Climatological Assessment of Spatiotemporal Trends in Observational Monthly Snowfall Totals and Extremes over the Canadian Great Lakes Basin

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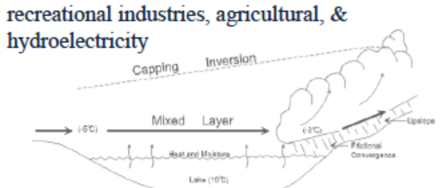
ABSTRACT

The Laurentian Great Lakes Basin (GLB) is susceptible to lake effect snowfall (LES). Rising global temperatures can influence monthly snowfall totals and extremes. This research focuses on the under-studied region of the Canadian snowbelts, primarily Lakes Superior and Huron-Georgian Bay. Thirty-six year (1980 to 2015) historical spatiotemporal trends were computed to analyze monthly LES totals and LES predictor variables in response to a changing climate. Results indicate a significant decline in LES despite an increase in instability and LST, and a decrease in ice cover. The decrease in LES is most likely due to warming air masses and inefficient moisture recycling over the Lakes. Extreme snowfall intensity, frequency, and duration were also analyzed and show a decrease in extremes, predominantly along the Canadian domain of Lake Superior's snowbelt.

1. INTRODUCTION

Lake Effect Snowfall

- Generated by boundary layer convection initiated by cold and dry continental air masses advecting over relatively warm lakes, which produces turbulent moisture and heat fluxes, inducing LES
- LES endangers life, property, transportation, recreational industries, agricultural, & hydroelectricity



Knowledge Gap

- Climatological analysis of recent trends and extremes in LES is lacking over Canada's Great Lakes Basin (GLB) snowbelts

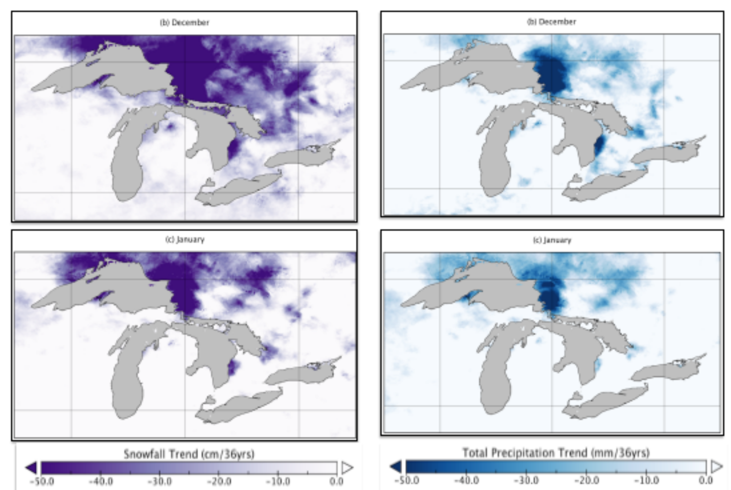
Objectives

- Analyze historical spatiotemporal trends in monthly snowfall and total precipitation over Canada's GLB snowbelts from 1980 to 2015
- Determine spatiotemporal trends in LES predictor variables that influence LES trends
- Assess the regional spatiotemporal trends in extreme snowfall intensity, frequency, and duration in response to recent climate change

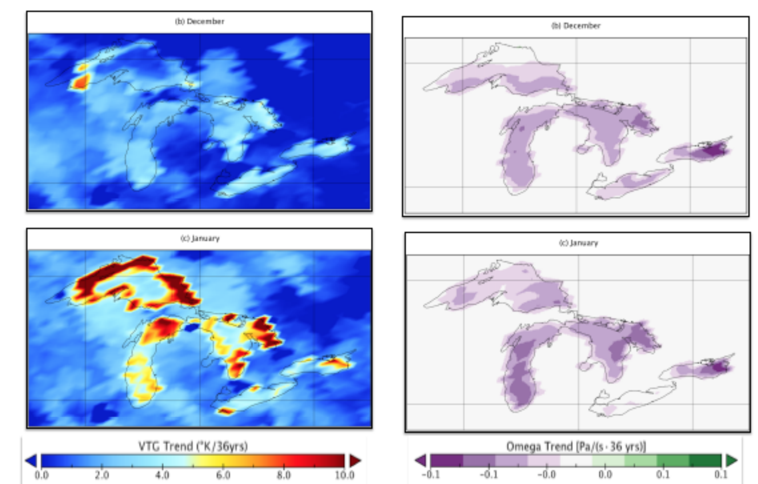
2. METHODOLOGY

Variable	Description	Source	Size
Snowfall	$H_n = [0.1 \cdot P_n]/\rho$	Daymet	1 km
Precipitation		Daymet	1 km
Omega / LST		NARR	32 km
VTG	$VTG = T_{LST} - Tair_{850}$	NARR	32 km
Ice Cover		CIS	
Intensity	Determined by the 99th percentile	Daymet	1 km
Frequency	Number of snowfall days ≥ extreme threshold	Daymet	1 km
Duration	Maximum number of consecutive snowfall days ≥ extreme threshold	Daymet	1 km

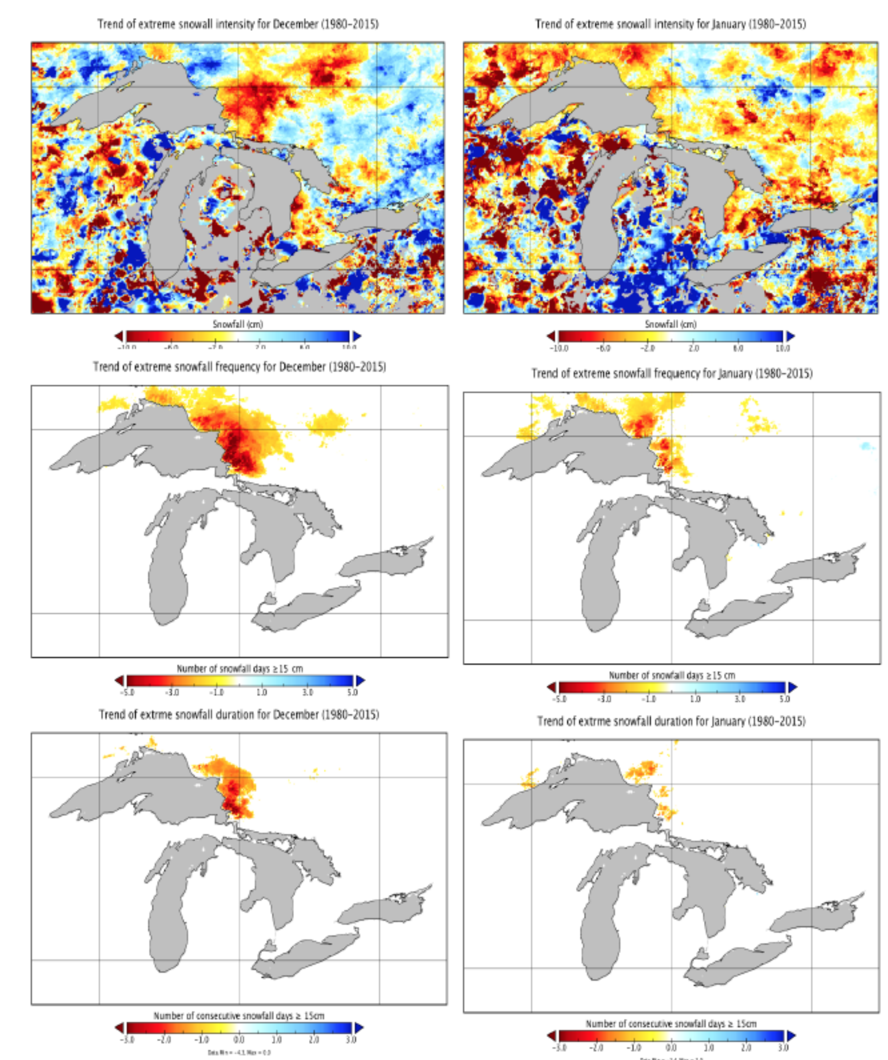
3. RESULTS



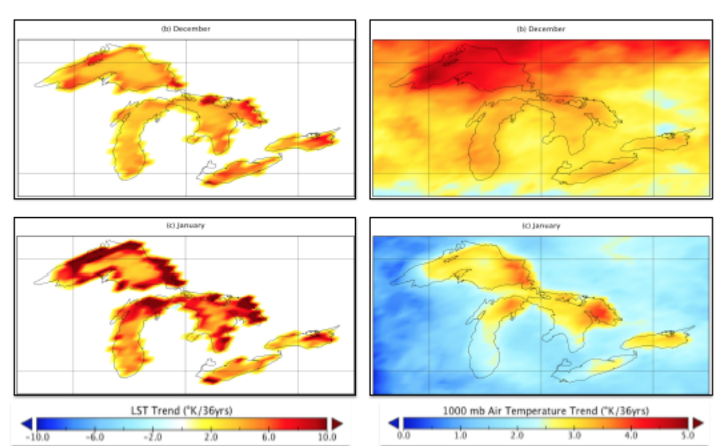
Figures 1. Monthly total December and January snowfall trends (left) and total precipitation trends (right)



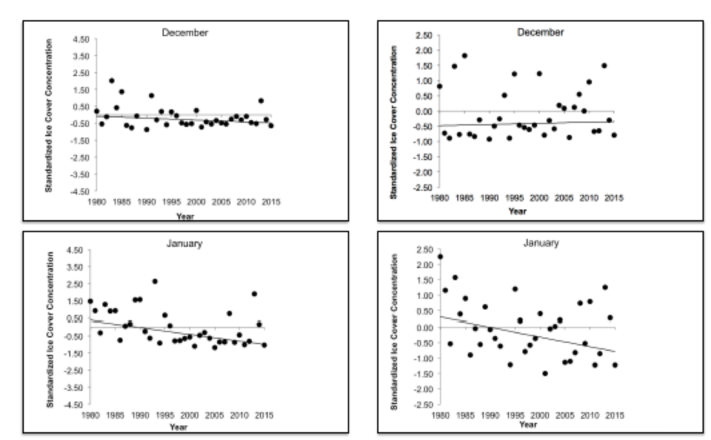
Figures 2. Monthly average December and January VTG trends (left) and omega trends (right)



Figures 5. Monthly December (left) and January (right) trends in extreme snowfall intensity (top), frequency (middle), and duration (bottom)



Figures 3. Monthly average December and January LST trends (left) and 1000 mb air temperature trends (right)



Figures 4. Monthly total ice cover accumulation trends in December and January for Lake Superior (left) and Lake Huron-Georgian Bay (right)

- Similar decrease in total monthly snowfall and total precipitation trends suggest changes in atmospheric moisture storage
- Increased instability linked to increased LST and decreased ice cover, suggesting increased evaporation into the atmosphere
  - Increased evaporation consistent with observed trends in both ice cover and LST (Wang et al. 2012; Austin and Colman 2007; Blanken et al. 2011; Spence et al. 2011)
  - Agrees with Hunter et al. (2015), who in early 1990s, observed abrupt increase in evaporation over Lake Superior, but have seen decrease in over-lake precipitation within the past 20 years
- Increase in air temperature allows air parcel to hold more water vapor, which can be advected farther distances downwind to the southern Great Lakes before saturating and precipitating out
  - In agreement with Notaro et al. (2013), who suggest that increased air temperatures during the cold season leads to smaller fraction of snowfall accumulation and a decrease in snowfall by approximately 9%
  - Notaro et al. (2013) suggests inefficient moisture recycling because precipitation response is 2.3x smaller than evaporation over the Great Lakes, with greater moisture entering atmosphere as vapor and clouds during LES season
- Decrease in extreme snowfall intensity, frequency, and duration occurs predominantly for Lake Superior's Canadian snowbelt
- Trends in snowfall extremes differ among and within snowbelts

4. CONCLUSIONS

- Despite LES predictor variables responding in favour of greater LES production, increased moisture fluxes into the atmosphere have led to decreased LES over Canada's GLB
- It is acknowledged that other regional processes, including changes in cold air outbreaks, can influence LES trends and should be analyzed in a future study
- The performance of the Canadian Regional Climate Model (CRCM 5), coupled with the FLake model, is currently being evaluated for its simulation of LES within the snowbelts of the GLB and Mackenzie River Basin

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