State of Climate Change Science in the Great Lakes Basin

A Focus on Climatology, Hydrological and Ecological Effects

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Outline

1. About the OCC
2. State of Climate Change Science in the Great Lakes
   - Physical Effects
   - Environmental Chemistry and Pollutant Effects
   - Ecological Effects and Biodiversity
3. Climatology: Modeling & Trends
   - Confidence and Uncertainty
4. Key Messages
About OCC

The OCC was established in 2011 as a centre of expertise providing research and analysis services to municipalities, conservation authorities, and the broader public sector.
OCC in Brief

• We aim to deliver timely and high quality advice to Ontario’s public and private sector to support development and implementation of climate change mitigation and adaptation work.

• We coordinate research, analysis and interpretation amongst diverse expert groups to stimulate innovative thinking.

• We facilitate knowledge exchange to ensure the effective underpinning of policy and action resides in evidence-based approaches.
State of Climate Change Science in the Great Lakes Basin: The Context

• Climate impacts were included as an Annex of the 2012 Great Lakes Water Quality Agreement (GLWQQA) and the Canada-Ontario Agreement (COA) on Great Lakes Water Quality and Ecosystem Health ratified in 2014.

• Project partners include Environment Canada, the Government of Ontario and McMaster University.
Project Objectives

To provide researchers, managers and decision makers with a time-stamped (2015) examination of the state of climate change science in the Great Lakes Basin.
Project Objectives

• To understand how climate change science is being used for impact analysis and adaptation planning in the Great Lakes region

• To identify trends and knowledge gaps to inform future work and new priorities for climate change science in the Great Lakes
Synthesis of Climate Change Impacts in the Great Lakes

Theme 1: Physical Effects
- Water Temperature
- Water levels & surface hydrology
- Ice dynamics
- Groundwater
- Natural Hazards

Theme 2: Environmental Chemistry & Pollutants
- Chemical effects
- Nutrients
- Pollutants

Theme 3: Ecological Effects and Biodiversity
- Aquatic species
- Trees and plants
- Wildlife
- Pathogens and parasites
- Invasive species
Theme 1: Physical Effects

Ice Dynamics
- Cover
- Duration
- Thickness
- Extent

Decreasing

Climatology
- Air Temp.
- Precip.
- Wind
- Freezing Rain

Groundwater
- Winter recharge

Water Levels
- Lakes
- Rivers
- Wetlands

Natural Hazards
- Flood
- Fire

Increasing

Least Confident

Most Confident

Least Confident

Most Confident

Ontario Climate Consortium

www.climateconnections.ca
Theme 2: Environmental Chemistry and Pollutants

Decreasing

Most Confident

Least Confident

Increasing

Most Confident

Other Organohalogenes
Nitrogen
Oxygen

pH
Phosphorus
Carbon
Mercury
Theme 3: Ecological Effects and Biodiversity

Aquatic Species

• Less coldwater fish habitat
• Changes in competition due to range changes
• Fragmented rivers may impede expansion ability of species
• Changes in timing of phenology of amphibians
Theme 3: Ecological Effects and Biodiversity

Tress and Plants

- Tree species climate niche will shift northward
- Reduced growth rates for trees in the South (likely)
- Plant productivity may increase if not limited
- Distribution and abundance of wetlands will change.
- Wetland vegetation requiring little water may grow well
Theme 3: Ecological Effects and Biodiversity

Wildlife

- 45% decrease in optimal habitat for 100 climate threaten bird species in Ontario.
- Increased risk of hybridization
- Earlier breeding and hatching of bird species
- Disruptions to predator-prey relationships
Theme 3: Ecological Effects and Biodiversity

**Invasive species**
- Non-native species may increasingly become established
- Further expansion north of existing invasive species

**Pathogens**
- Increase in range and prevalence for both animals and humans
- Changes in parasite-host relationships
Confidence in Research Themes

Confidence determinations based on Mastrandrea et al. (2010) matrix for the IPCC 5th Assessment Report

![Confidence Matrix Diagram](image-url)
### Confidence in Research Themes

<table>
<thead>
<tr>
<th>Theme</th>
<th>Data confidence</th>
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<tr>
<td>Air temperature</td>
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<tr>
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<td>Wind</td>
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<td>Ice storms</td>
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<td>Carbon</td>
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Knowledge and Research Gaps

• Better characterize the impacts of climate change on lakes
• Integration of interconnections of ecosystem responses to climate change
• Improve the understanding of:
  • Groundwater recharge and discharge patterns, including the influence of groundwater changes on streamflow
  • Consequences of disturbed regimes
  • Climate change and direct effects on chemical exposure, fate and transport
• Better dissemination of research and findings to resource users, decision makers and practitioners
Climatology: Modeling and Trends
Climate Modeling: An Overview

- Climate models simulate the interactions that drive the Earth’s climate (e.g., atmosphere, land surface).
- Climate models discretize equations for energy and fluid motion and integrate these over time.
- Processes are solved within each grid and at the interface between grid cells.
- Local-scale processes (e.g., convection) can be difficult for models to capture.
Climate Model Resolution

Global Climate Model (GCM)

- 20 Climate Modeling Centres
- ~150 to 200 km² grid cells

Regional Climate Model (RCM)

- Downscaled Models (Dynamically or Statistically)
- ~10 to 50 km² grid cells
Climate Trends in Ontario: Annual Temperature

Historical (1981-2010)

Future (2080s)

Credit: Zhu and Deng (2014). Ontario climate change projections
Climate Trends in Ontario: Extreme Precipitation

Historical (1981-2010)  
Future (2050s)

Credit: Zhu and Deng (2014). *Ontario climate change projections*
Climate Trends in Peel Region: Extreme Precipitation

1-Day Maximum Precipitation
- Historical: 37mm
- 2050s: 8% increase

5-Day Maximum Precipitation
- Historical: 59.2mm
- 2050s: 10% increase

Extreme precipitation driven commonly driven by:
1. Large-scale synoptic systems
2. Local scale convection (thunderstorm, lake-breeze convergence)
Knowledge Gaps in Climate Modeling

- Local Earth and atmospheric feedback processes across the Basin, including those driven by detail missing in current models (e.g., land cover).
- Need for integration of:
  - Emerging model scenarios into research
  - Land use-regulation and management
  - Cumulative effects of environmental and climate stressors and impacts
  - Spatial dynamics of lakes into water temperature modeling
  - Changes in wind into ice dynamic models
- Validate model performance by prognostic and retrospective analyses.
Uncertainty in Climate Modeling

• Why does uncertainty exist?
  - Natural variability between locations
  - Large-scale variation in climate due to oscillations (e.g., El Nino)
  - Embedded assumptions within climate models
  - Missing information to drive climate models (e.g., local convective activity, historical wind data)

• Certain climate indicators are more uncertain to predict than others (e.g. Extreme Winds very difficult)
Dealing with Uncertainty

1. Strive to incorporate the best available climate data and trends in assessments when addressing impacts or designing systems.

2. If possible, use an ‘ensemble’ approach with models and scenarios to account for a range of plausible futures (e.g., test system sensitivity).

3. Be conservative when estimating risk with climate information.

4. Recognize ongoing decisions and human action will influence the future climate conditions and there will be a need for updating standards informed by climate data.
Dealing with Uncertainty: Characterizing Confidence in Climate Trends

- Temperature, Extreme Heat: **Very Likely** Increase
- Extreme Cold: **Very Likely** Decrease
- Precipitation, Extreme Precipitation: **Likely** Increase*
- Wind Velocity: **About as Likely as Not** to remain unchanged

*Likely more precipitation overall, however more will fall as short-isolated events. Greatest increases are winter & spring.

<table>
<thead>
<tr>
<th>Term</th>
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<tbody>
<tr>
<td>Virtually certain</td>
<td>99 – 100% probability</td>
</tr>
<tr>
<td>Very likely</td>
<td>90 – 100% probability</td>
</tr>
<tr>
<td>Likely</td>
<td>66 – 100% probability</td>
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<tr>
<td>About as likely as not</td>
<td>33 – 66% probability</td>
</tr>
<tr>
<td>Unlikely</td>
<td>0 – 33% probability</td>
</tr>
<tr>
<td>Very unlikely</td>
<td>0 – 10% probability</td>
</tr>
<tr>
<td>Exceptionally unlikely</td>
<td>0 – 1% probability</td>
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Key Messages

• Climate change may be the greatest environmental challenge facing ecosystem health in the Great Lakes Basin.

• Anticipated climate impacts are widespread, and some are more likely than others.

• It is important to include climate model outputs and trends when addressing climate change in a project, but...

• Shift away focus from ‘precise’ future climate conditions being provided from climate models.
  – Instead: Flexible solutions & strategies are needed that address greatest impacts and provide multiple benefits.
Thank You

Questions?

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