# Potential Effects of Climate Change on the Coast of Southern Lake Huron

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# Outline

* Introduction
* Predicted changes in temperature and precipitation
* How will these factors influence key coastal processes in the ABCA, including:
  1. Lake Huron lake level – mean lake level and range of fluctuations;
  2. Effects of reduced ice cover on storm frequency, magnitude and wave climate;
  3. Littoral drift magnitude and patterns;
  4. Cohesive coast nearshore and sub-aerial bluff erosion;
  5. Aeolian sand transport and coastal dune formation and stability.
* Discussion

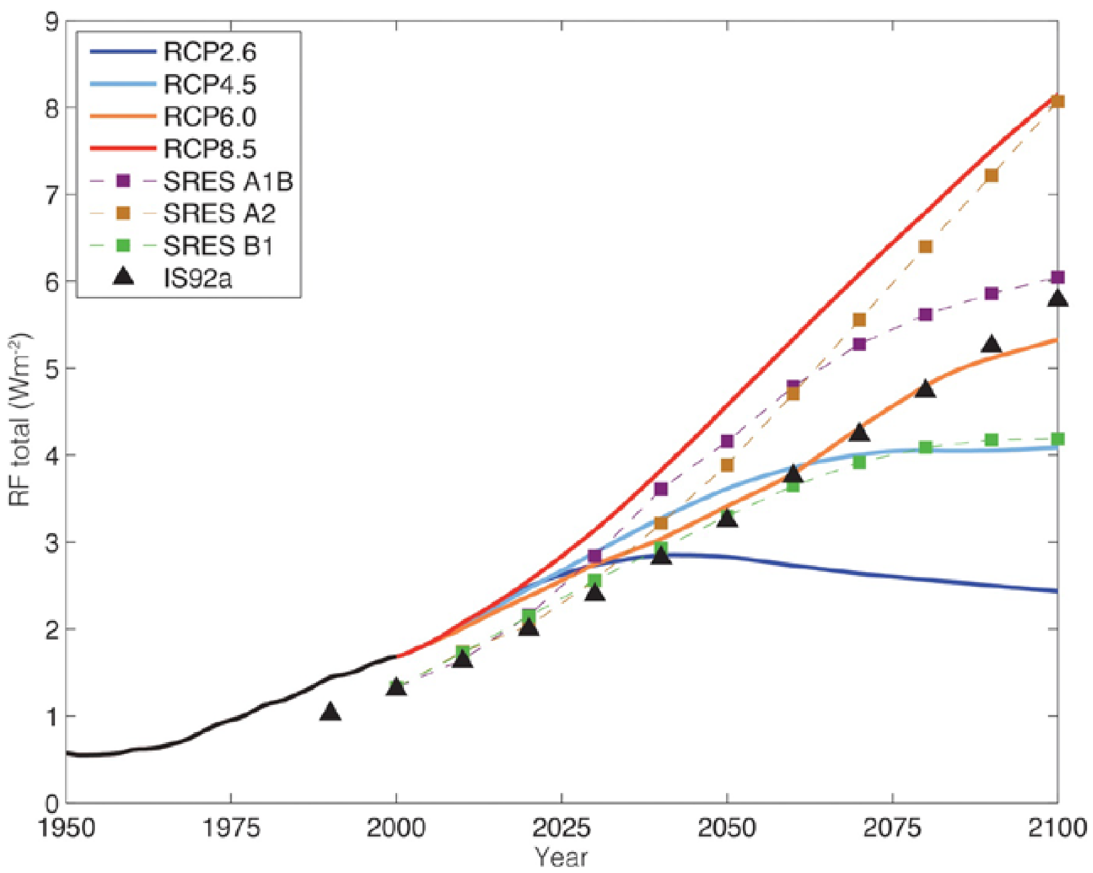
# Introduction

* General consensus among scientists that Global Climate Change related to enhanced greenhouse gases is real
* Modelling using 3rd generation Global Climate Models (GCMs) provides plausible predictions which can be used to address issues related to adaptation and management
* Predictions are made using various scenarios for future emissions – high to low – and this results in a range of potential changes

# Global Climate Models

* GCMs are computer models that simulate the characteristics of the earth surface and lower atmosphere
* In this application they are used to compare the effects of different scenarios of atmospheric $CO_2$ on climate over the earth as a whole.
* Grid cell 150-300 km
* Regional Climate Models grid cells ~10 km so can give adequate representation for area size of Great Lakes region

# Scenarios for Greenhouse Gases




Various scenarios for greenhouse gas emissions and atmospheric change from the IPCC Fourth Assessment Report (RCP2.6 etc.) and Fifth Assessment Report (SRES A1B etc.). IS92a represents a 1%/annum increased in CO2 from 1990 to 2100.

# Definitions

* **Weather** - describes processes in the atmosphere at, or close to the earth surface, over a short period of time (hours to days)
* Measurements of air temperature, clouds, precipitation, wind speed and direction, pressure
* **Climate** - summation of weather over substantial period of time; decades to centuries, to millennia
* Described by statistical measures such as the mean and standard deviation of parameters such as precipitation, temperature, pressure
* **Climate Change** – changes in the statistical properties of climate variables over the period for which climate is defined

# Definitions

* **Climate Variability** - describes fluctuations in the statistical properties of climate variables over the period for which climate is defined – e.g. decadal scale variations in temperature or precipitation where climate is defined for several hundred years
* **The Dilemma** – how do we distinguish between a fluctuation and the start of a change in climate?

# Sources

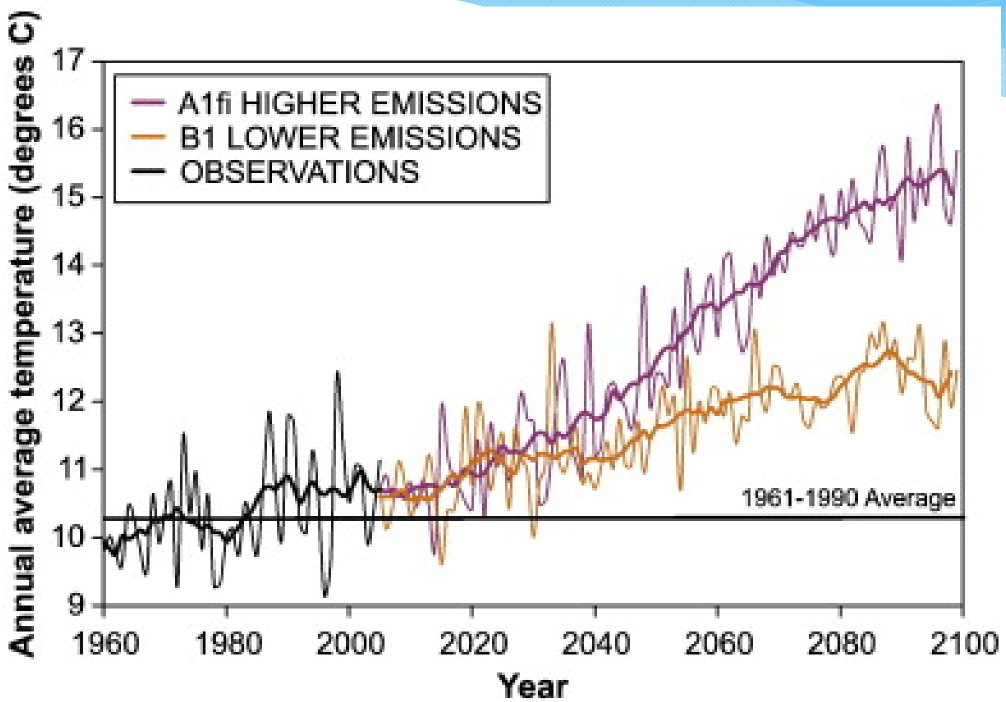
## Government, NGOs, Science and Social Science


* Intergovernmental Panel on Climate Change (IPCC), 2013. Summary for policymakers. In: Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.
* McDermid, J.L., Dickin, S.K.,Winsborough, C.L., Switzman, H., Barr, S., Gleeson, J.A. Krantzberg, G., and Gray, P.A., 2015. State of Climate Change Science in the Great Lakes Basin: A Focus on Climatological, Hydrological and Ecological Effects. Prepared jointly by the Ontario Climate Consortium and Ontario Ministry of Natural Resources and Forestry to advise Annex 9 - Climate Change Impacts under the Great Lakes Water Quality Agreement, October 2015.
* Wang, X., G. Huang, Q. Lin, X. Nie and J. Liu. 2015a. High-resolution temperature and precipitation projections over Ontario, Canada: a coupled dynamical-statistical approach. Q. J. Roy. Meteor. Soc., doi: 10.1002/qj.2421.
* Peck, A., P. Prodanovic and S.P. Simonovic. 2012. Rainfall intensity duration frequency curves under climate change: city of London, Ontario, Canada. Can. Water Resources. J. 37: 177-189.

# Changes in Temperature

* Temperature increase of 1-2°C over past 60 years in the Great Lakes region
* Increase larger in north of region
* Greater increase in minimum winter temperatures than increase in maximum summer temperatures
* All effects expected under climate change scenarios
* Trends are predicted to continue through to 2100 – increase in mean temperatures by 2-7°C in southern Ontario (McDermid et al., 2015) and 6-8°C under some scenarios (Wang et al., 2015a)
* The number of frost-free days will increase significantly and greater frequency of extreme heat alerts.

# Predicted Temperature Change




Observed and model-simulated historical and projected future annual average temperatures for Chicago, in degrees Celsius. Model simulations show the average of the GFDL 2.1, HadCM3, and PCM models for the SRES A1fi (higher) and B1 (lower) emission scenarios (**after Hayhoe et al., 2012**)…

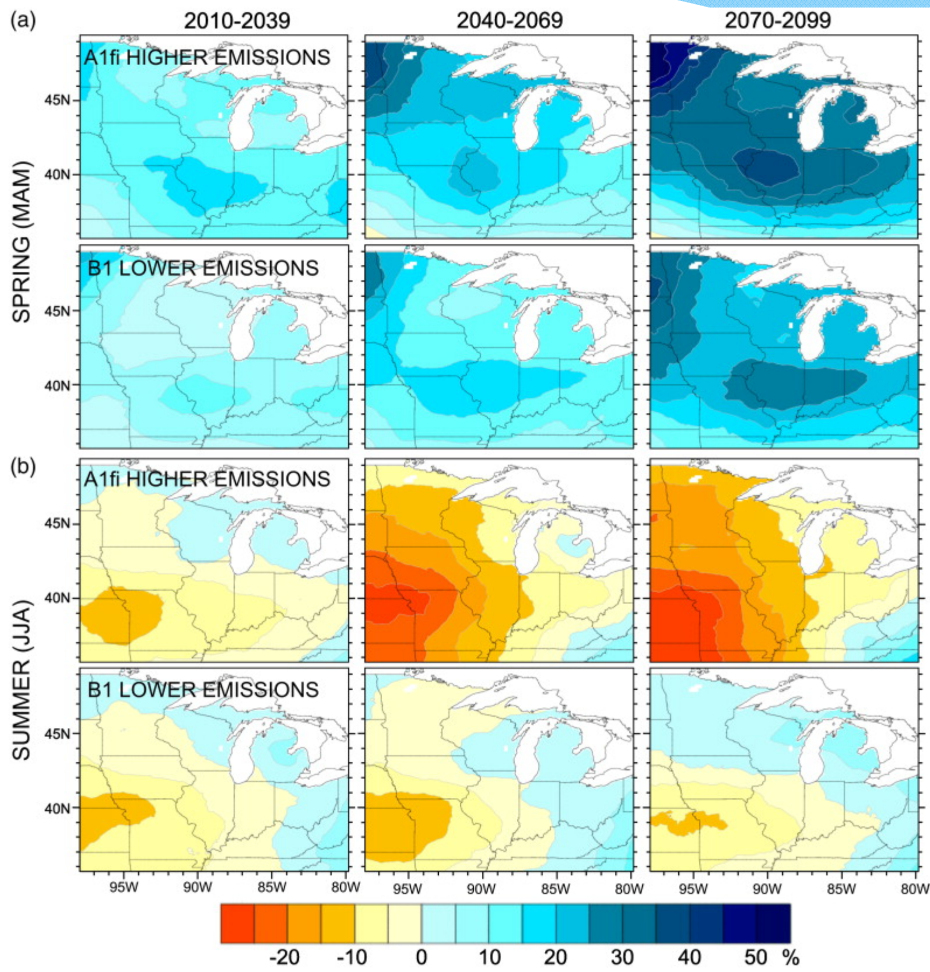
# Changes in Temperature

* Confidence in these projections is generally high
* Increased temperatures will influence the temperature of lake waters, stratification and the timing of turnover
* It will lead to significant decrease in the extent and duration of winter ice cover on the lake
* It will likely lead to increased evaporation

# Changes in Precipitation

* Confidence in these projections is generally much lower than for temperature
* Possible increases up to 20% by end of century – more in northern regions
* Decrease in proportion falling as snow
* Decrease in lake effect snowfall except mid- to late-winter
* Increase in heavy downpours

# Predicted Changes in Precipitation




Projected change in (a) spring (Mar–Apr–May) and (b) summer (Jun–Jul–Aug) average precipitation as simulated under the SRES A1fi (higher) and B1 (lower) emissions scenarios by the average of the subset of 3 AOGCMs (**Trumpicas et al., 2015**)

# Changes in Storms and Winds

* Suggestions of increased wind speeds – particularly during major storm events
* However, low confidence in this and changes to storm tracks.
* Shape and size of Lake Huron limit significant changes to waves and storm surge

# Effects on Coastal Processes Within the ABCA Shoreline

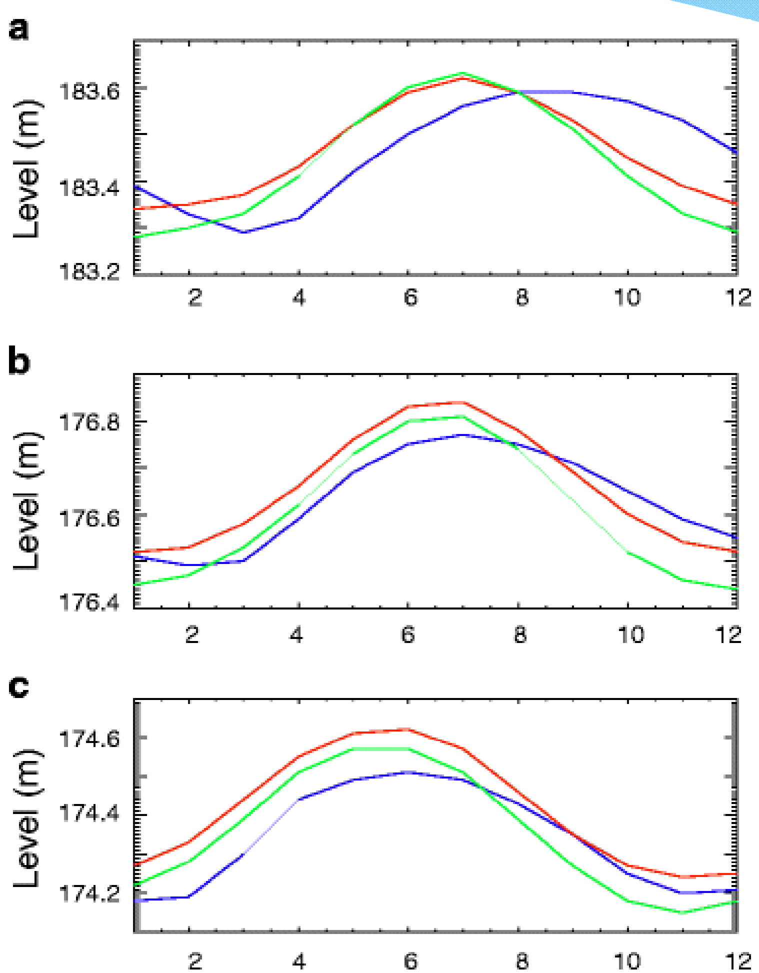
In this section we consider potential effects of Climate Change on:

1. Mean lake level and lake level fluctuations
2. Wave climate
3. Littoral drift magnitude and direction
4. Erosion of cohesive bluff shorelines
5. Aeolian sand transport and dune stability

# Lake Level

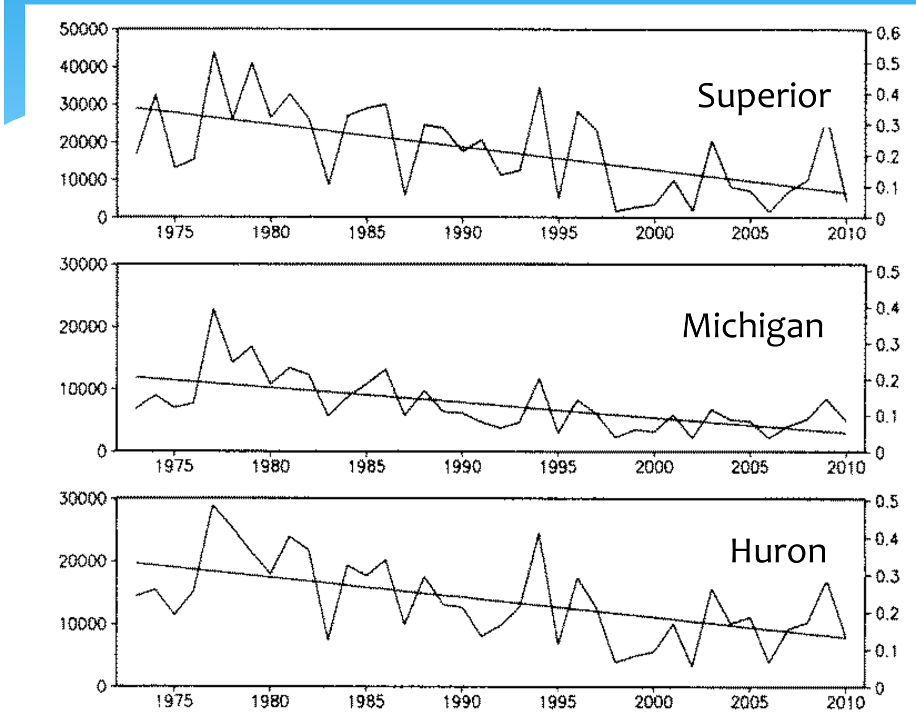
* Increase in temperature and decrease in ice cover should lead to increased losses through evaporation from lake and evapotranspiration from basin and thus lower mean lake level
* May be compensated for by higher precipitation, particularly over northern regions
* Best to assume stable means – perhaps slightly lower if high emissions scenario prevails – and similar range of fluctuations
* Seasonal cycle may be altered with lower level at end of summer and higher level in winter

# Predicted Change in Seasonal Cycle




Lake level mean seasonal cycle for: a Lake Superior; b Lake Michigan – Huron; c Lake Erie.
observed 1962–1990
GLRCM 1962–1990;
GLRCM 2021–2050.
Units are m referenced to the International Great Lakes Datum 1985. **(MacKay and Seglenick, 2013)**

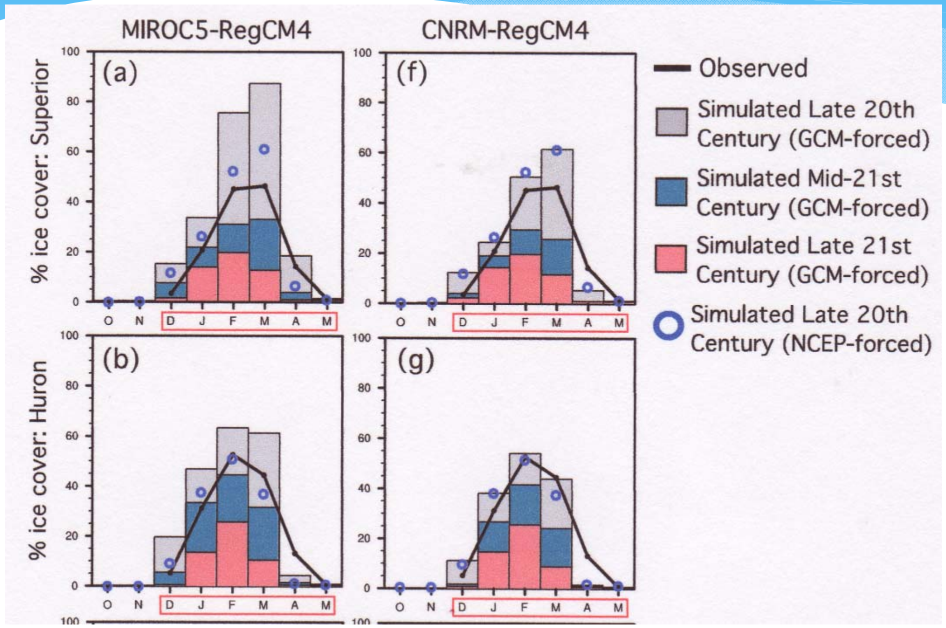
# Ice Cover and Wave Climate




Annual mean lake ice cover ($km^2$) for the period 1973-2010
**(Wang et al., 2012)**

- Ice cover very sensitive to increased temperature – already signs of shorter ice season and reduced ice cover
- Inter-annual variation linked to ENSO and AO/NAO oscillations
- Predictions are for ice cover to continue to decline rapidly

# Ice Cover and Wave Climate




Modelled changes in maximum lake ice cover for several scenarios
**(Notaro et al., 2015)**

* The predicted increase in air and lake temperatures in the 21$^{st}$ century will lead to further decreases in the extent and duration of ice cover on Lake Huron.
* Modelling by Notaro et al. (2015) shows a decrease in maximum ice cover in February from the present level of about 50% to about 40 % by mid-century and 25% near the end of the century

# Ice Cover and Wave Climate

* Decrease in the duration and extent of ice cover will permit wave generation by storms in late December and January, and again in March and early April
* Will lead to an increase in the total annual wave energy.
* Effect may be magnified because these periods are often associated with more intense storms than in the middle of the year.
* Will have implications for nearshore sediment transport and wave erosion of cohesive shores

# Littoral Drift Magnitude and Direction

* Net southerly transport will continue in ABCA because of location at south end of lake
* Magnitude of total sediment transport will increase
* Magnitude of net southerly longshore transport may also increase
* Recent improvements in modelling using Delft3D and development of algorithm to model effects of ice on wave propogation may permit modelling of this (Manson et al., 2016a, b).
* Work in progress by Manson shows increase in total sediment transport off north shore of PEI increase up to 50% if ice disappears completely – likely similar magnitude for southern Lake Huron.

# Erosion of Cohesive Bluff Shorelines

* Reduced ice cover and increase in number of storm events will also lead to enhanced rate of erosion of till in nearshore due to abrasion
* In turn this will increase wave erosion of bluff toe and rate of bluff recession
* The magnitude of increase is likely to scale with the increase in wave energy and so an estimate can be generated from the predicted pattern of decrease in ice cover and the average wind regime for the winter period
* Can expect increase of 10-30% over next few decades in nearshore downcutting – net effect depends on whether mean lake level remains the same or decreases
* Note that erosion of bluff slopes may be enhanced if increase in rainfall and heavy downpours – especially in winter months

# Aeolian Sand Transport and Dune Stability

* Reduced snow cover and increased wave activity during the winter may lead to an increase in the potential sand transport into the foredune zone
* May be offset by wetter winters and erosion by storm waves
* Little impact on pioneer plant communities because of dominant effect of sand burial and tolerance for dry conditions
* Existing setbacks should be able to accommodate any small changes.

# Adaptation Strategies to Cope with Impacts of Climate Change

* Shoreline Management Plan should be sufficiently flexible and robust to accommodate these expected changes
* Will require continuing monitoring updating of data natural processes and of changing human demands