ONTARIO CLIMATE CONSORTIUM

# State of Climate Change Science in the Great Lakes Basin

## A Focus on Climatology, Hydrological and Ecological Effects

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Natural Channels Conference, Session M1D

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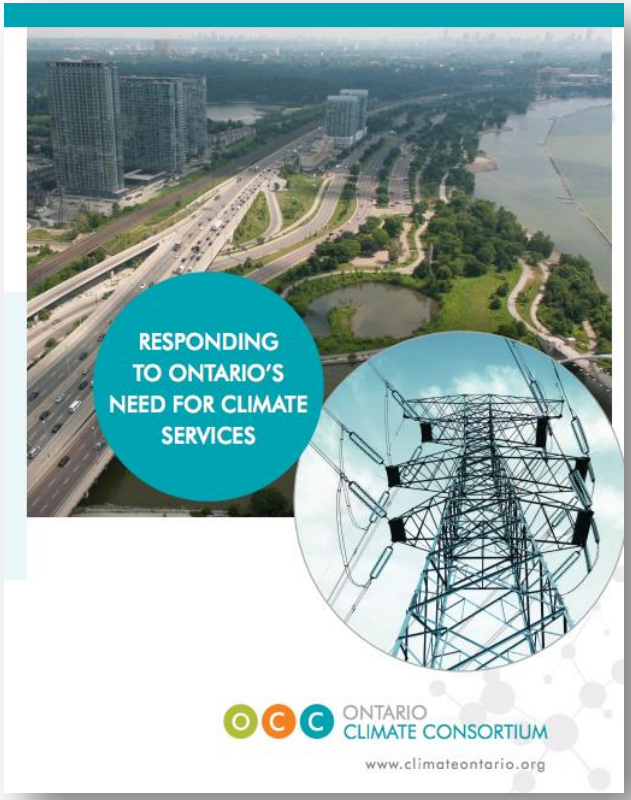
With support from: YORK UNIVERSITÉ UNIVERSITY, McMaster University, Western, Region of Peel Working for you, University of Guelph, Toronto and Region Conservation for The Living City

# 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.

Toronto and Region Conservation for The Living City · YORK UNIVERSITÉ UNIVERSITY · McMaster University · Region of Peel Working for you · Western University · Canada · University of Guelph

# 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.

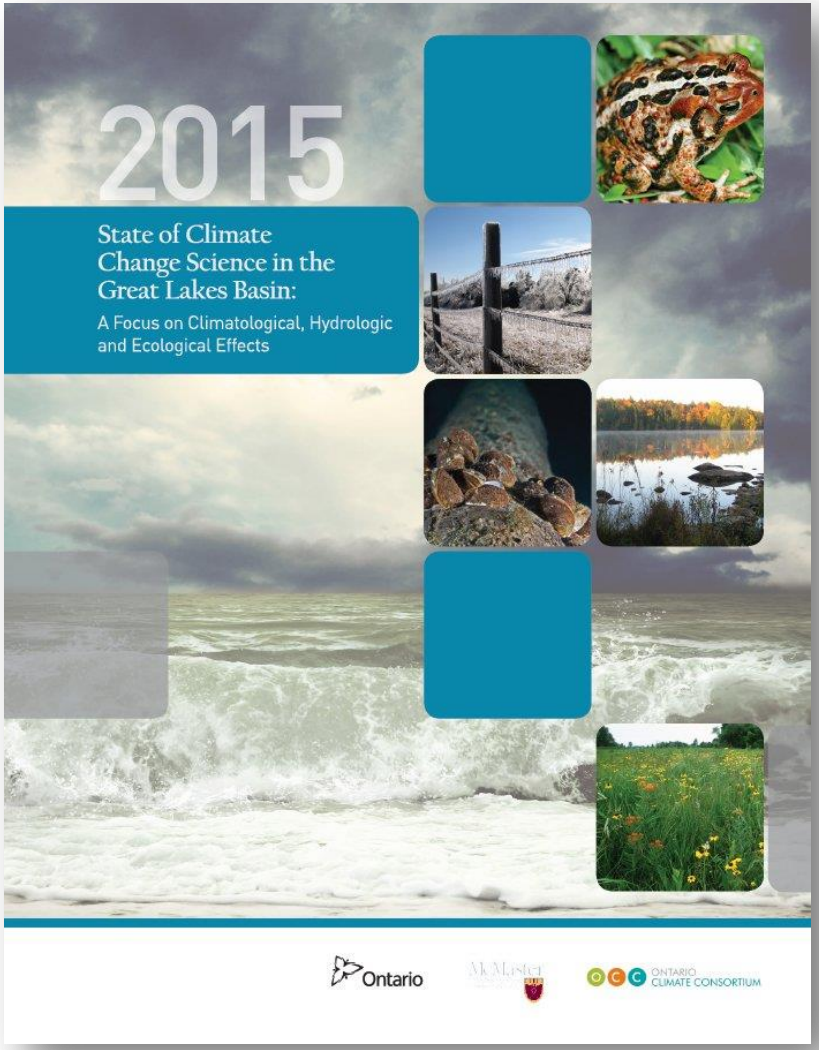
- We facilitate knowledge exchange to ensure the effective underpinning of policy and action resides in evidence-based approaches.

# 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 (GLWQA) 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

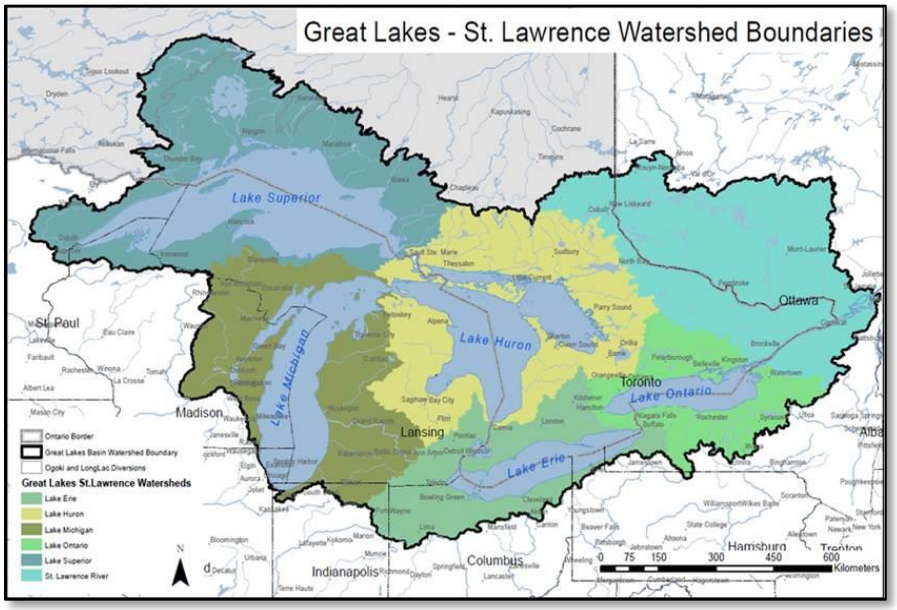
- To understand how climate change science is being used for impact analysis and adaptation planning in the Great Lakes region
- To identify trends and knowledge gaps to inform future work and new priorities for climate change science in the Great Lakes

Environment Canada

Environnement Canada

Ontario

McMaster University




Project Study Area: Laurentian 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

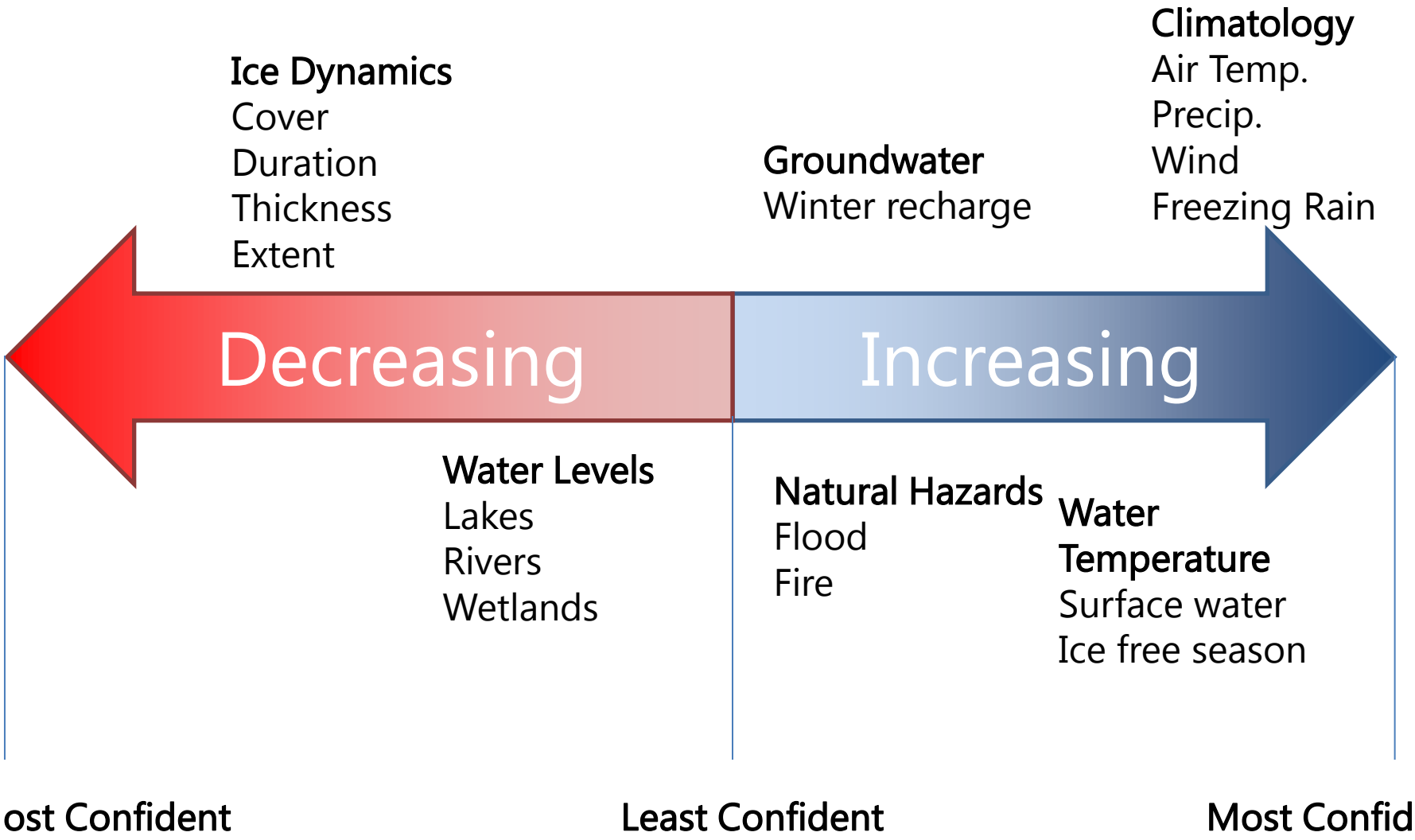
**Theme 2: Environmental Chemistry & Pollutants**

- Chemical effects
- Nutrients
- Pollutants

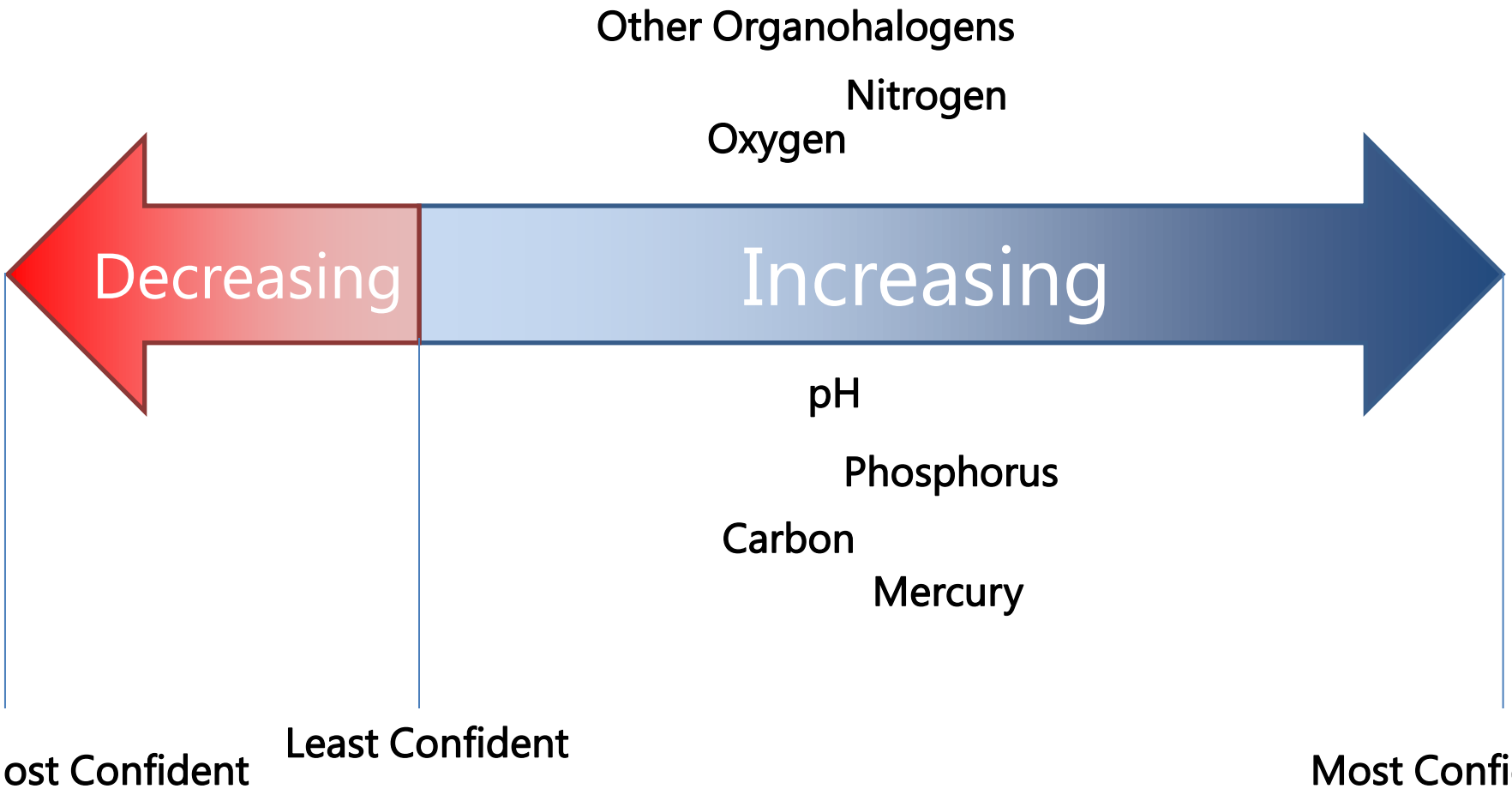
**Theme 3: Ecological Effects and Biodiversity**

- Aquatic species
- Trees and plants
- Wildlife
- Pathogens and parasites
- Invasive species

# Theme 1: Physical Effects



# Theme 2: Environmental Chemistry and Pollutants

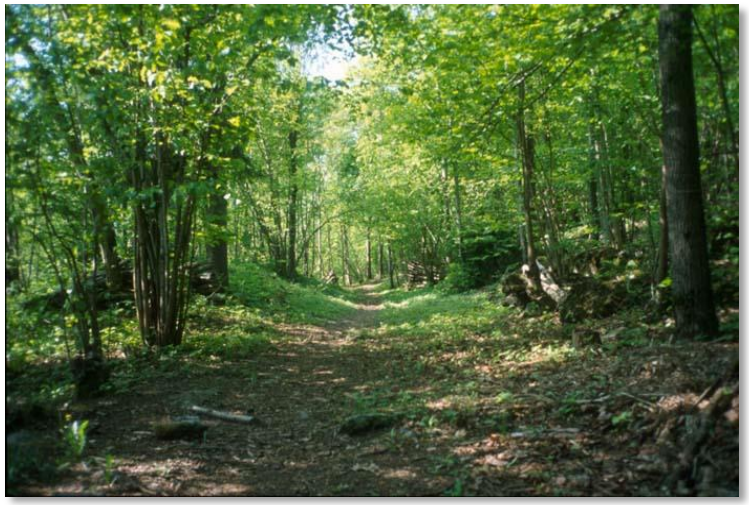


# Theme 3: Ecological Effects and Biodiversity

## 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

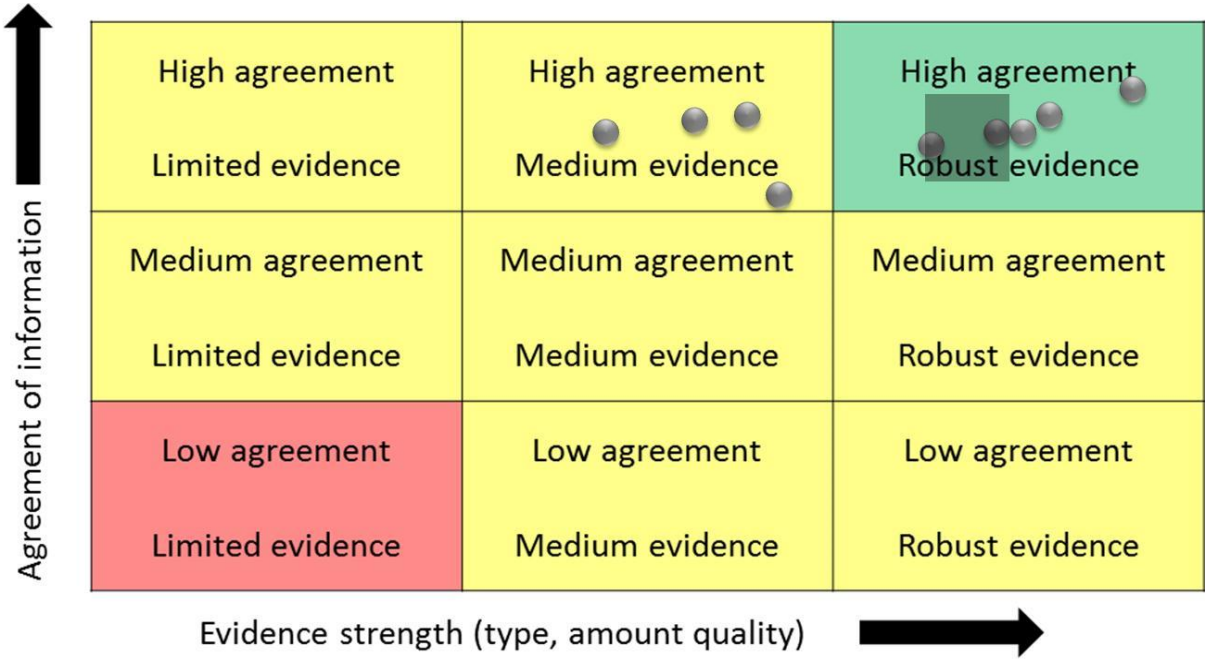
- Non-native species may increasingly become established
- Further expansion north of existing invasive species

## 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 in Research Themes

| | Theme | Data confidence |
|---|---|---|
| Physical Effects | **Climatology** | |
| | Air temperature | high evidence<br>high agreement |
| | Precipitation | high evidence<br>medium agreement |
| | Drought | low evidence<br>high agreement |
| | Wind | low evidence<br>low agreement |
| | Ice storms | low evidence<br>low agreement |
| | **Water temperature** | |
| | Lakes | high evidence<br>low agreement |
| | Rivers | low evidence<br>high agreement |
| | Wetlands | low evidence<br>low agreement |
| | **Water levels and surface hydrology** | |
| | Lakes | high evidence<br>low agreement |
| | Rivers | low evidence<br>high agreement |
| | Wetlands | low evidence<br>low agreement |
| | **Ice dynamics** | |
| | Lakes | medium evidence<br>high agreement |
| | Rivers | low evidence<br>low agreement |
| | **Groundwater** | low evidence<br>low agreement |
| | **Natural Hazards** | |
| | Flooding | medium evidence<br>medium agreement |
| | Fire | medium evidence<br>medium agreement |
| Environmental Chemistry and Pollutants | **Oxygen** | low evidence<br>low agreement |
| | **Acidity (ph)** | low evidence<br>low agreement |
| | **Phosphorus** | low evidence<br>low agreement |
| | **Nitrogen** | low evidence<br>low agreement |
| | **Carbon** | low evidence<br>low agreement |
| | **Mercury and other organohalogens** | low evidence<br>low agreement |

| | Theme | Data confidence |
|---|---|---|
| Ecological Effects and Biodiversity | **Aquatic species** | |
| | Range shifts | medium evidence<br>medium agreement |
| | Genetic changes | low evidence<br>low agreement |
| | Altered phenology | low evidence<br>low agreement |
| | Habitat alteration | medium evidence<br>medium agreement |
| | **Trees and plants** | |
| | Range shifts | medium evidence<br>medium agreement |
| | Genetic changes | medium evidence<br>medium agreement |
| | Altered phenology | medium evidence<br>medium agreement |
| | Habitat alteration | medium evidence<br>medium agreement |
| | **Wildlife** | |
| | Range shifts | medium evidence<br>medium agreement |
| | Genetic changes | low evidence<br>low agreement |
| | Altered phenology | medium evidence<br>medium agreement |
| | Habitat alteration | medium evidence<br>medium agreement |
| | **Pathogens and parasites** | |
| | Aquatic | low evidence<br>low agreement |
| | Trees and plants | low evidence<br>high agreement |
| | Wildlife | low evidence<br>low agreement |
| | **Invasive species** | |
| | Aquatic | low evidence<br>high agreement |
| | Trees and plants | low evidence<br>high agreement |
| | Wildlife | low evidence<br>low agreement |

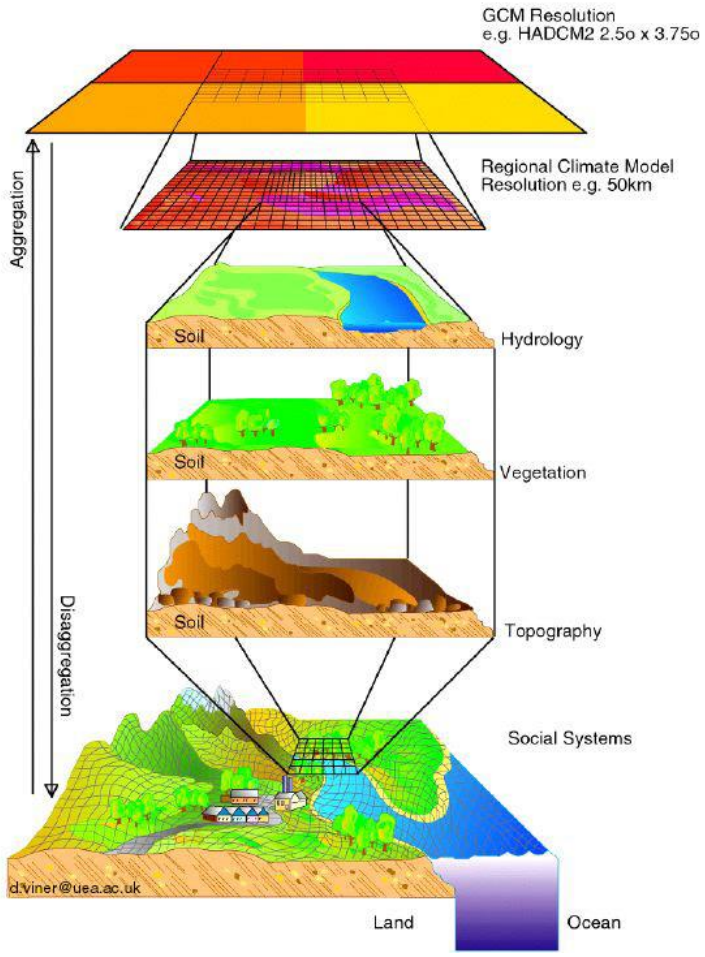
# Knowledge and Research Gaps

- 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

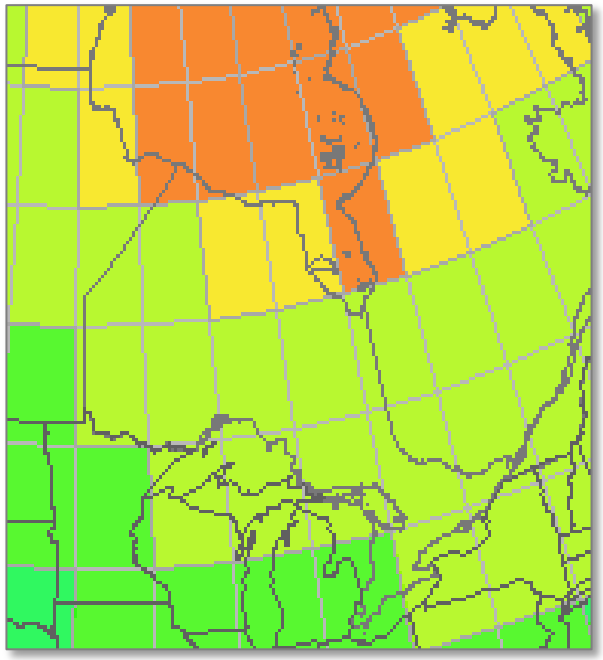
# Climatology:
# Modeling and Trends

# 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.

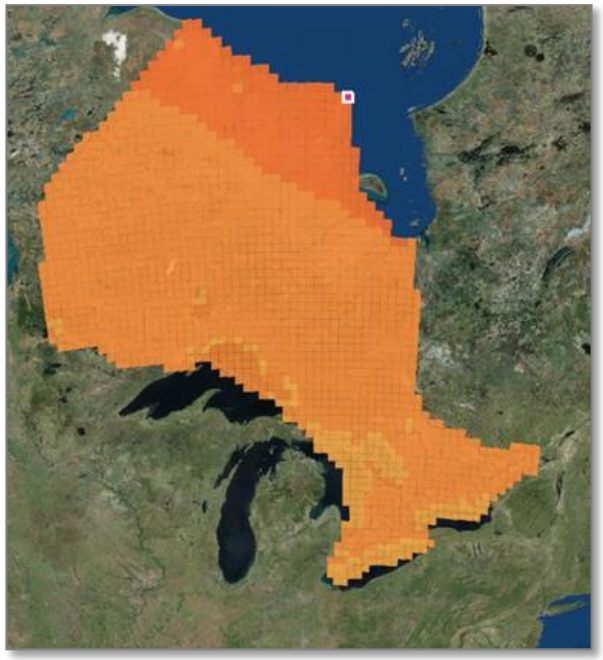


# Climate Model Resolution



## Global Climate Model (GCM)

- 20 Climate Modeling Centres
- ~150 to 200 km$^2$ grid cells

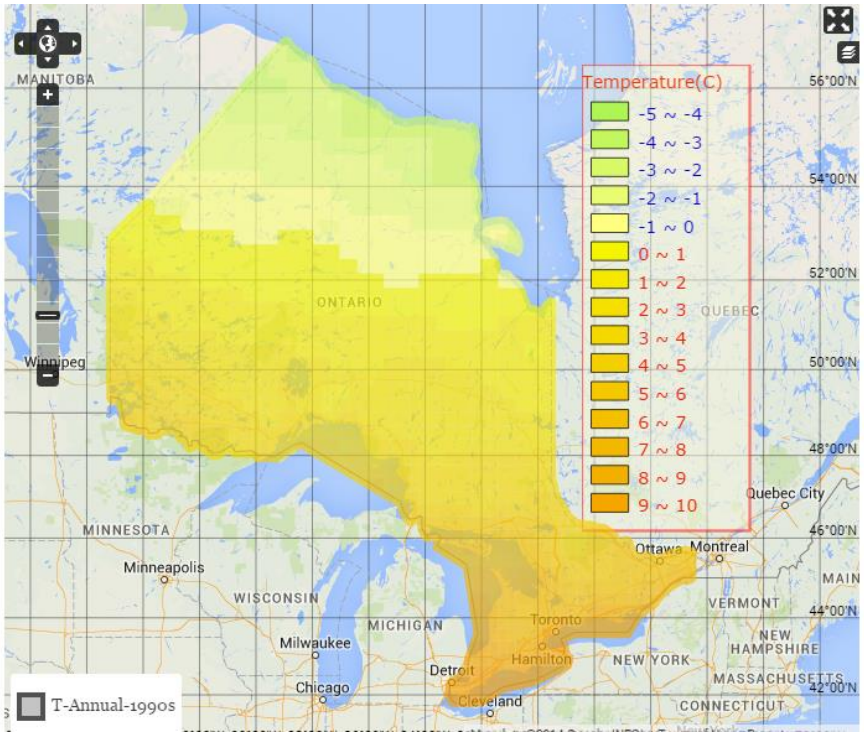


## Regional Climate Model (RCM)

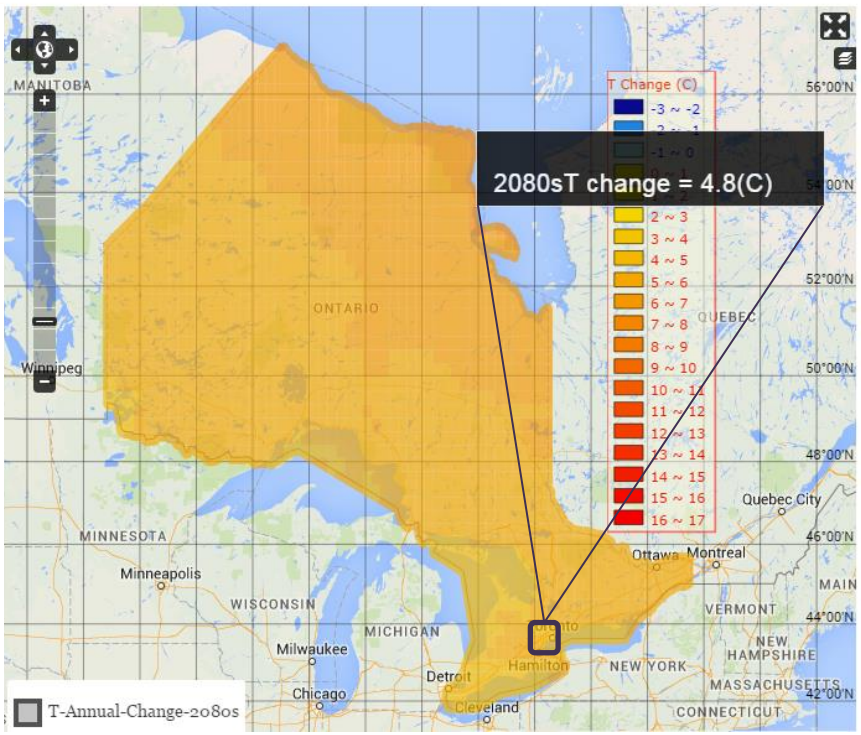
- Downscaled Models (Dynamically or Statistically)
- ~10 to 50 km$^2$ grid cells

# Climate Trends in Ontario: Annual Temperature

**Historical (1981-2010)**




**Future (2080s)**

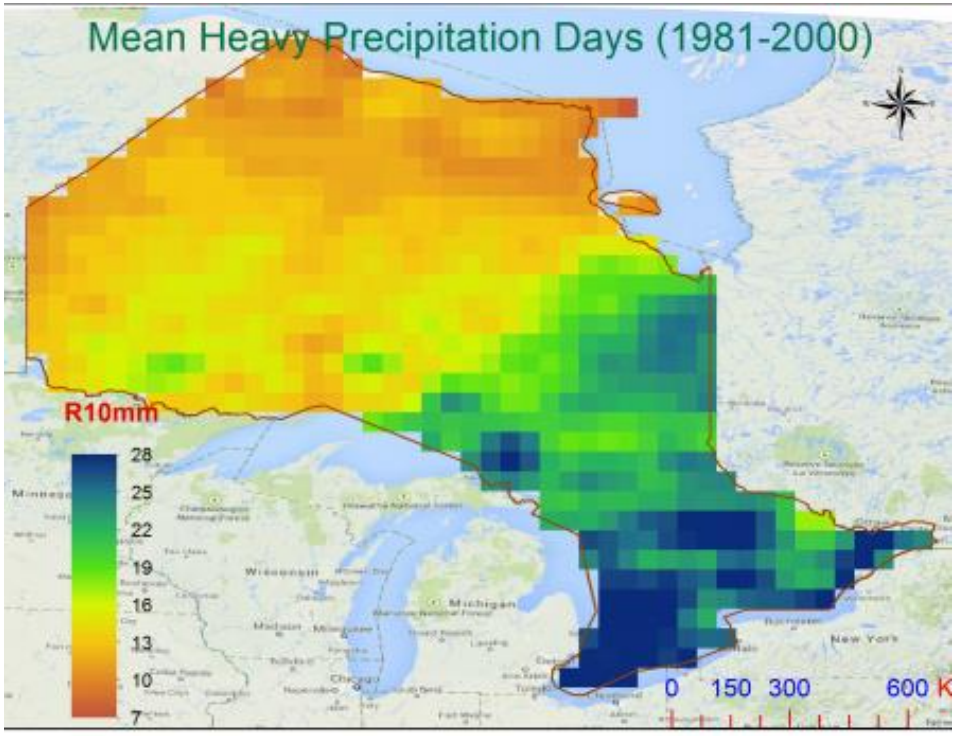



Credit: Zhu and Deng (2014). *Ontario climate change projections*

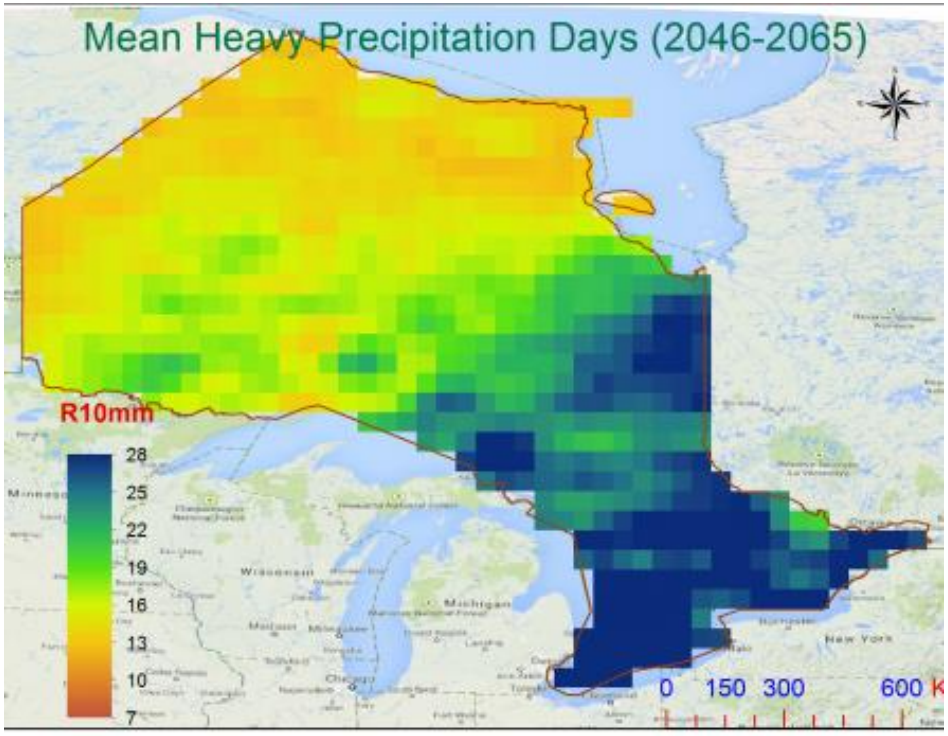
Credit: Zhu and Deng (2014). *Ontario climate change projections*

# 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)

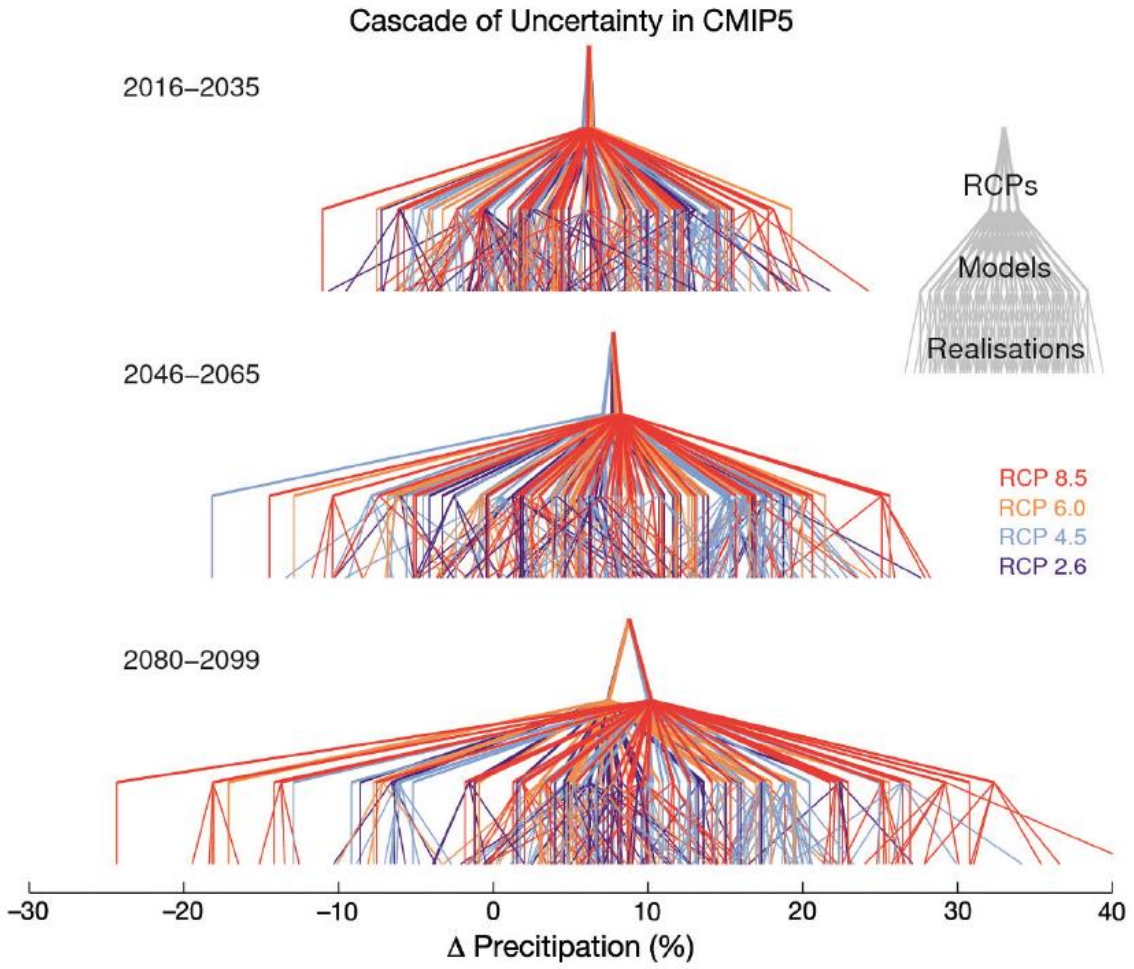
# Knowledge Gaps in Climate Modeling

- 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)

# Reality of Uncertainty




From: Wilby et al. (2014)

# 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

| Term | Likelihood of the Outcome |
|---|---|
| Virtually certain | 99 – 100% probability |
| Very likely | 90 – 100% probability |
| Likely | 66 – 100% probability |
| About as likely as not | 33 – 66% probability |
| Unlikely | 0 – 33% probability |
| Very unlikely | 0 – 10% probability |
| Exceptionally unlikely | 0 – 1% probability |



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

# 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.

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# Thank You

## Questions?

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