SIMMER WORKSHOP (Science, Policy & Heat-Health Decision Making) Toronto

Weather & Climate Modelling in Toronto & The Significant Results for Public Health

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Address

- What is novel about the approach?
- How does the research help inform policies to reduce heat-related health impacts?
- How could this information feed into an integrated model?

Why Use a New Approach?

- **To address our reservations with GCM / RCM**
  - Cell Areas Too Big (North Bay & Buffalo = same)
  - No Great Lakes, Niagara Escarpment, ORM etc
  - 30 Year Normal (latest available in 2006 = 1960-90
  - All About Means NOT our COSTLY EXTREMES
- **To give us independence from the status quo**
  - Re: coasts, forests, agriculture, ice … etc
  - We (80%-90%) live in cities & need answers re cities
- **To give us control over parameters considered**
  - We need answers re the extremes of heat & pptn.

New Questions

…. To Answer: New Questions

- Focused on obtaining data concerning:

  Future Extremes-of-Weather

  (e.g., Heat Waves & Torrential Storms)

rather than …

Future Averages-of-Climate

(e.g., Average Temperature & Average Rainfall)

But examined such "Averages" to check model validity!

Three Intended Phases

- **Phase 1**
  - Examine What Happens Now and Why
  - ie **What Drives our Weather & Climate?**
- **Phase 2**
  - Comparative Modelling Assessment for Toronto
  - **Best Models? Scales? Time Periods? Scenarios?**
- **Phase 3**
  - Fully Model at Appropriate Scale & Time Period etc
  - **Consistency of Changes with Climate Drivers?**

But ….

- Following RFP Call
  - With help from Science Advisors Group
- Realized the strongest Proposal -- also included part of Phase 2
- So We Opted for a **Phase 1+ Approach**
- **Would Still Like to do Phase 2 (ii) + Phase 3**

New & Innovative Local Model Approach

- Global Climate Models + Regional Climate Models + **Local Weather Model** (1km^2 Cells)

- **SENES Consultants** ran the computer models

- **ADVISORS & PEER REVIEW GROUP**
  - Environment Canada
  - Ontario Ministry of the Environment
  - Toronto Regional Conservation Authority

- Subsequently adopted by US National Centre for Atmospheric Research + MOE + UofT (W.R.Pelltier)

Major Components of New Approach

- Dynamic Downscaling from GCM/RCM to WRF
  - WRF – Weather Research Forecast Model
- 10 Year Period
  - 2000-2009 & 2040-2049
- 1 km x 1 km grid scale
- A1B scenario

Future Weather Modelling

- **Global Climate Model (GCM)** output data was "fed" into the Hadley U.K. Met. Centre's **Regional Climate Model (RCM / Precis)**
- RCM output data was then "fed" into the **Weather Forecast Model (WRF)** for an area greater than the GTA but focusing on Toronto
- Used Future IPCC Scenario **A1B** with a moderate economic/political outlook and a **"likely" future reality** – **looked at extremes**

New Approach & New Questions

- Included **Local Influences** (Great Lakes, Niagara Escarpment & Oak Ridges Moraine)
- Examined **10 Year Periods** (not 30 Year Periods)
- Wanted to obtain data and information concerning the **future extremes-of-weather** rather than the **future means-of-climate**.
- Such as **HEAT WAVES**
  - not just average annual or average summer temps.

Heat Wave …. Definition

- A meteorological heat wave is defined by Environment Canada (Meteorological Service of Canada (MSC) - Ontario Region, 2009b) …. as ….
- **… three or more consecutive days in which the maximum temperature is greater than or equal to 32°C.**

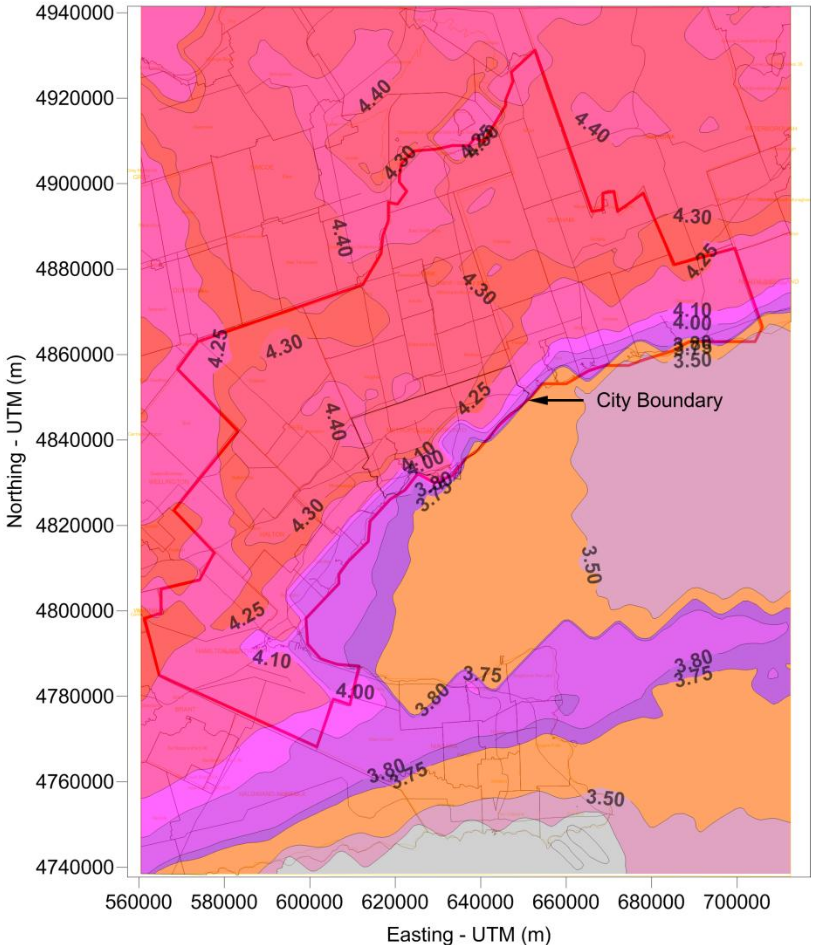
Historical Data…… monitored

- **17 heat waves** occurred in period **1971-2000** at Toronto Pearson International Airport Met. Stn.
- Average of 0.57 heat waves per year (17/30)
- The majority (65%) of heat waves lasted for the defining three days; …. however,
- one heat wave lasted for **6 days**,
- two heat waves lasted for **4 days**, and
- three heat waves lasted for **5 days**

Future …. **modelled**: Heat Waves

- Looking at ………………….. **2040-2049**
- We project **2.5 occurrences / year** on average (>3 consecutive days w max. >= 32°C)
  - Almost a 4.5x increase (from 0.57 to 2.5)
- **Spatial Variation:**
  - 7.7 occurrences at Toronto Pearson,
  - 4.4 occurrences at Etobicoke North
  - 2.9 occurrences at the Don Valley East
  - 0.2 occurrences at Scarborough

Future Temperature Differences



Average annual temperatures increase by 4.4°C

BUT non-uniformly due to cooling influence of Lake Ontario, Simcoe etc

But …..

- Perhaps Examining **Max Daily Temps together with High Overnight Temperatures (>24°C)** could be more Valuable?
- We are currently extracting the relevant data (stay tuned – but hopefully by Year End)

- Combinations of **Heat Waves + SMOG Events**
  - Mostly spatially ubiquitous events
  - But magnified in areas of Urban Canyons
  - And other areas of poor urban street ventialtion

Future Warmer Temperatures

- ***Average annual temperatures increase by 4.4^{o}C***

- Projected **average winter** temp. increases by **5.7^{o}C**.
- Projected **average summer** temp. increases by **3.8^{o}C**.

- The **extreme daily minimum** temperature
  - “becomes less cold" by **13^{o}C**.
- The **extreme daily maximum** temperature
  - "becomes warmer" by **7.6^{o}C**.

Future Extreme Heat

From 2000-2009 To 2040-2049

- **Mean Max. Daily Temperature** … 33°C – **44°C**
  - Maximum daily air temperature is recorded at a weather station by selecting the highest 1-hourly air temperature within each period. (Averaged here over 10 years)

- **Number of Days/Year > 30°C** … 20 – **66**

Humidex

… From 2000-2009 to 2040-2049

- **Number of days Humidex >40°C eq** 9 – **39**
- **Maximum Humidex** … 48°C eq – **57°C eq**

A Humidex above 45 is "dangerous"

When the humidex hits 54, heat stroke is imminent

- *Note: Humidex remains within 10% of present for most of year but increases by 40% in February, and by 20% in July through to September (TEO Study)*

Confidence in Results: Temperature

- **Compared with Monitored Means** (2000-2009)
  - Toronto's Climate-Weather Model v.1= ***8.70°C***
  - EC's CRCM v.4.2.3 = ***6.69°C***
  - Monitored Data from Pearson = ***8.73°C***

- **Compared with Other Models** (2040-2049) for GTA
  - *NB Compares High versus Low Resolution Models*
  - Our Delta ***4.4°C*** compares favourably with Low Res Models showing Deltas from **-2.7°C** to **6.3°C**

Application of Results

- What the City wanted to obtain was data and information concerning the future extremes-of-weather rather than the future means-of-climate.

- Extremes are more significant for public operations, and both hard and soft service provision ranging from such basics as flood appropriate sewer & culvert pipe sizing,
- to heat wave appropriate load-bearing resistance of road surface materials,
- and …. heat appropriate public services for the elderly and disadvantaged.

Application of Results

- What we see now re: Heat will get ... MUCH WORSE !!

- Need Policy & Actions
- Need to Address & Adapt

ISSUE: Increased Summer Temperatures - A/C, Electricity Demand, Heat Vulnerability

Expected in **2040-2049:** Almost "**6 times**" **increase in A/C use** during days with greater than 24**°C**

ISSUE: Increased Summer Temperatures – Impact Air Quality (SMOG)

Heat Waves & SMOG Events go hand in hand

More Heat means More Smog

Heat & Smog

Years [Jan 1 to Dec 31]	**# of SMOG Advisory Events**	**# of SMOG Advisory Days**
2003	5	12
2004	6	14
2005	14	48
2006	5	11
2007	11	29
2008	6	13
2009	2	4
2010	2	8
2011	1	1
2012	8	16
Total (2003-2012)	60	156
Average (2003-2012)	6	15.6

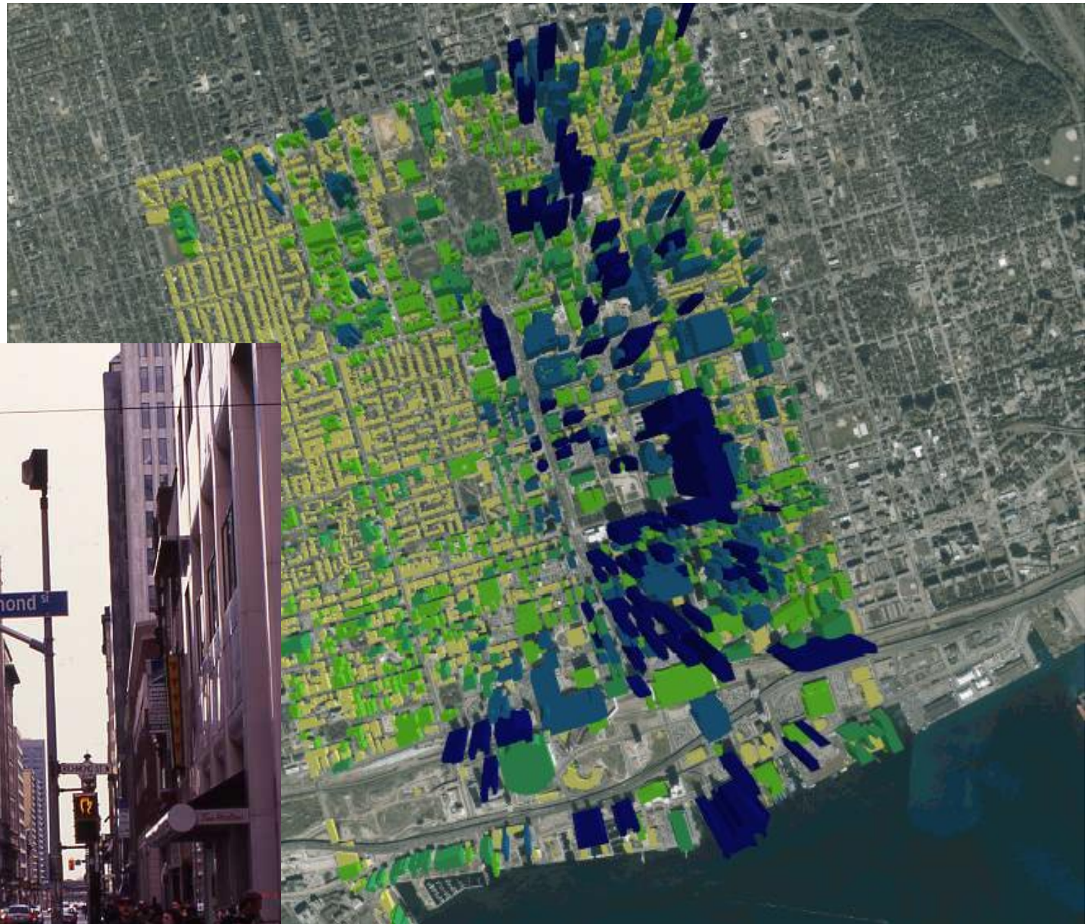
New Directions (3)

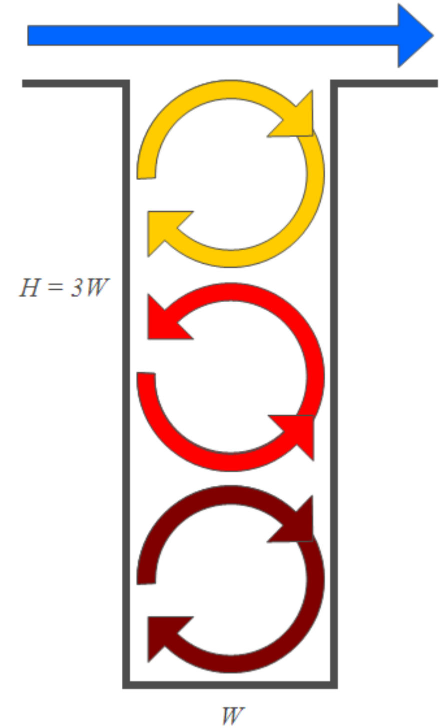
Adaptation (Urban Planning & Urban Design)

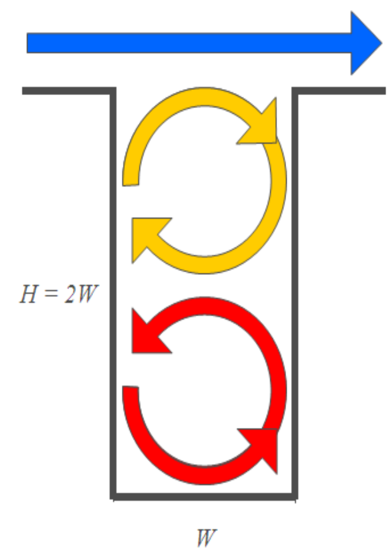
- Amend Provincial Policy Statement (PPS) -- done
- Include in City's Official Plan -- done

- Tool Kit for Planners (Urban Design) -- in progress
- Test & Develop Concepts → Standard -- in future
  - Develop Appropriate Designs & Configurations from 3-Dimensional AQ Modelling & Technical Analysis of Downtown Tall Buildings & Streets

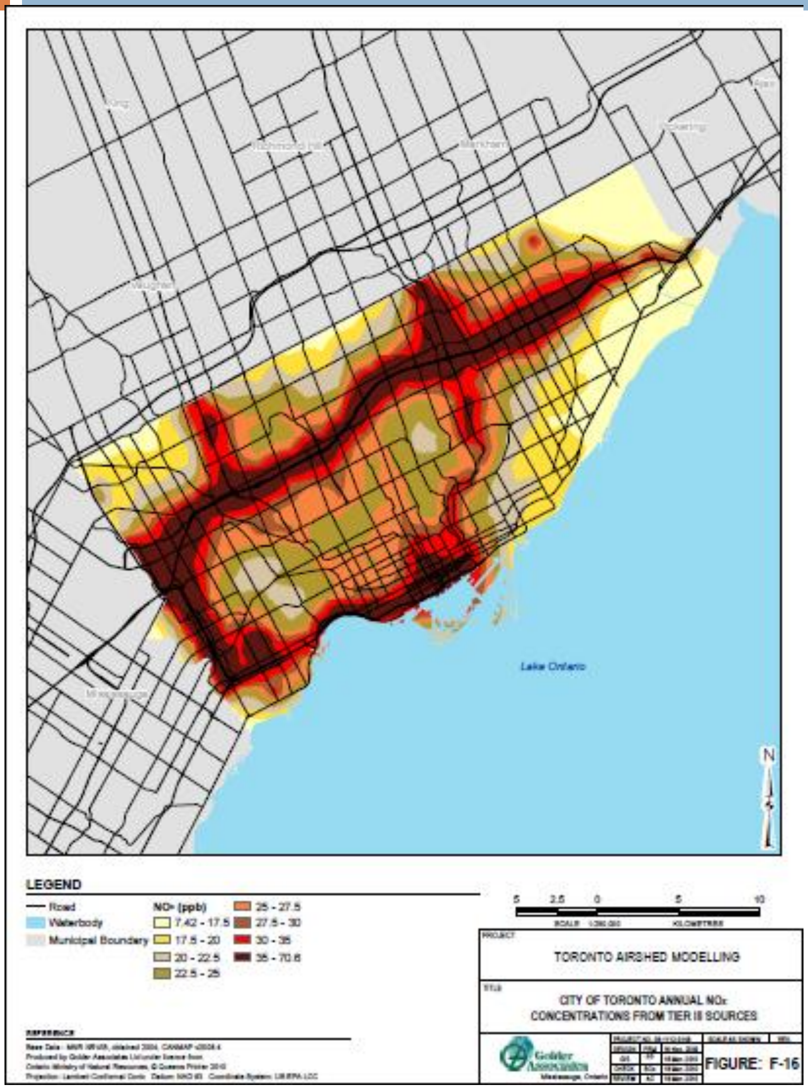
Urban Canyon Problems

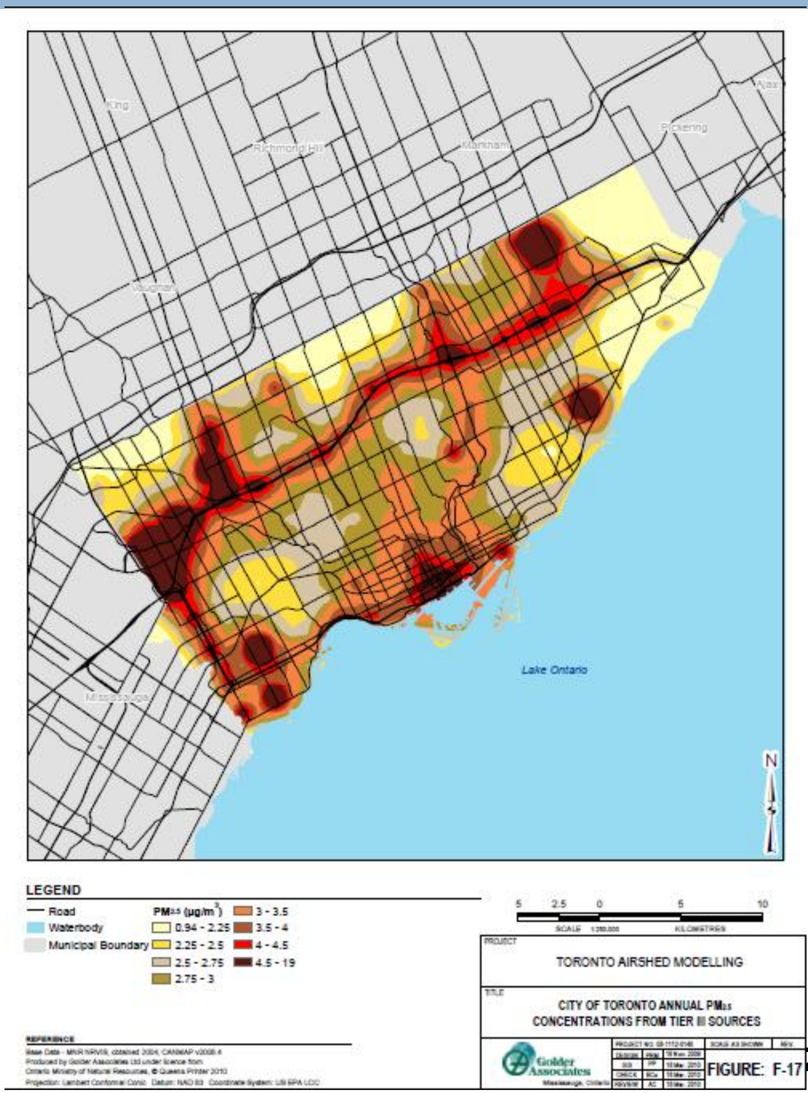






NO_x Ann $PM_{2.5}$ Ann

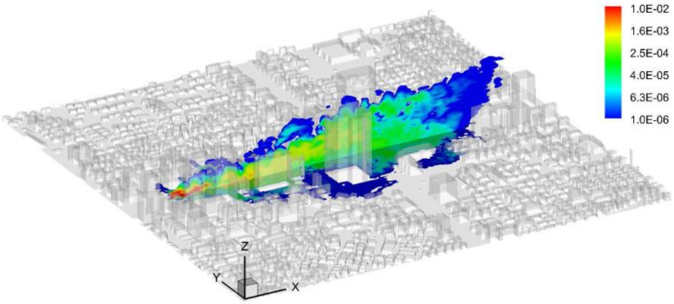


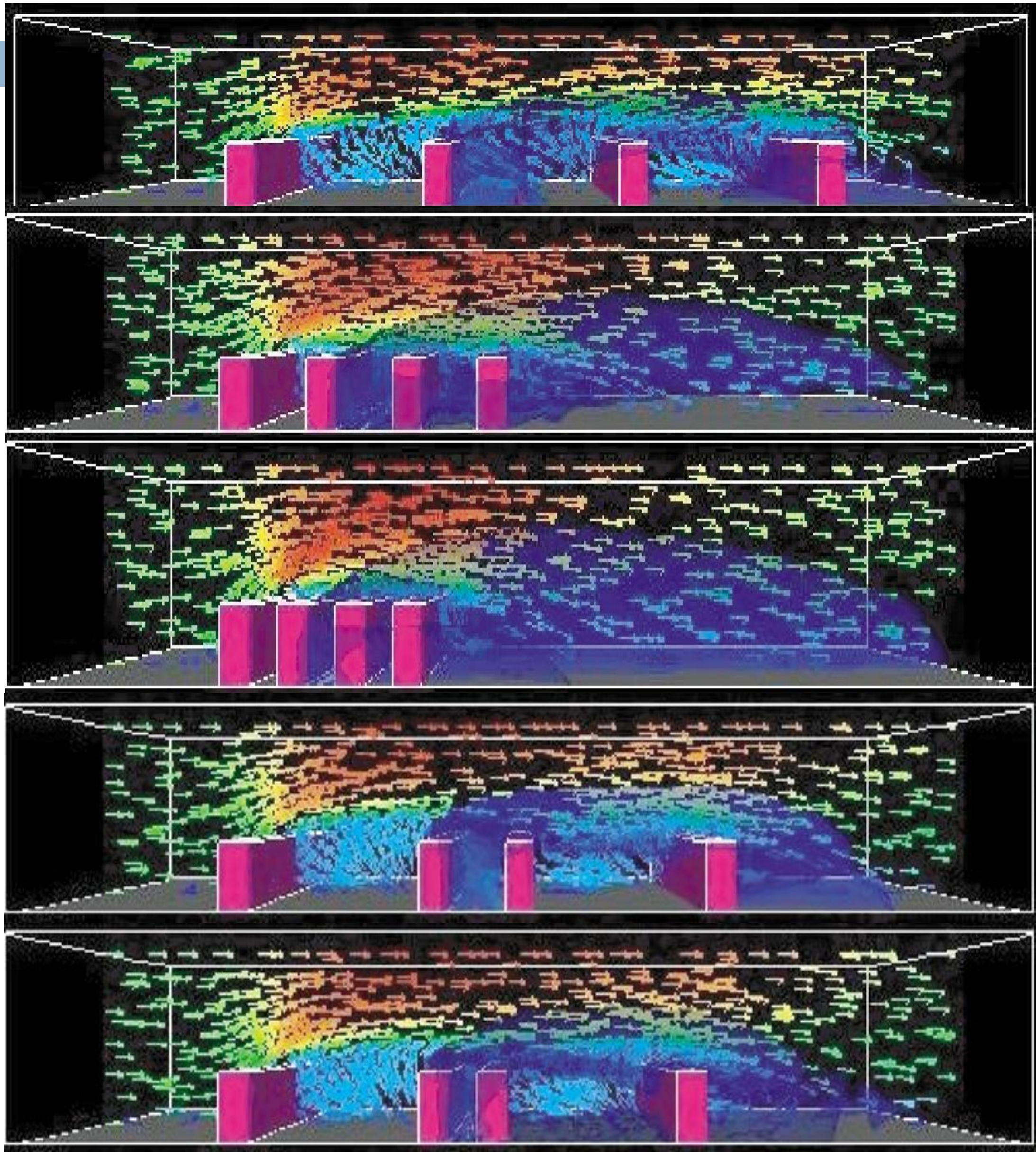


AQ in Downtown Canyons Today

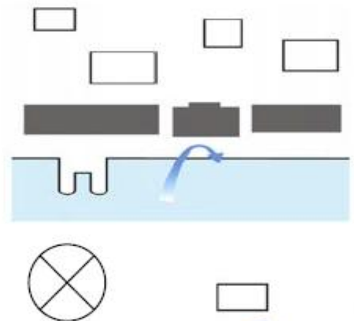
General Air Quality in Downtown Urban Canyon Areas of Toronto expressed as a percentage of Provincial Ambient Air Quality Criteria		
	Percentages of AAQCs by Time Period Considered	
Air Quality Model Approaches	Worst Case Day [Once a Year]	Average Day [Year Long]
Modelled Results as Verified Against Monitored Data of Toronto as a Featureless Plain **NO BUILDINGS**	**150%**	**75%**
Modelled Results (same as above) but adapted using simple proportional land use coverage (GIS data) to better represent Complex Urban Terrain **BUILDINGS INCLUDED**	**250%**	**125%**

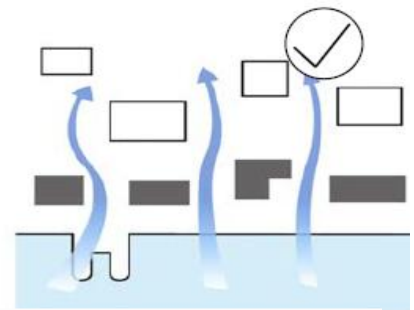
3D AQ Modelling - Computer + Physical

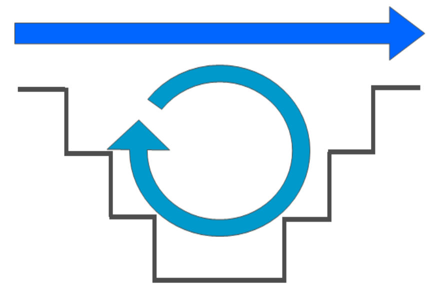


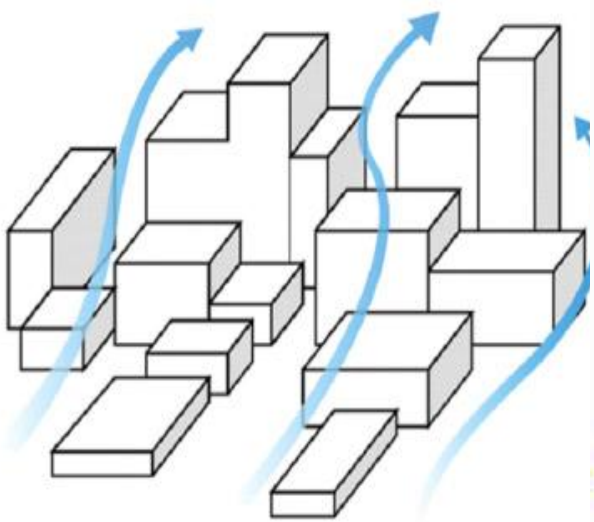


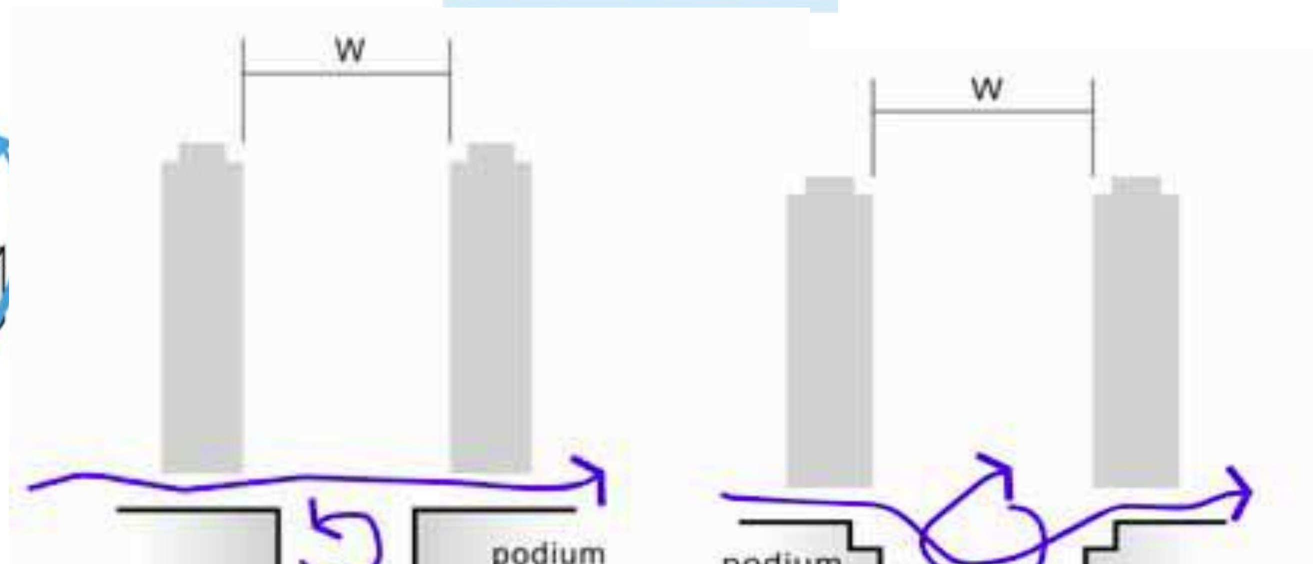
Buildings & Street Design



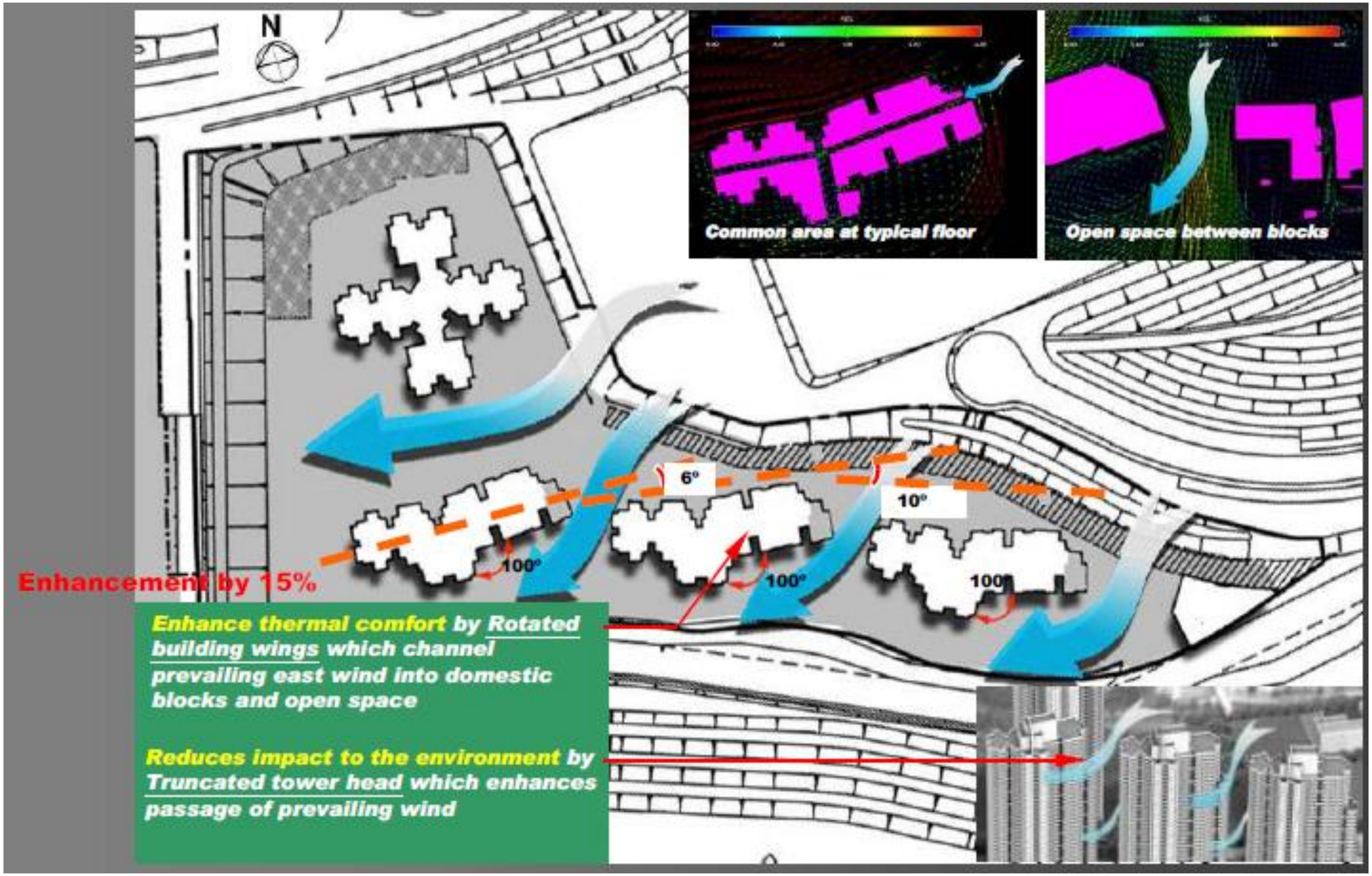








Air Flow Between & Through Buildings



How to Use Weather-Climate Data in an Integrated Model

- Use to address growth of future heat problems for all policies, actions etc to the same level of threat
- Allow subsequent completion of Phase 2 and Phase 3 to be incorporated into integrated model
- Ongoing monitoring of Temperature etc re: recent past & present coupled with comprehension of “Climate Drivers” to validate patterns of changes
- Provide feedback re needs from integrated model to inform future local weather-climate assessments

It will get much hotter more often!

The End

Questions and Answers

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