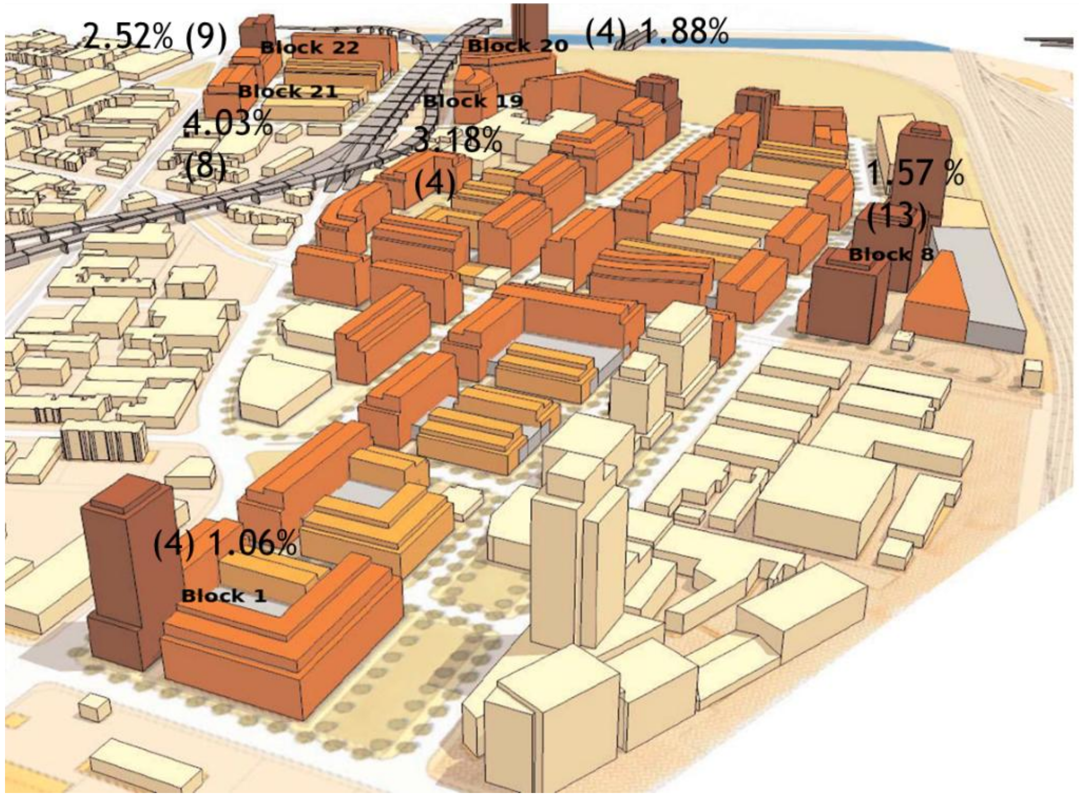




Wind atlas + CFD results: wind energy

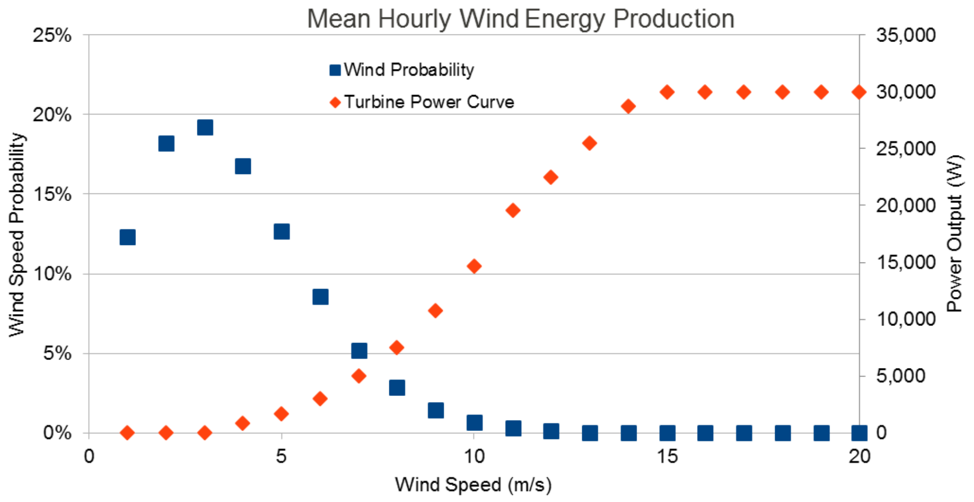


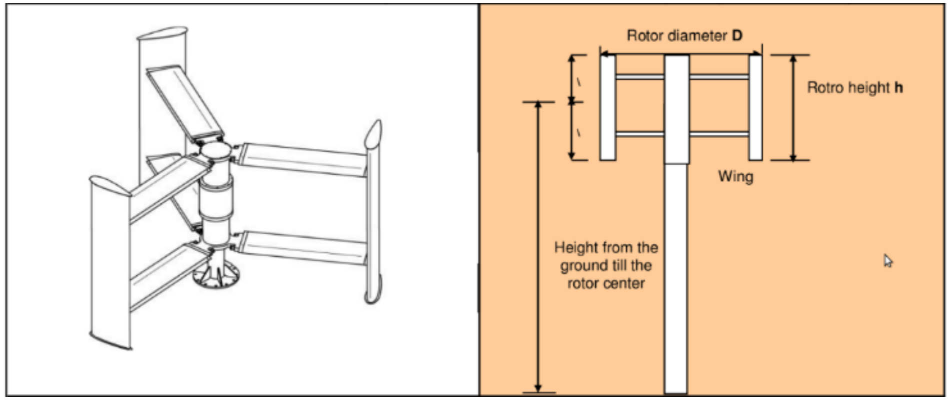
Wind potential



Delivered energy

Wind turbines vs. available wind

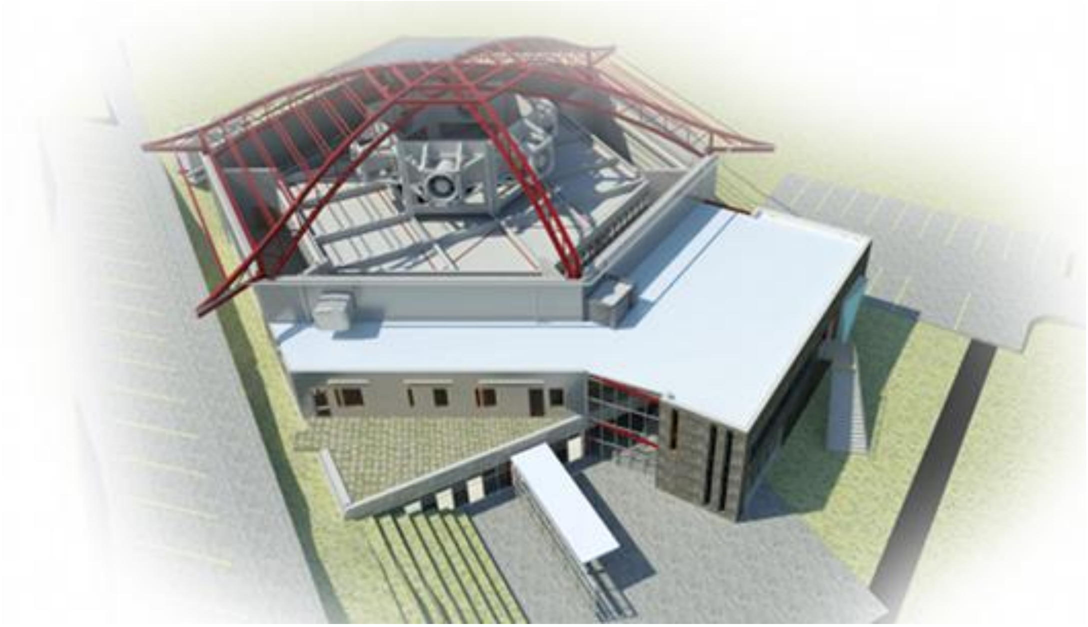




Rotor Diameter = 10 m
Rotor Height = 8 m

Nominal Power = 30 kW
Nominal Speed = 11.8 m/s
Cut-in Speed = 4 m/s
Cut-out Speed = 20 m/s

The Wind Engineering Energy and Environment (WindEEE) Dome



- **WindEEE Dome : new three dimensional and time-dependent wind chamber**
- **can simulate various wind systems from sheared winds and gust fronts to tornadoes and downbursts**
- **a multi-scale, multi-purpose facility for wind research**

www.windeee.ca

WindEEE: Preliminary Design

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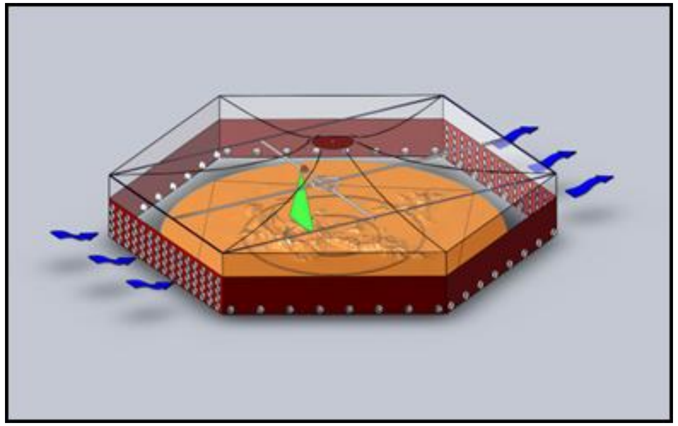
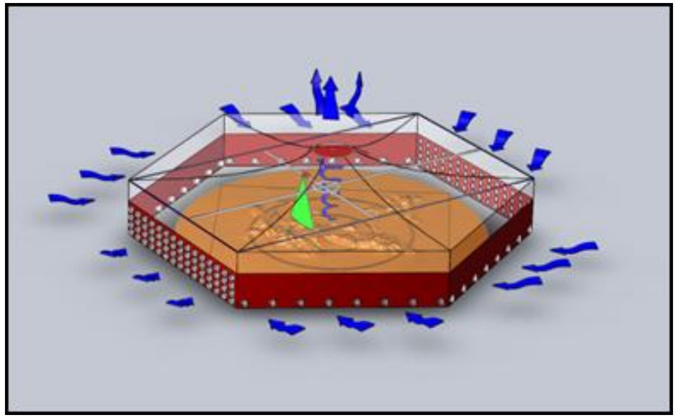
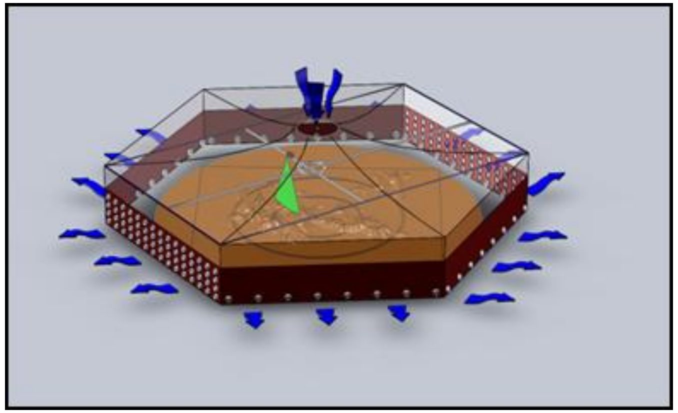
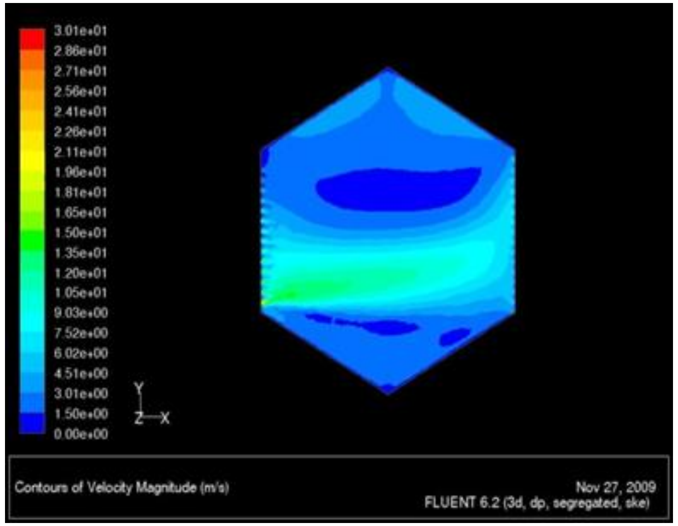
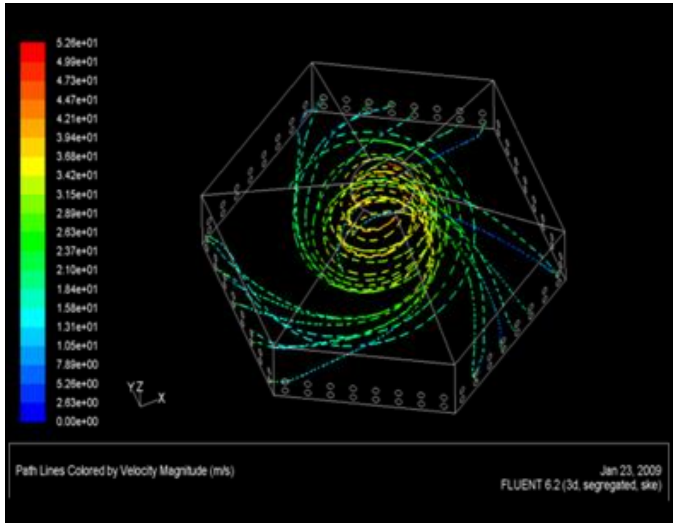
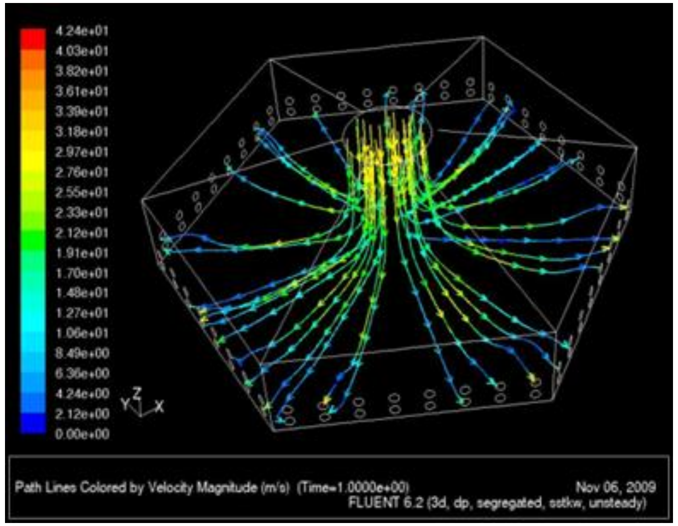
straight/sheared flow	tornado flow	downburst flow
		







WindEEE: Engineering Design

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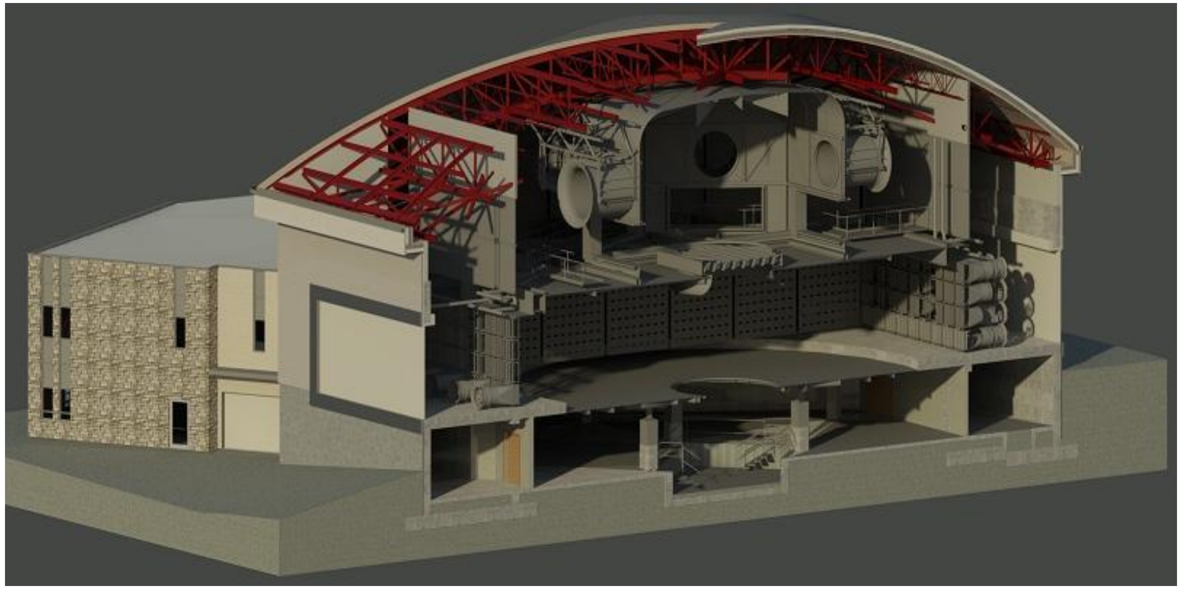
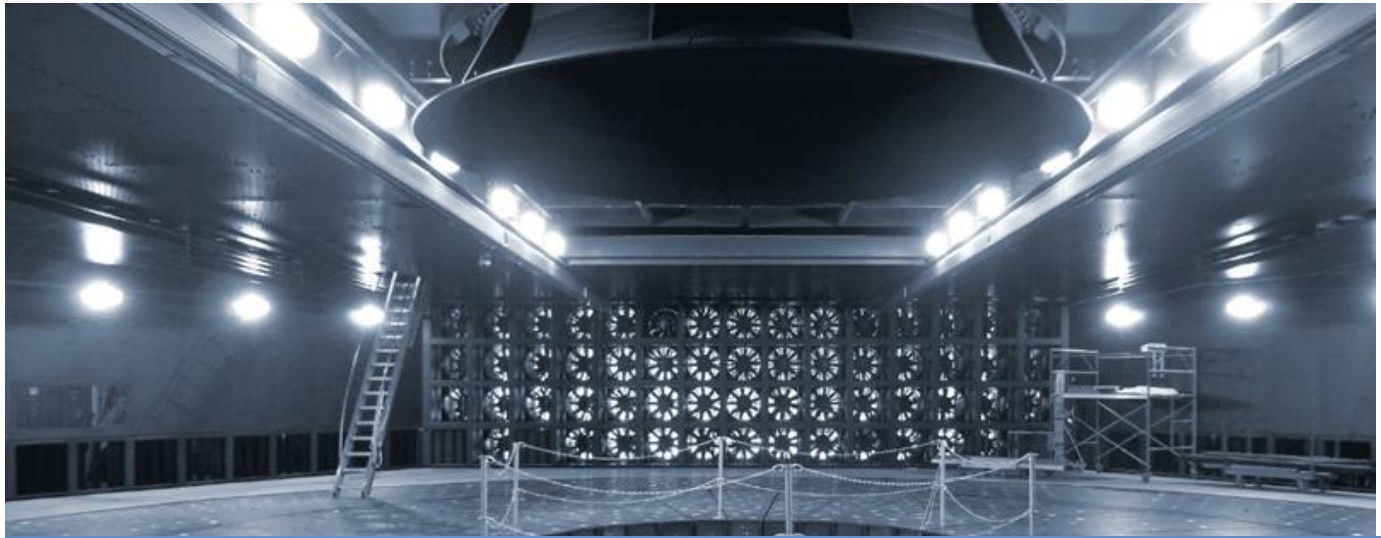


- 106 individually controlled fans
- 2 MW maximum power
- 5 m lift and turntable
- 1600 floor roughness elements

WindEEE: Research Ready

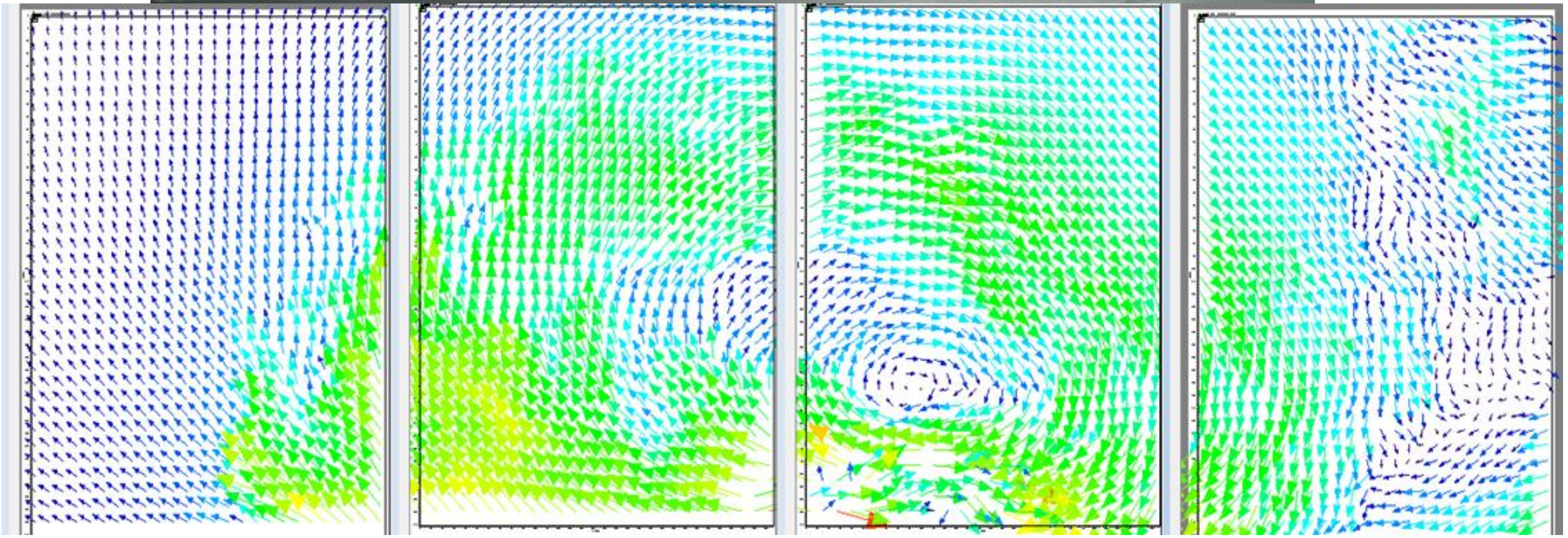


Six Initial Design Specifications:

- Straight Mode Uniform
- Straight Mode Boundary Layer
- Straight Mode Shear
- Tornado
- Downburst
- Reversed Flow Mode

+ HH 7 ☺

WindEEE: Tornadoes and Downbursts



A new approach

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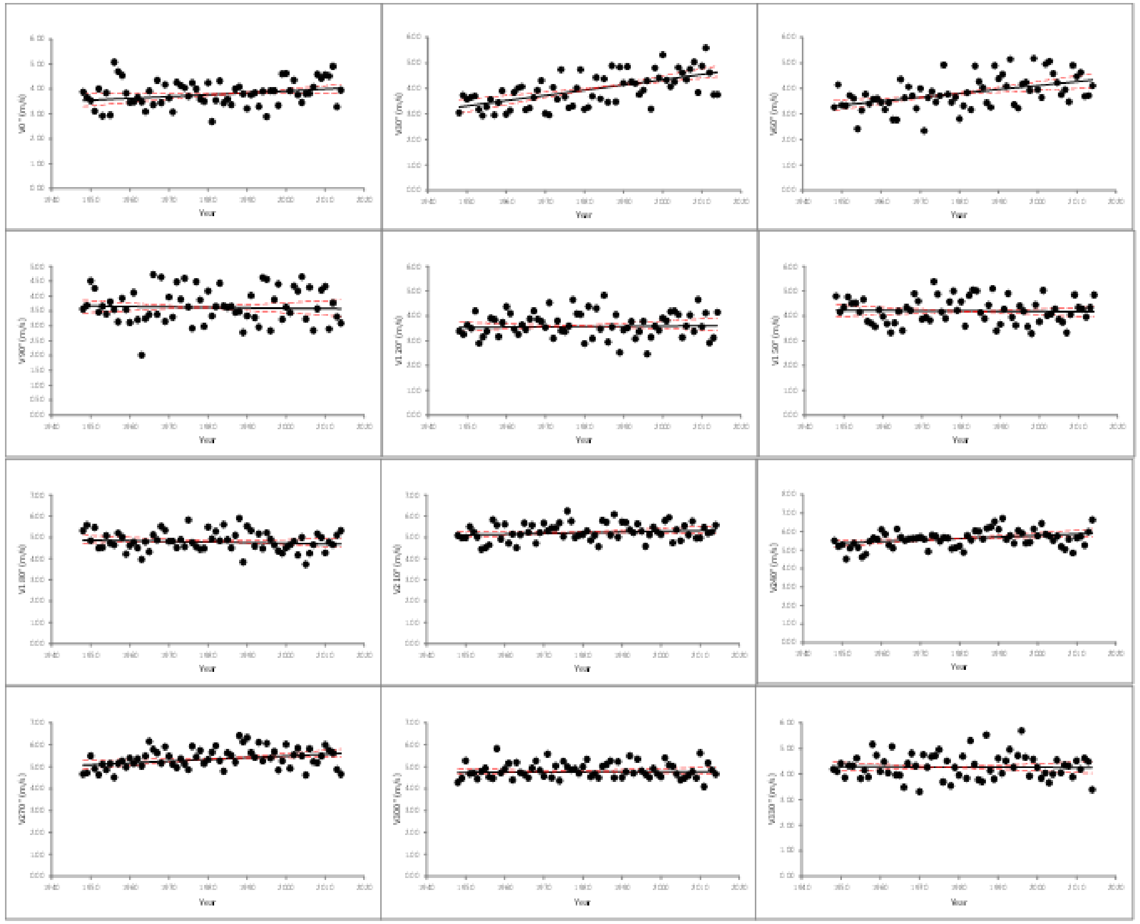
- **Coupling NWP models with WindEEE physical simulator**
- **Wind profiles from NWP models are inflow conditions for WindEEE**
- **Placing model of a city block and running simulation with realistic inflow conditions**
- **Benchmarking micro-scale models by controlled parametrization**

Thank you!

www.windeee.ca

Numerical Modeling: Trend Data Analysis



Mean Annual Wind Speed per Direction

Mann-Kendall non-parametric test for trend (Mann, 1945; Kendall, 1970)

Sen's slope estimator (Sen, 1968)

$$S = \sum_{y_1=1}^{n-1} \sum_{y_2=y_1+1}^{n} sgn(x_{y_2} - x_{y_2}).$$

$$Y = Q(y - 1948) + B,$$

D. Romanic, H. Hangan-Sustainable Cities and Society (2015)