Climate Modelling – The Needs and Realities of Cities

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Messages

- while 80% of Canadians live in cities
- there has been little study of the impacts of climate change on municipalities
- changes in frequency and magnitude of extreme weather events have significant social and financial consequences
- combinations of weather events are also crucial based on prior experience
- good decisions need detailed local information

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Municipal Infrastructure

- municipalities come in many shapes and sizes
- how to replace aging infrastructure across the municipality
- hard infrastructure ages and is replaced
  - "same again" vs. "advisable but still affordable"
- soft services
  - public cooling places during heat waves
- expensive to install and maintain
- how do future conditions match up with life-spans of installed and aging infrastructure?
- these decisions need locally specific information

The Reality of Climate Change

- accepting that climate change and weather patterns are changing
  - how much and how soon?
  - what changes will occur to extreme event intensity and distribution (both temporally and spatially)
  - gradual changes in annual mean values of temperature and precipitation are largely irrelevant
- the costs of doing too much or too little can be high but the cost of doing nothing may be even higher!
  - uncertainty is crucial

What is Missing?

- great averages but the models don't include:
  - the Lake Ontario and locally significant topography
  - influences of urban land use
  - the reality that changes are escalating not matching what is happening now
- extremes
  - heat waves, droughts, intense storms
  - increased frequency
  - magnitude and duration
- expected constancy of precipitation
  - reduction in snowfall
  - increased likelihood of severe summer storms
- largely impacts older fully built areas
  - supercharged sub-surface sewers back up onto the surface

Year	Record Events
2000	wettest summer in 53 years
2001	driest growing season in 34 years
	first ever "heat alert"
2002	warmest summer in 63 years
	5th coldest Spring ever
2003	rare mid-Spring ice storm
	Pearson Airport used a month's supply of glycol de-icer in 24-hours
2004	year of the wettest summer
2005	warmest January 17 since 1840
	January 22nd blizzard with whiteouts
	August 19 storm washed out part of Finch Avenue
2006	23 tornadoes across Ontario (14 normal)
	record one-day Ontario summer power demand of 27,005 MW
2007	protracted January thaw
	2nd least snow cover ever in Toronto (½ the normal amount)
	2-to-3 times the normal number of hot days in the summer
	record latest-in-season string of +30°C days around Thanksgiving
2008	Toronto's 3rd snowiest winter ever
	record for highest summer rainfall
2009	3rd rainiest February in 70 years
	one of the wettest summers on record
	unusually mild and storm-free and snow free November in Toronto
	first snow-free November at Pearson Airport since 1937

Recent Toronto Weather Events

Appropriate Science and Why … 1

- How Best to Downscale?
  - Statistical Approach
    - requires lengthy and reliable dataset of large scale climate elements plus local climatic conditions (LACKING)
    - does not engender confidence in a doubting public
  - Dynamic Approach
    - continuation of same approach taken by GCMs and RCMs
    - advantages
      - produces data and results where there is no data
      - based on fundamental and accepted physical principles
      - internally physically consistent

Appropriate Science and Why … 2

- What GCM or RCM Results to Start with?
  - governed by what was available to the team
  - Hadley Centre GCMs and RCMs
    - used HadCM3 (300x300 km grid) to drive PRECIS (50x50 km grid)
- Which SRES Scenario?
  - A1b – QUMP 15 (emphasizes extremes)
- Which Present and Future Time Periods?
  - recent 10-year period (most recent period available at time of the study – 2000-2009)
  - future 10-year period (not too far into the future since we wanted to engage local politicians – 2040-2049)

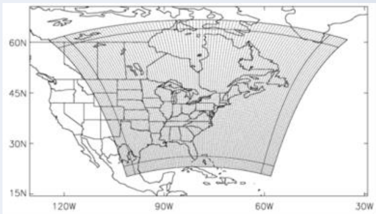
Dealing with Uncertainty

- at the time of the study the approach used was new and untried and municipalities are afraid to take risks
- the city insisted that study include a **meteorologist's assessment** of the current climate drivers and local modifying conditions
  - future case had to be accompanied by a logically acceptable physical explanation of why the future would be different
- used a **peer review group** of climate modellers and meteorological science advisors to oversee every stage

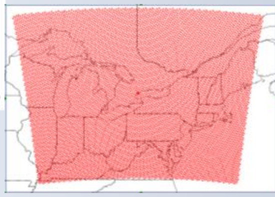
A Sequenced Approach

1. simulate the global climate
   - HADCM3 (300x300 km grid 6-hour time resolution)
   - IPCC A1b using Quantifying Uncertainty in Modelling Predictions (QUMP) 15 variation (to emphasize convective tendency and extremes)
2. simulate regional climate
   - PRECIS (50x50 km grid 6-hour time resolution)
3. simulate weather drivers over Southern Ontario
   - WRF-NMM (4x4 km grid 20-second time step aggregated to 1-hour averages)
4. simulate weather details over Greater Toronto Area
   - WRF-NMM (1x1 km grid, 20-second time step aggregated to 1-hour averages)

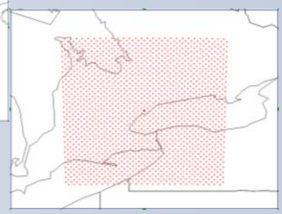
Domains



global and regional



4x4 km grid



1x1 km grid

How Well Does the Model Work … 1

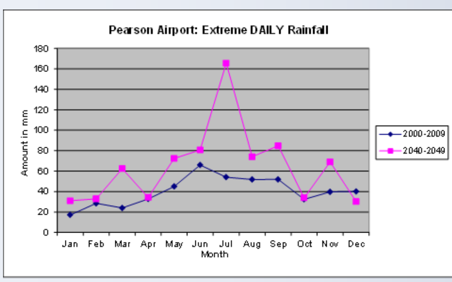
- 2000-2009
  - simulated period using historical analysis fields to drive WRF-NMM
  - compare against hourly observations to assess capability of model to reproduce observed near-surface fields
- 2000
  - drive WRF-NMM with PRECIS RCM output (to assess additional error introduced by driving the weather model with RCM output)

How Well Does the Model Work … 2

- climate models often correct their outputs by applying a “bias” correction (difference between modelled and observed values)
- our approach was not to correct or hide the error but rather just document it
  - gives a truer picture of the level of confidence in the model

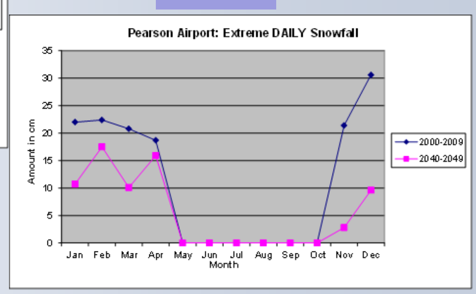
Daily Extreme Precipitation

2000-2009 and 2040-2049



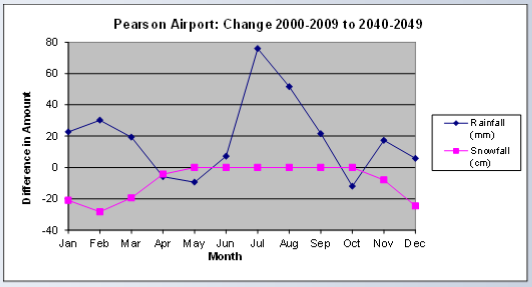
RAIN

SNOW



Monthly Precipitation Differences

2000-2009 to 2040-2049



Maximum Precipitation Intensity over the Period in millimetres / hour															
Return Period	1-Hour			2-Hour			6-Hour			12-Hour			24-Hour		
	1940-2003	2000-2009	2040-2049	1940-2003	2000-2009	2040-2049	1940-2003	2000-2009	2040-2049	1940-2003	2000-2009	2040-2049	1940-2003	2000-2009	2040-2049
2-Year	22.0	12.7	22.0	14.0	9.9	18.4	5.8	5.4	9.3	3.5	3.3	5.5	2.2	1.9	3.3
5-Year	29.5	17.2	32.2	18.0	12.6	25.0	7.6	7.3	14.8	4.7	4.2	8.0	2.9	2.3	4.7
10-Year	35.0	20.2	39.0	20.0	14.3	29.4	9.0	8.6	18.4	5.2	4.7	9.7	3.3	2.6	5.6

Number of Storms by Year

OBSERVED

Year	Total	Summer	Winter
2000	32	25	7
2001	18	11	7
2002	26	20	6
2003	30-	21	9
2004	35	16	19
2005	31	15	16
2006	29	16	13
2007	20	15	5
2008	26	18	8
2009	33	18	15
Average	**28**	**18**	**11**

MODELLED

Current Period (2000-2009)				Future Period (2040-2049)			
Year	Total	Summer	Winter	Year	Total	Summer	Winter
2000	28	16	12	2040	15	10	5
2001	26	16	10	2041	23	14	7
2002	39	23	16	2042	22	14	8
2003	30	16	14	2043	21	18	4
2004	32	16	15	2044	27	19	8
2005	28	16	11	2045	32	26	5
2006	32	18	14	2046	21	15	6
2007	32	16	16	2047	24	19	5
2008	30	16	14	2048	27	21	6
2009	26	15	11	2049	21	17	4
Average	**30**	**17**	**13**	**Average**	**23**	**17**	**6**

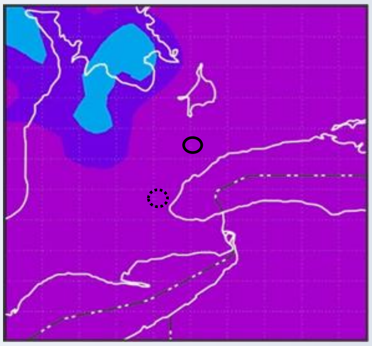
23% fewer storms overall; 57% fewer winter storms; but same amount of precipitation overall

Bringing it Together in the Municipality

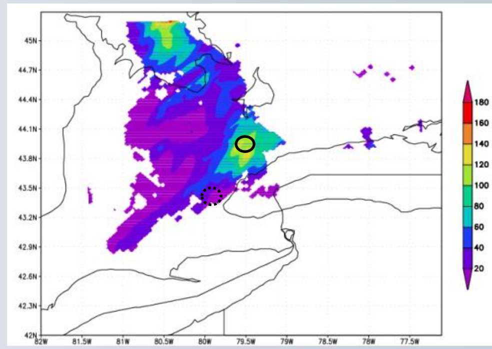
Parameter	2000-2009	2040-2049
100 Year Return Period Max Daily Rain (in mm)	81	204
Max Rain in one day (in mm)	66	166
Number of Days >30°C	20	66
Number of Days with Frost (Minimum T < 0°C)	128	70
Number of Days Air Conditioning Required (T>24°C)	33	180

An Historical Example

- 19 August 2005
  - localized centre of high intensity rainfall
- high storm flow in a small creek
  - unable to pass through a culvert partially blocked by a fallen tree
  - destruction of a major arterial road and culvert under it
- lengthy road closure and high economic losses
  - re-routing of transit buses cost $1.5 million in extra fuel
  - reconstruction and improvements = $47 million
  - private insurance damage costs = $600 million (most from flooded basements)



12x12 km grid simulation



1x1 km grid simulation

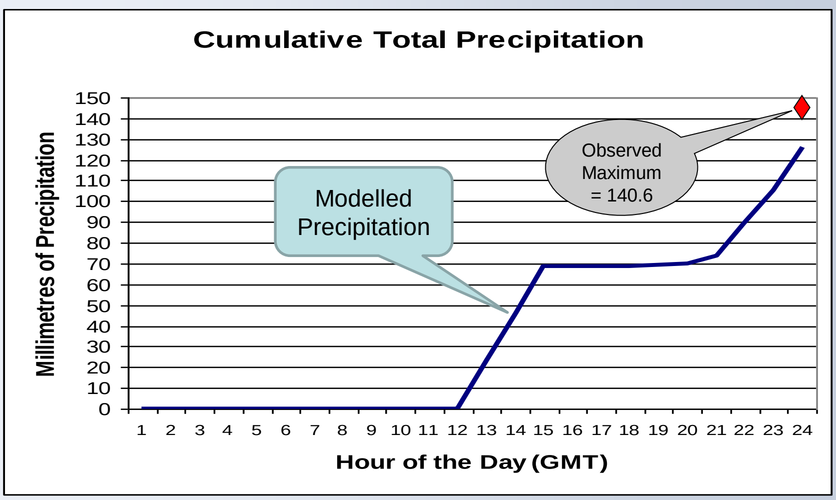
OBSERVED OVER 24 HOURS

O Finch Avenue (141mm)
◌ Pearson Airport (43mm)

19 August 2005

FINCH AVENUE WASHOUT RAINFALL PREDICTION

How Good is the Washout Simulation?




imagine the result