Climate Change in Canada and Implications for Urban Flooding

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Environment Canada

ARC Webinar 4 – Climate Change & Urban Flooding
May 20, 2008

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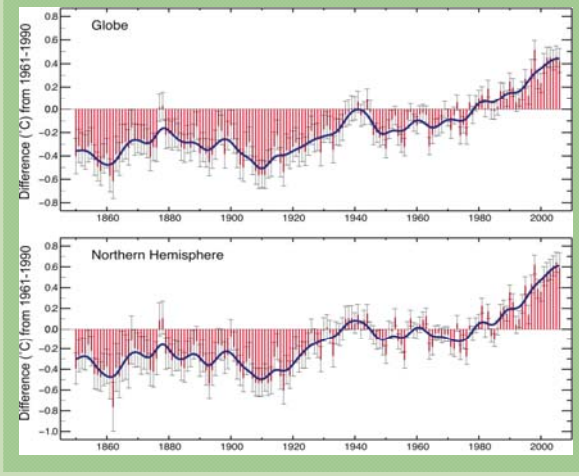
A Globally Warming Climate

"Warming of the Climate System is Unequivocal" (IPCC, 2007)



- 0.74°C increase in mean temperature from 1906-2006
- 11 of last 12 years (1995-2006) warmest on instrumental record since 1850
- Most of observed increase in temps since 1950 very likely due to anthropogenic increase in GHG

Source: IPCC (2007)

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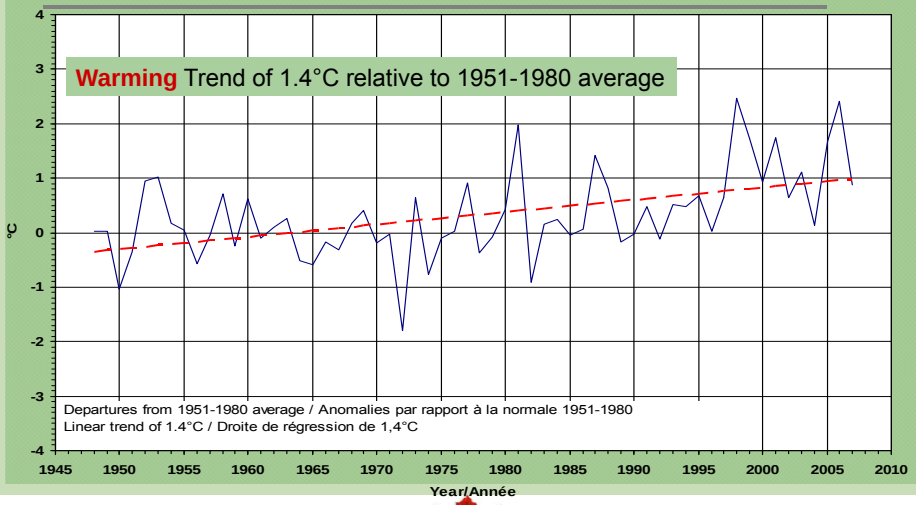
Warming in Canada

Annual National Temperature Departures and Long Term Trend
1948-2007



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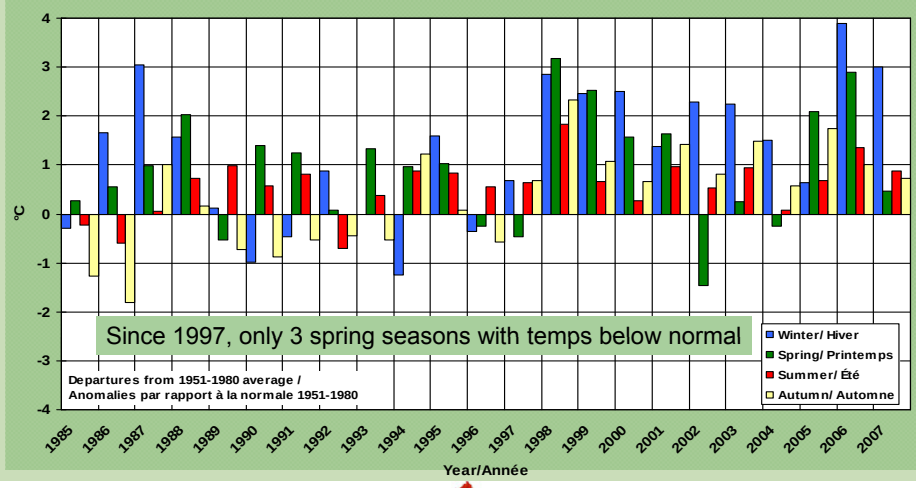
Warming in Canada

Seasons National Temperature Departures from 1951-1980 Average



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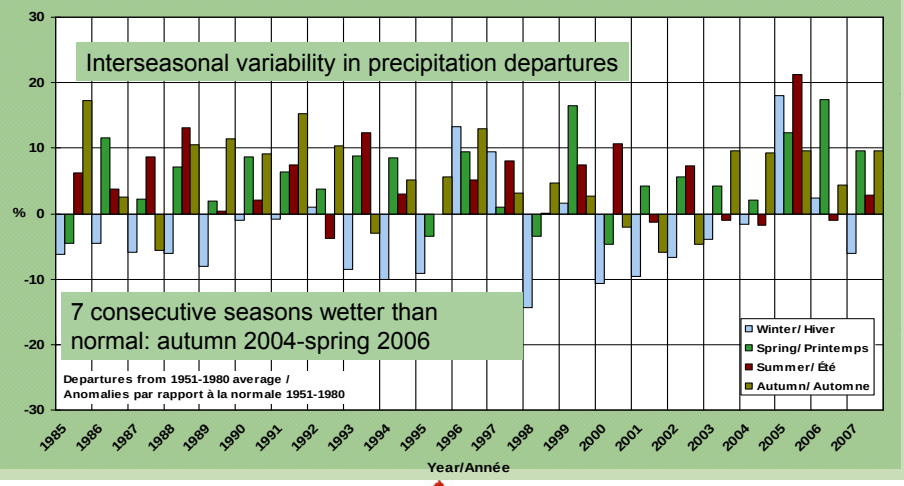
Changing Precipitation Patterns in Canada

Seasons National Precipitation Departures from 1951-1980 Average



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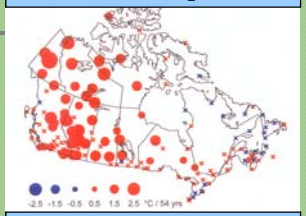
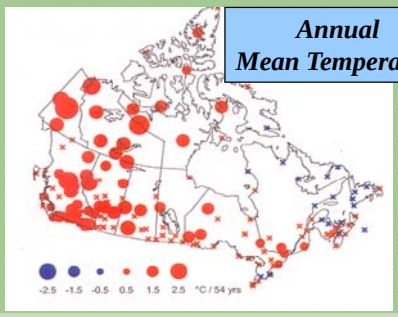
BUT Warming has Not Been Uniform across Canada

- Greatest warming western Canada
- Non-significant cooling in east
- Changes in mean, max & min temps

Annual Maximum Temperature

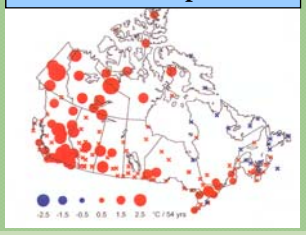


Annual Mean Temperature



Trends from 1950-2003

Annual Minimum Temperature

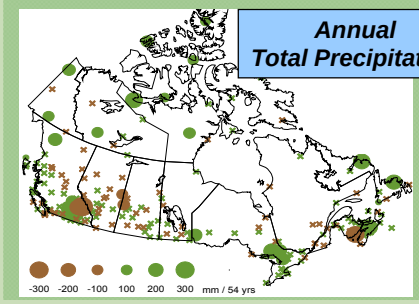


Source: Environment Canada Climate Research Division, Vincent and Mekis, 2006

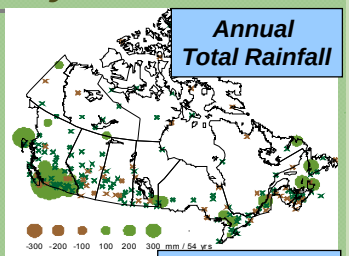
Variations in Precipitation Trends Across the Country

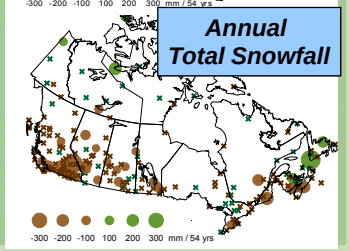
Over most of Canada:

- Getting wetter but non-uniform changes
- Generally more rain and less snow
- **Potential implications for flooding**



Trends from 1950-2003

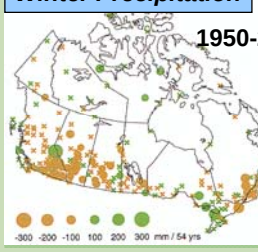


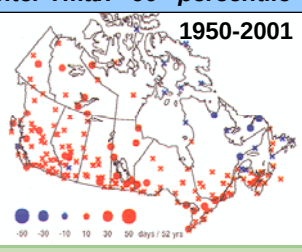


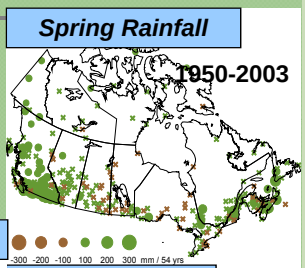
Source: Environment Canada Climate Research Division, Vincent and Mekis, 2006

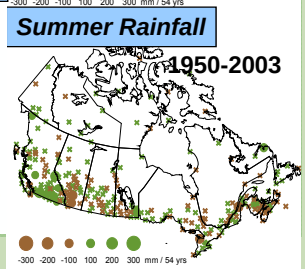
Seasonal Variations are Important as Well

- Much of Canada is wetter in spring
- Wetter, drier across Canada in summer
- Significantly **drier** in many areas in winter
- **Warmer** winters
- **Potential implications for ice jam, snowmelt, winter rain flooding; timing of spring freshet**





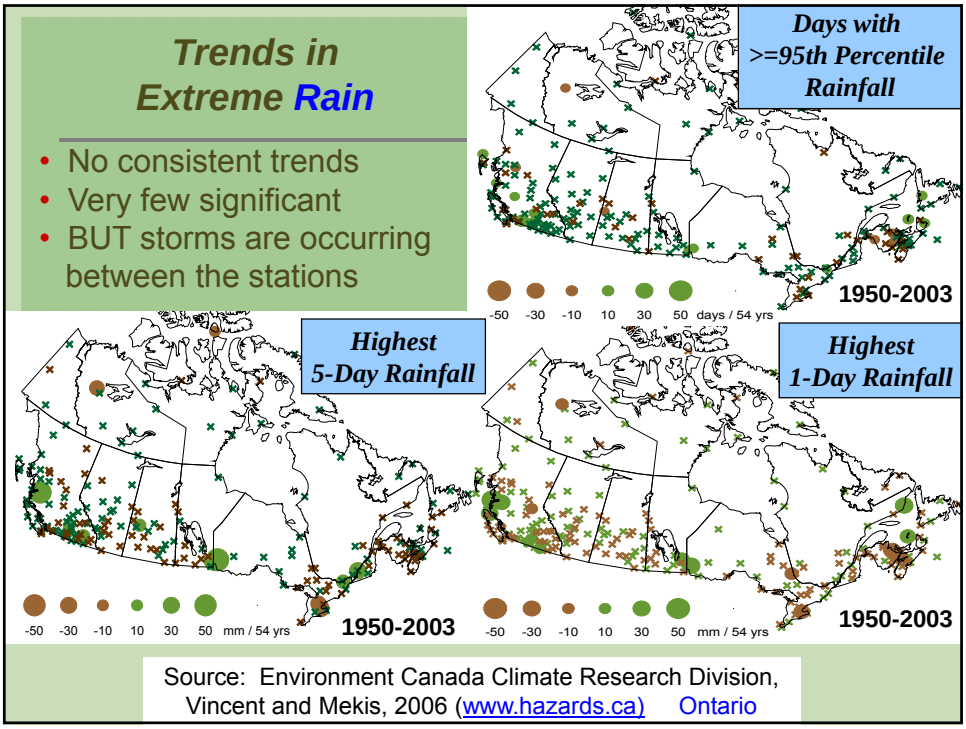




Source: Environment Canada Climate Research Division, Vincent and Mekis, 2006

Trends in Extreme Rain

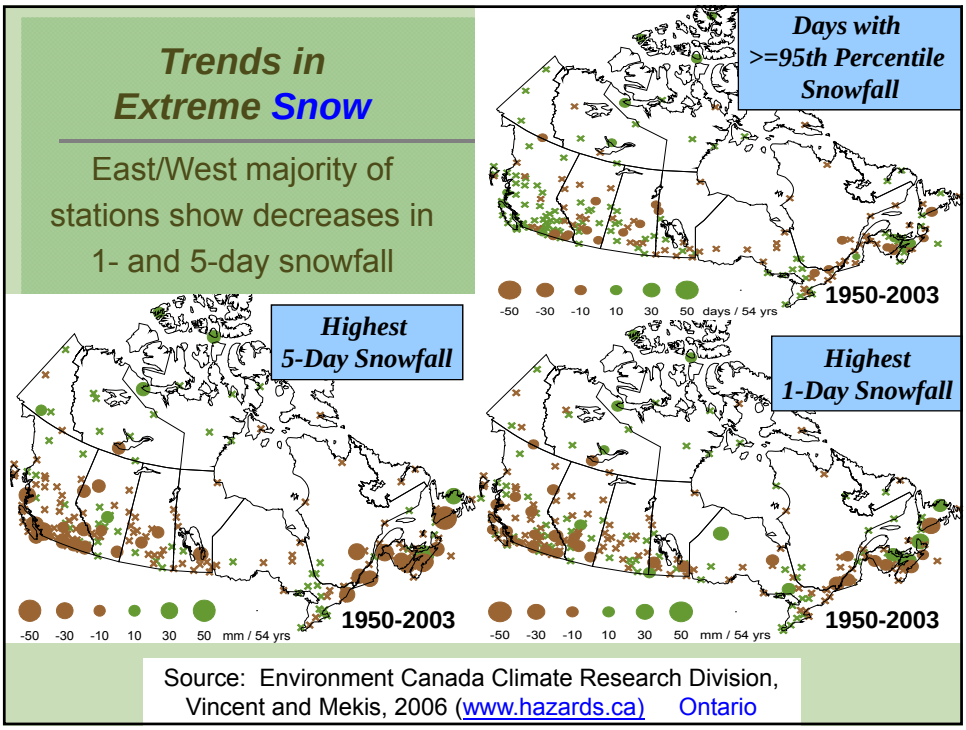
- No consistent trends
- Very few significant
- BUT storms are occurring between the stations



Source: Environment Canada Climate Research Division, Vincent and Mekis, 2006 (www.hazards.ca) Ontario

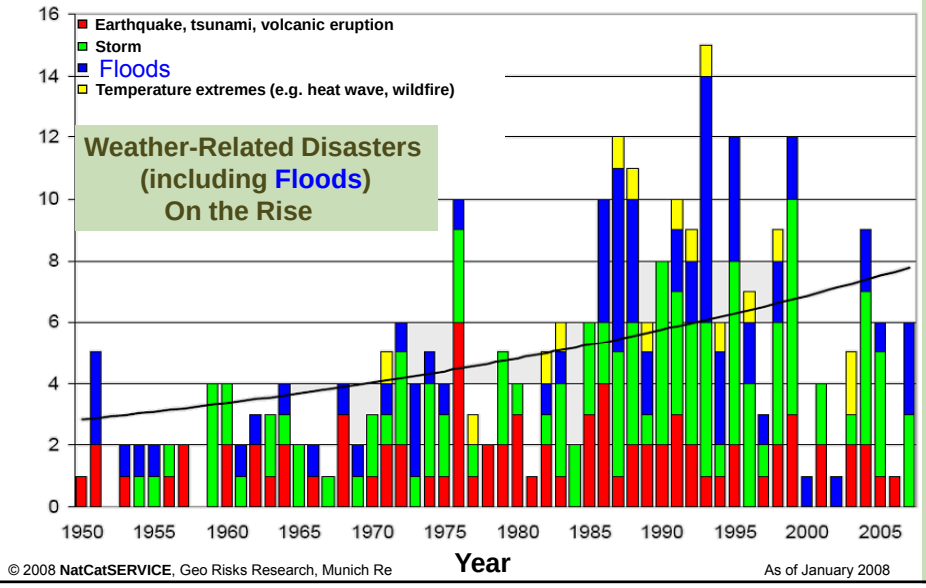
Trends in Extreme Snow

East/West majority of stations show decreases in 1- and 5-day snowfall



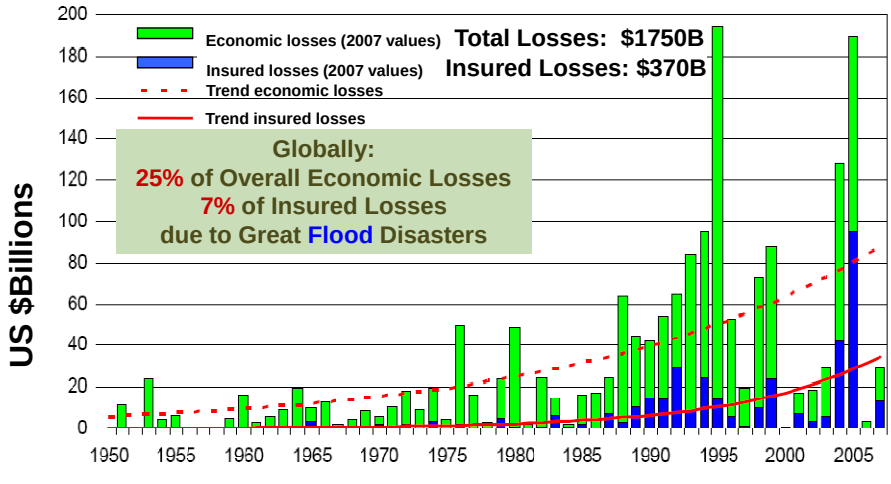
Source: Environment Canada Climate Research Division, Vincent and Mekis, 2006 (www.hazards.ca) Ontario

Great Natural Disasters Worldwide 1950 – 2007
Number of Events



As of January 2008

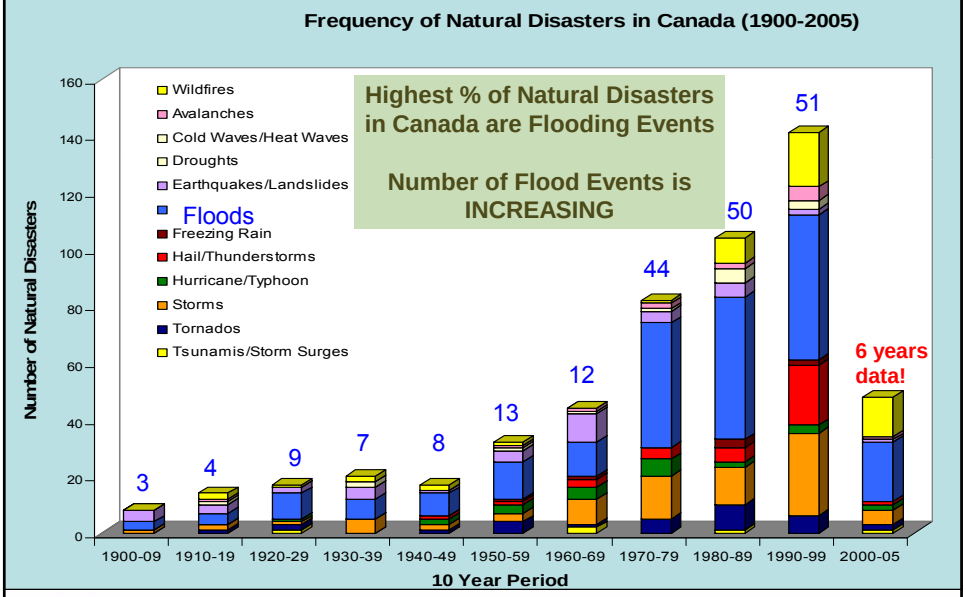
Great Natural Disasters Worldwide 1950 – 2007
Economic and insured losses



As of January 2008

(Great natural disasters defined as > 100 deaths and/or US$ 100M in claims)

Natural Disasters in Canada



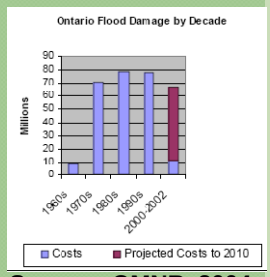
Public Safety and Emergency Preparedness Canada | Sécurité publique et Protection civile Canada

KEEPING CANADIANS SAFE

A Provincial Perspective on Costs, Occurrence of Flooding

In **Ontario**:

- Flood frequency/intensity are increasing
- Flood damage costs are escalating
- Severe storms attributed to the escalation of flood damage
- State of emergency/municipal disaster has been declared virtually every year since 1995



Source: OMNR, 2004

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Causes of Flooding in Canada

- **Rapidly melting snowpack**
  - most common type of flooding in Canada
  - generally occurs in spring but also during sudden winter thaws
  - additional rain on snowpack can exacerbate flooding
- **Ice Jams**
  - form during both freeze-up & breakup periods
  - usually breakup jams have greatest flood potential
  - breakup jams in spring or during winter thaws
  - additional rainfall can exacerbate flooding
- **Thunderstorms**
  - intense, usually short duration, events leading to flash flooding
  - areal coverage generally limited/localized

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Causes of Flooding in Canada (cont'd)

- **Rainfall associated with:**
  - large scale weather systems
  - tropical & extratropical storms, hurricanes
- **Storm surge and Seiche effects**
  - coastal storms with high wind and wave action
- **Outburst floods**
  - sudden drainage/release from lakes dammed by glaciers/moraines
  - occur in western Canada

ALL of the above can impact on urban communities

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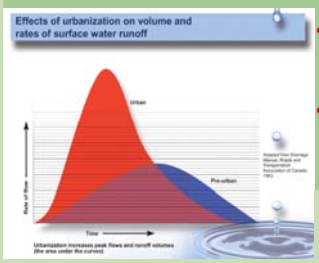
Urban Flooding

Changes in Climate/Weather/Sea Level coupled with Urban Vulnerability

- Vulnerable Infrastructure: high $ investment BUT aging, deteriorating with fewer $ being spent to replace/retrofit (design to past climate?)
- Vulnerability increases with higher population density & when flooding impacts on electrical, electronic, communication systems



- Increased vulnerability with community location (e.g. coastal, near/on floodplain)
- "Human" element with concerns over public safety, damage/destruction to private property

Urban land use/impervious surfaces result in increases to peak flows & runoffs

Vulnerability to Flooding

Snowmelt

Red River Flood, MB – April, May 1997

- Higher than normal fall precipitation
- Major early April storm dumped additional 50-70 cm of snow on near record snowpack of 250 cm
- Most severe flood on river since 1826
- Red River rose >12 m above winter levels
- 28,000 people forced to evacuate
- Estimated damage losses: over $800 Million
- Damages PREVENTED by flood control works/dykes (including Red River floodway) estimated at over $6 Billion

Vulnerability to Flooding
Ice Jams

Badger, NF – February, 2003

- Ice jam backup in 3 rivers on Feb 15
- Water levels rose 2.5 m in 1 hour
- State of emergency declared
- Town evacuated: ~1100 people
- After the flood: temps <-20C, encasing town in ice over 1 meter thick

Nechako River, BC – December 2007

- 6 km long ice jam
- State of emergency, evacuations in Prince George

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Vulnerability to Flooding
Intense Thunderstorms

Photo credit: Rachel Kulasas

Edmonton Storm – July 11, 2004

- Over 100 mm rain, up to golf ball size hail in just over 90 minutes
- Evacuation of West Edmonton Mall
- Storm sewer overflow, basements flooded
- $180 million in damages

Toronto Storm – August 19, 2005

- Up to 175 mm of rain; 103 mm in 1 hour
- ~3 hours in duration
- Road failure, erosion, major channel realignment
- Ontario's costliest weather disaster
- Estimated insured losses >$500 million

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Vulnerability to Flooding
Rainfall from Large Scale Storm Systems

Saguenay, QB – July 1996

- 290 mm of rain in less than 36 hours
- 10 deaths
- Canadian Red Cross assisted in evacuations of over 15,000 people from homes
- Roads, bridges washed out
- Estimated costs at $1.7 billion

NS, south NB, west NL – March 31, 2003 (early April)

- Heavy rain + thaw: ~80-120 mm rain
- Evacuations in Truro, NS
- State of emergency Oxford, NS
- Roads, bridges washed out
- Estimated $15.6 million losses NS public infrastructure alone (2003)

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Vulnerability to Flooding
Rainfall from Large Scale Storm Systems

Southern Alberta – June 2005

- 3 major rainfall events about a week apart
- Monthly rainfall totals close to 400 mm in some areas (Calgary International Airport 278 mm)
- Unprecedented flooding on Bow, Elbow Rivers
- 14 communities declared states of emergency
- Thousands of evacuations (including 2000 in Calgary)
- One of costliest natural disasters in AB history
- Estimated losses (insured, uninsured) of over $400 million

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Vulnerability to Flooding
Storm Surge

Atlantic Canada – January 21, 2000

- Intense winter storm – snow, rain, wind and storm surges/coastal flooding
- Storm surge of 1.4 m coincided with high tides
- Coastal areas flooded, including downtown Charlottetown
- Charlottetown's max water level of 4.22 m exceeded previous record by 39 cm
- Damage estimates for all areas ~ $20 million

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Globally to the Regional & Local Scale in Canada

- Scientific evidence indicates that our climate and its extremes ARE changing
- Occurrence, severity of floods increasing, and flood-related economic losses on the rise
- Urban communities and infrastructure are particularly vulnerable to flooding

Will CLIMATE CHANGE Potentially Lead to an Increased Risk of Urban Flooding in the 21st Century?

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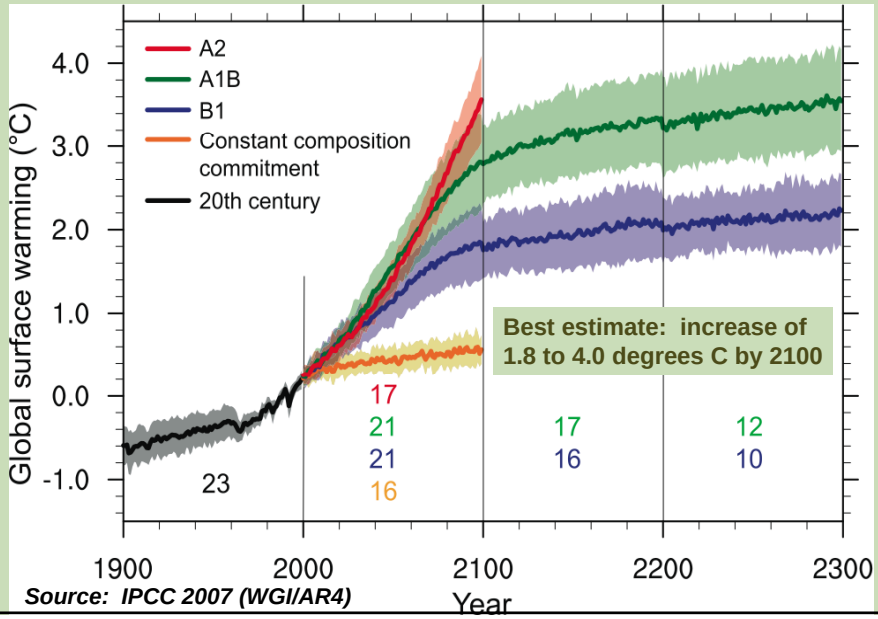
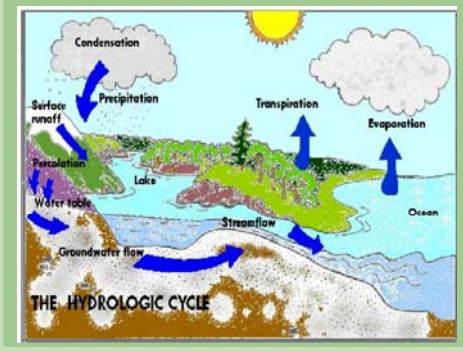
Global Temperatures Continue to Rise
Greater Warming with Greater Increase in GHGs



Source: IPCC 2007 (WGI/AR4)

CLIMATE CHANGE
More than Just Global Warming

A warmer atmosphere with increased water holding capacity will very likely result in:



- ✓ Altered precipitation patterns
- ✓ Changed atmospheric circulation and storm tracks
- ✓ A more active hydrological cycle with more frequent and intense precipitation events, with increased flood risk

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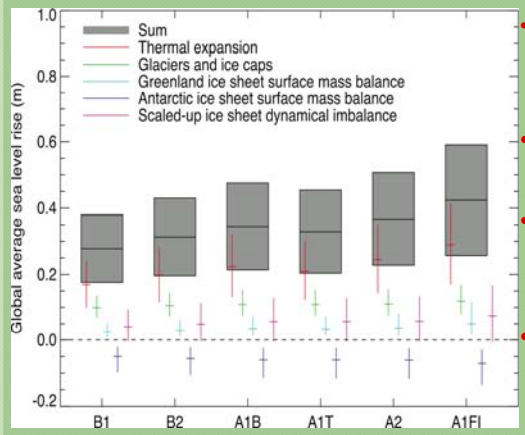
Climate Change Related Sea Level Rise in 21st Century



- GCMs project global rise in sea level of 0.2 - 0.6 m by 2100
- BUT still uncertainties in projections
- Complex effects of changes in ice flows, for example, not included in modelling
- Sea level rise on Canada's west, east, north coasts; **flooding implications**

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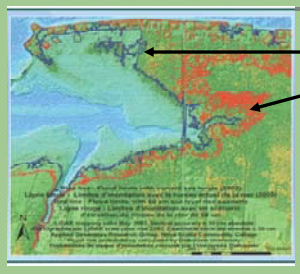
Climate Change and Sea Level Rise in Southeastern NB Coastal Zone



10 year return period Storm Surge, Pointe-aux-Bouleaux 2003, future 60 cm sea level rise

"The current 40-yer storm-surge return level is expected to become closer to a 5-year return level with a 60-cm sea-level rise scenario expected by 2100."

- Under climate change, sea level rise and large storm surges eventually phasing with sufficiently large tides…expect new record water levels in the study area and at Charlottetown
- **Flooding** will increase dramatically in frequency

Source: Environment Canada, 2006

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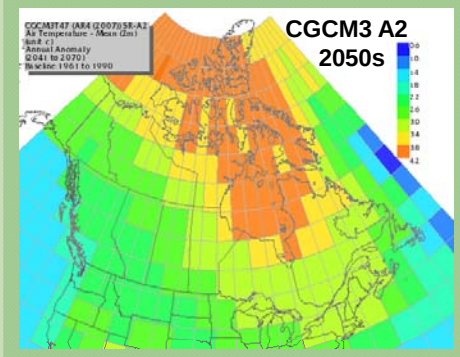
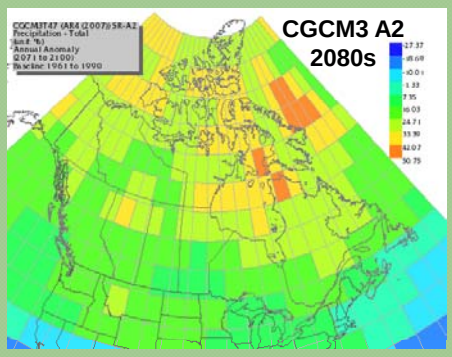
Warmer and Wetter in future Canada; BUT non-uniform seasonal and regional changes





Mean Annual Air Temperature — Mean Annual Precipitation

Changes relative to 1961-1990

Source: Environment Canada www.cccsn.ca

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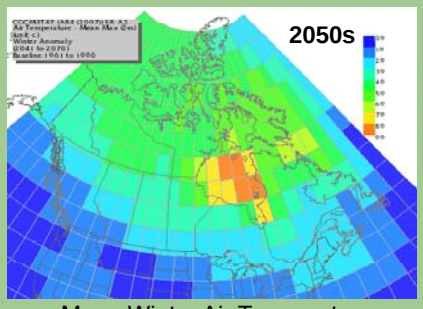
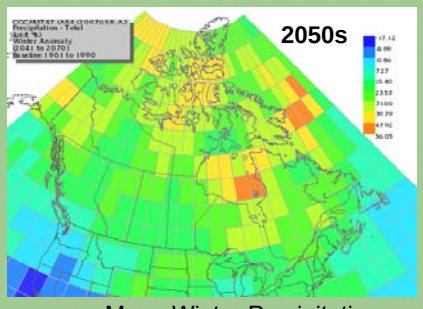
Warmer Winters in Future
GCMs have Regional Differences in Wetter or Drier

- Potential for increased risk of Ice Jam, Snowmelt, Winter Rain floods
- Changes in flood seasonality





Mean Winter Air Temperature — Mean Winter Precipitation

Changes relative to 1961-1990

Most GCM model scenarios project **WARMER**, **WETTER** winters in Canada by 2050s

Source: www.cccsn.ca

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CLIMATE CHANGE

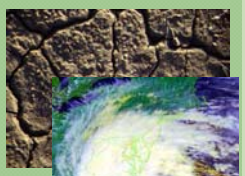
Changes in Precipitation Extremes, Sea Level

(IPCC 2007: AR4)

Very Likely (>90%)

- More intense, more frequent ***precipitation events***

IMPLICATIONS for Flooding



Likely (>66%)

- Increased frequency, severity of drought
- Increases in ***intense tropical cyclones***
- Increased occurrence of ***extreme high sea level***

IMPLICATIONS for Flooding

? Increases in thunderstorms, tornadoes, hail, etc.

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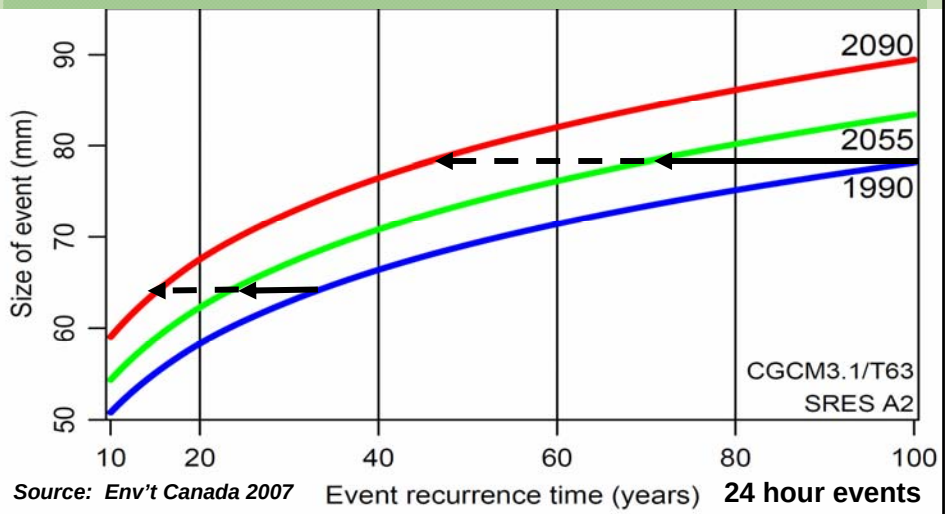
Projections of Extreme Precipitation Events in Canada

"Probability of precipitation events considered extreme in the year 2000 is expected to increase by at least a factor of 2 by the end of the 21st century."



Source: Env't Canada 2007

24 hour events

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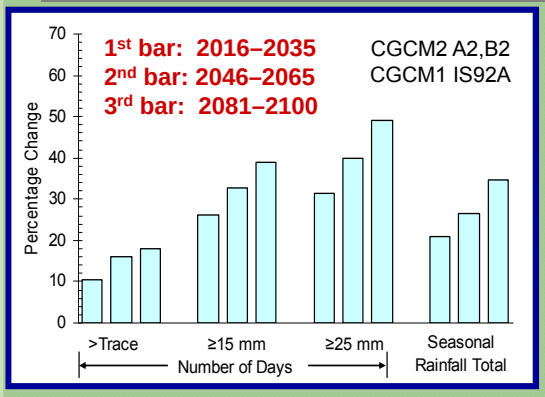
Projected Changes in Southern Ontario's Future Warm Season (Apr-Nov) Rainfall



- Averaged over 4 selected basins, 3-GCM ensemble, and relative to 1961-2002
- Increase in seasonal total (20-35%)
- Increase in # of days with rainfall, regardless of daily rainfall amount

BUT

Greatest increases (30-50%) in the heavier rainfall days (>=25 mm)

Source: Cheng et al., 2007

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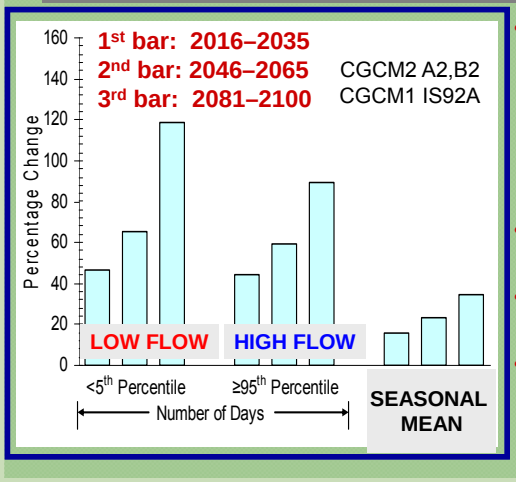
Projected Changes in Southern Ontario's Future Warm Season (May-Nov) Streamflow



- Modelled results averaged over the selected basins, 3-GCM ensemble, and relative to 1961-2002
- 45-120% increase in LOW flow
- 45-90% increase in HIGH flow
- 15-35% increase in SEASONAL MEAN streamflow

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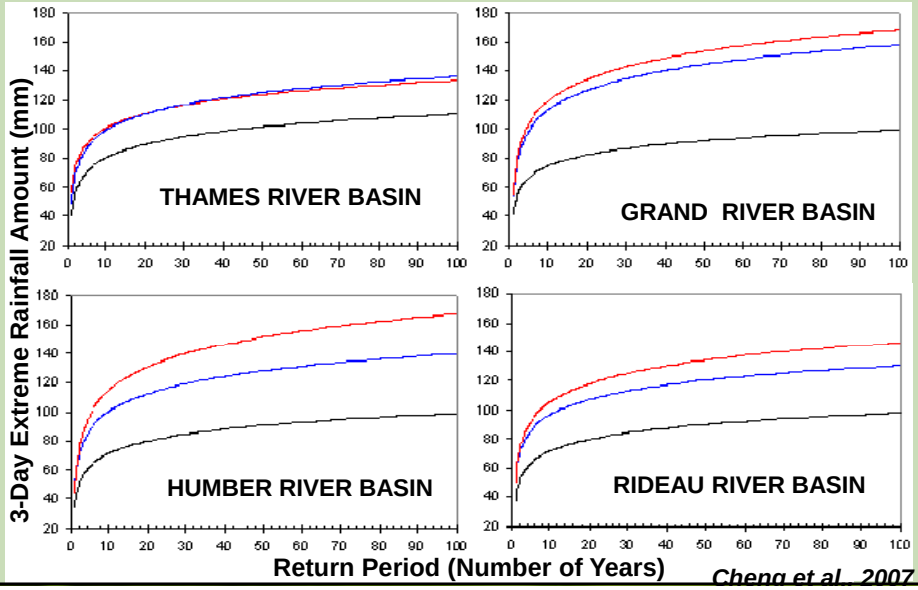
Return Period: 3-Day Accumulated Rainfall

(1961-2000, 2001-2050 and 2051-2100)



Cheng et al., 2007

In Conclusion

- Our climate and extremes are changing globally, nationally, regionally and locally
- Impacts will be significant, including increased risk of **FLOODING**
- Urban communities and built infrastructure are particularly vulnerable
- **MITIGATION** is essential in climate change planning to slow the rate of climate change

BUT

- **ADAPTATION** strategies will also be necessary

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In Conclusion

Adaptation will need to include no regret actions/plans. For example :

- Updated **flood plain maps**
- Better **disaster management** planning
- Improved **weather and flood forecasting/warning** programs
- Maintenance (or expansion!) of hydrological, meteorological **monitoring networks**
- "Greening of urban landscapes" in **land use** planning
- Monitoring & enforcement of policies/regulations of **land use** in floodplains, unstable areas

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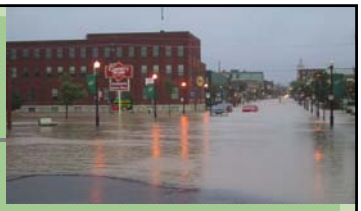
In Conclusion
(cont'd)



Building the adaptive capacity with no regret actions/plans for infrastructure, including:

- **Infrastructure monitoring, maintenance, lifecycle planning** programs (erosion, sedimentation monitoring as well!)
- Updated or increased **climatic design values** (retrofit or upgrade of old and building of new infrastructure)
- **Removal/replacement** of unsafe infrastructure

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Thank you!

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