Climate Change Science in the Great Lakes-St. Lawrence Region and an overview of future research needs

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Meeting of the Regional Body and Compact Council Science Team
September 2019

Outline

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1. Introduction
2. Historical climate patterns

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4. Concluding remarks

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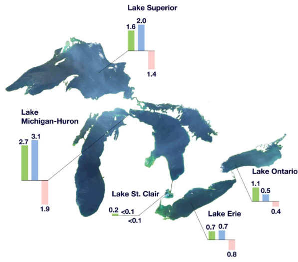
Runoff

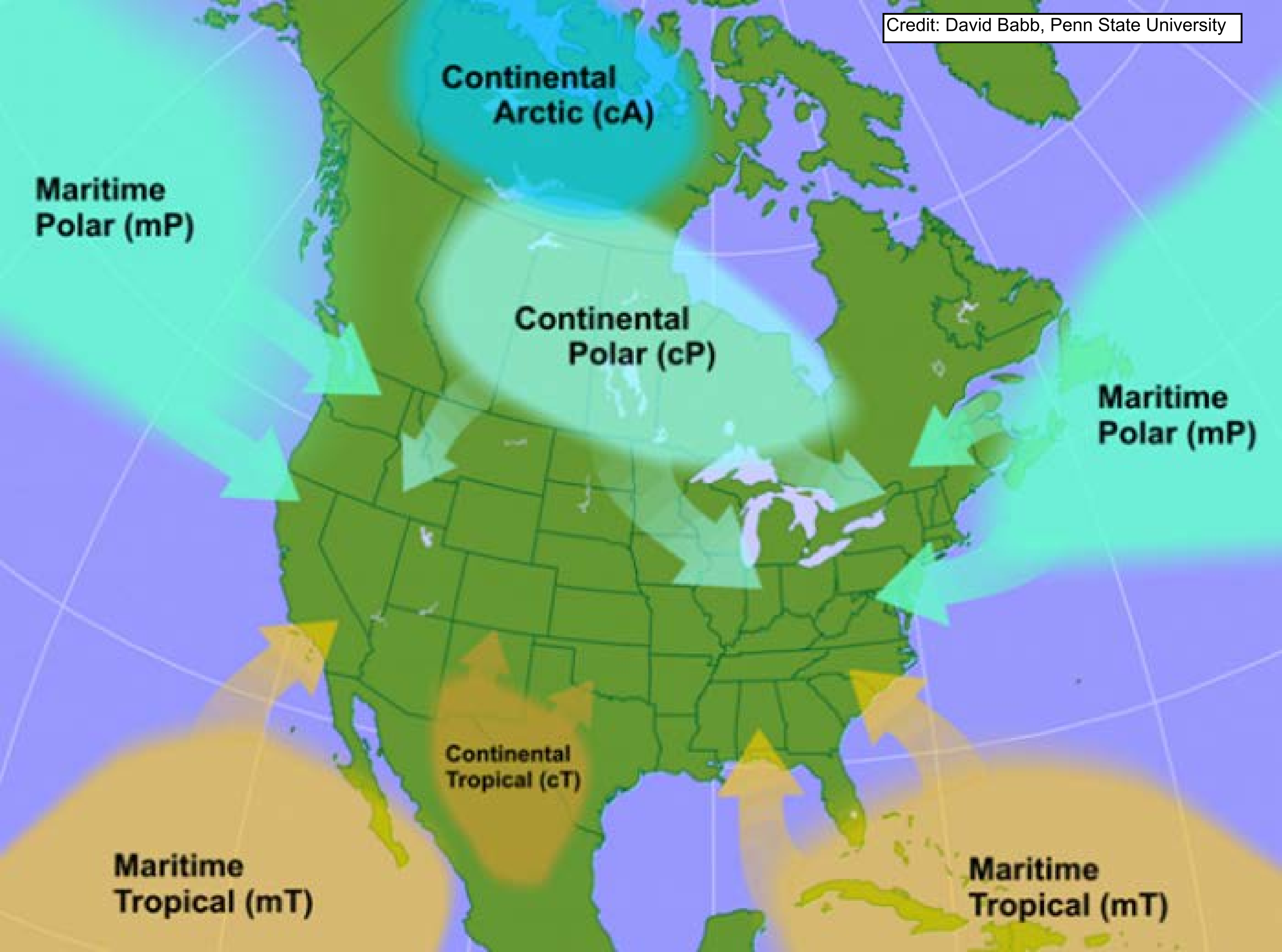
Overlake Precipitation

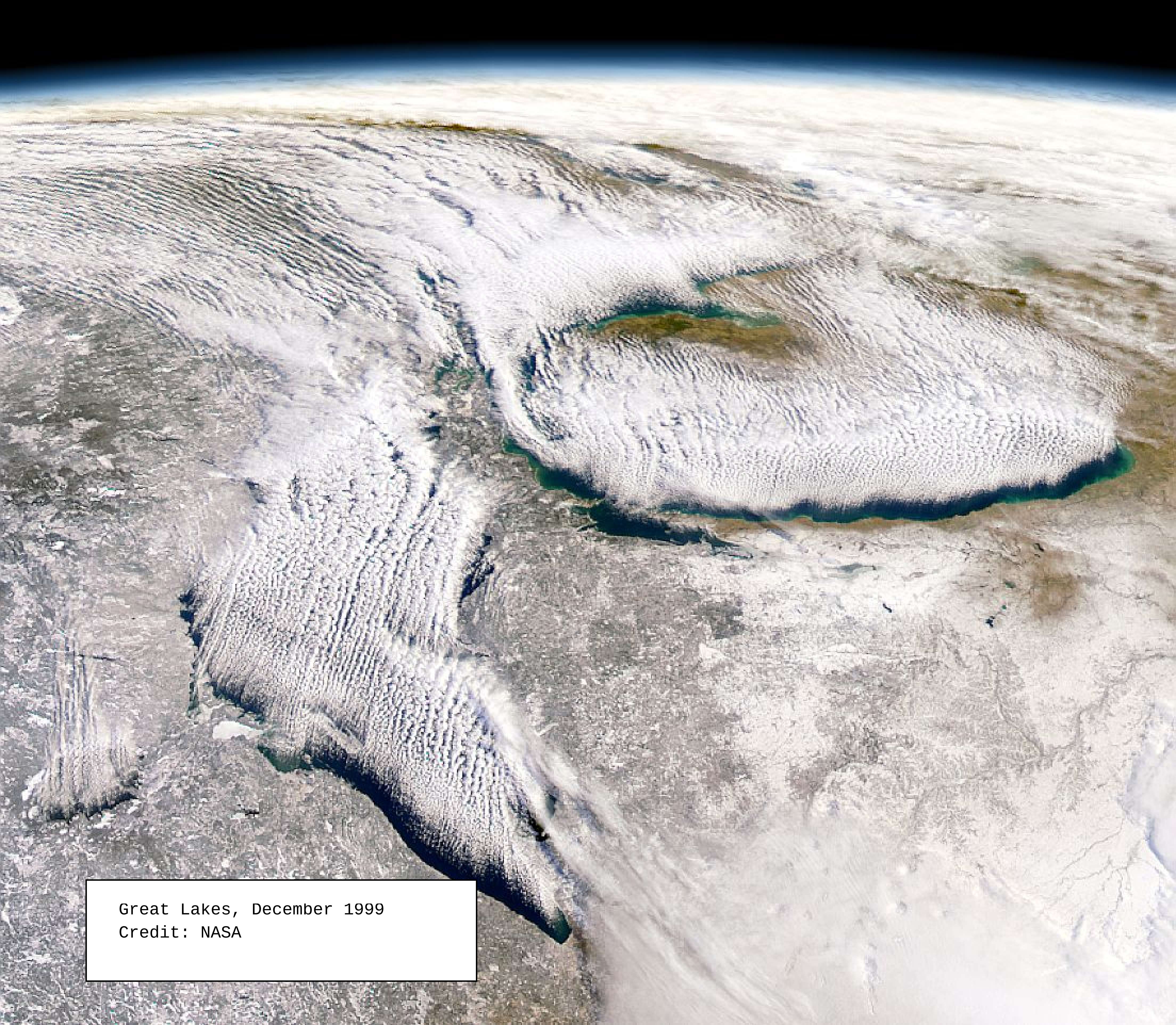
Overlake Evaporation

All values are averaged over the period 1950-2010 and are in thousands of cubic meters per second.



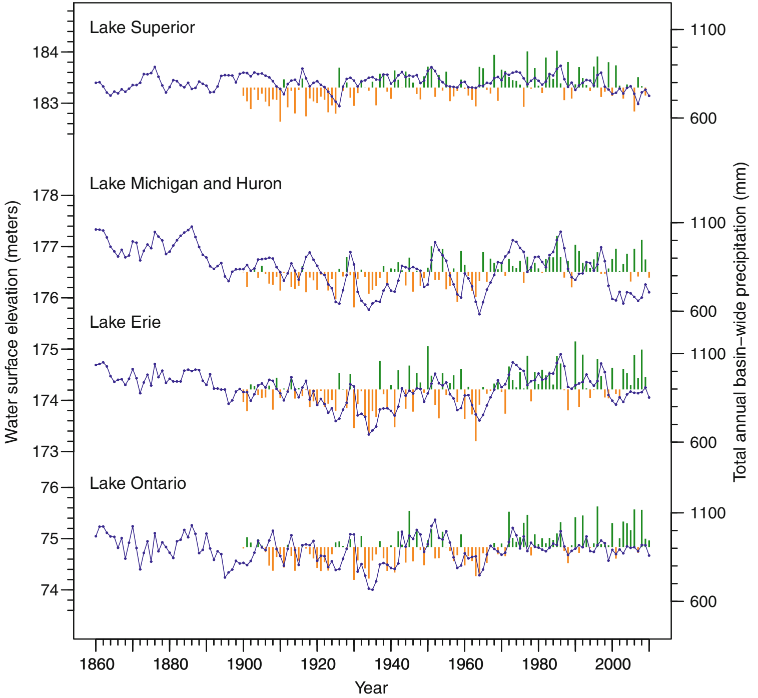
From: NOAA-GLERL

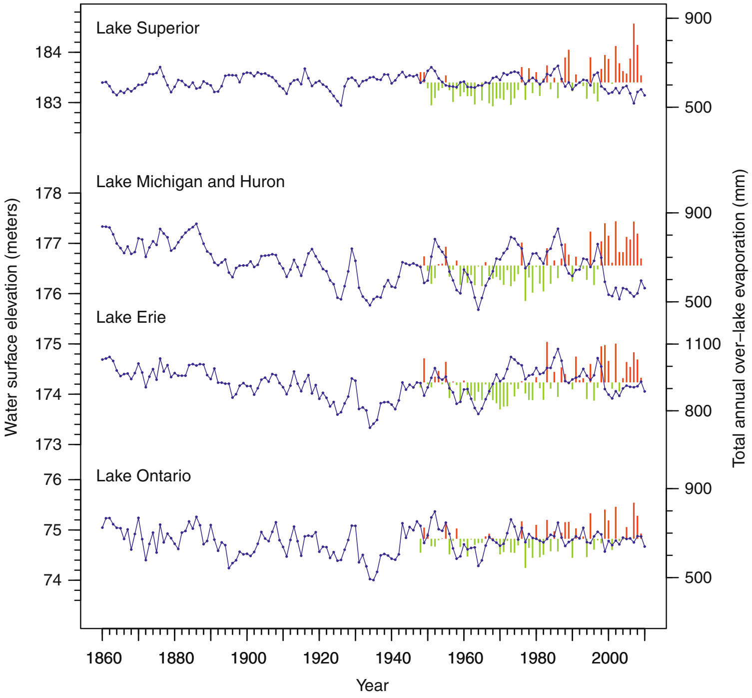

Credit: David Babb, Penn State University
Continental Arctic (cA)
Maritime Polar (mP)
Continental Polar (cP)
Maritime Polar (mP)
Continental Tropical (cT)
Maritime Tropical (mT)
Maritime Tropical (mT)



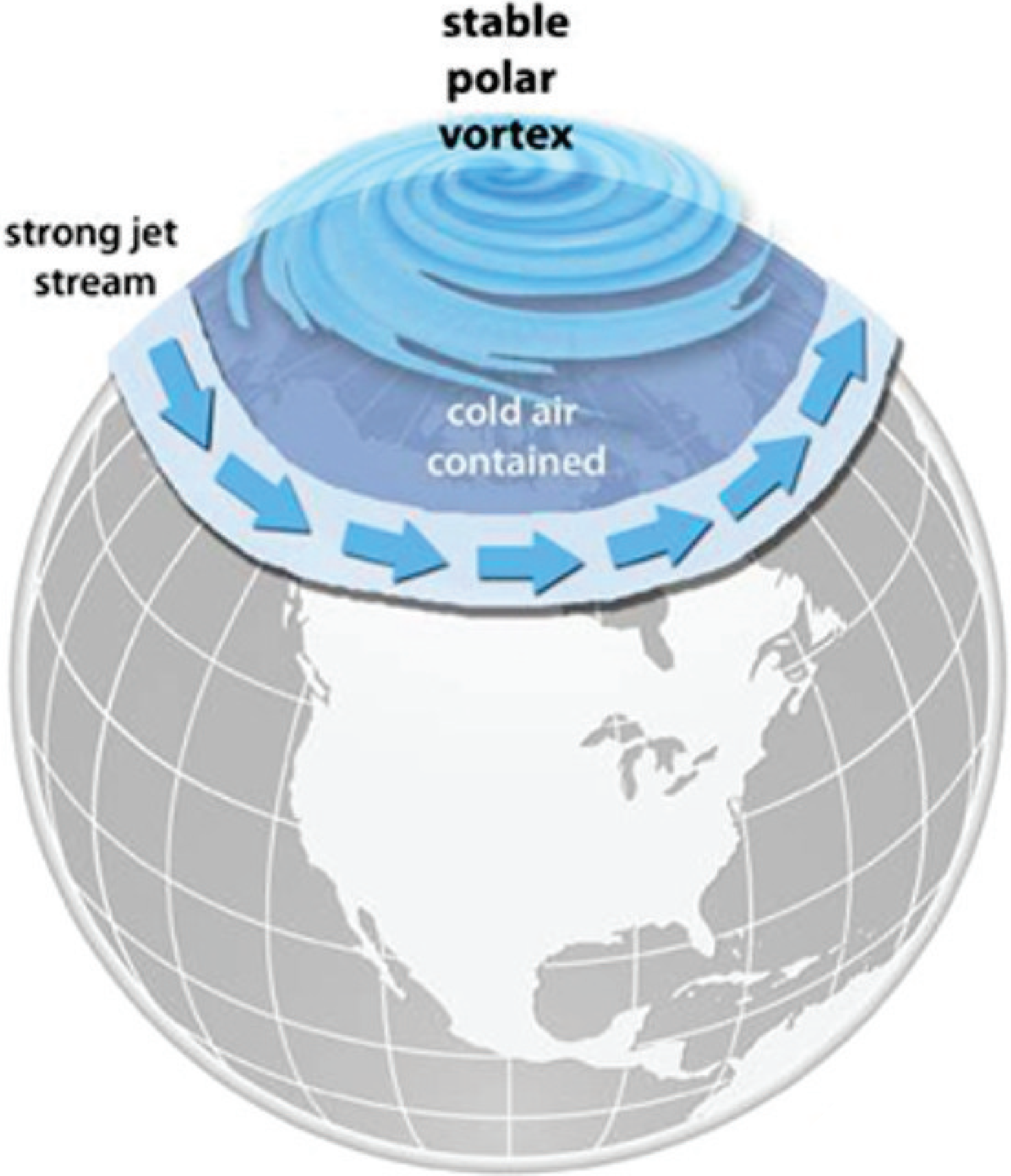
Great Lakes, December 1999
Credit: NASA

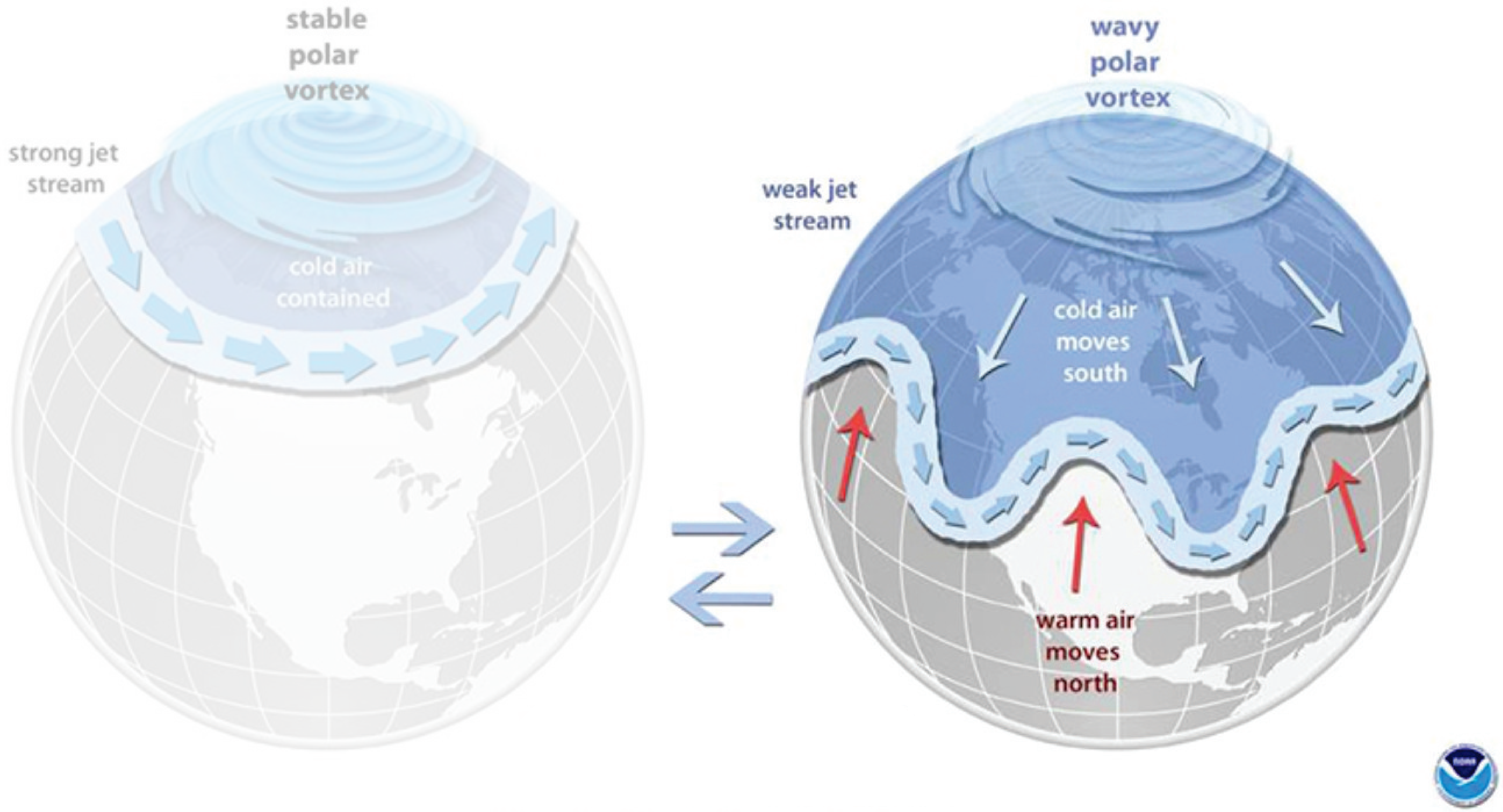
Outline


Lake Superior
Lake Michigan and Huron
Lake Erie
Lake Ontario
Water surface elevation (meters)
Total annual basin-wide precipitation (mm)
Year
184
183
178
177
176
175
174
173
76
75
74
1100
600
1860
1880
1900
1920
1940
1960
1980
2000



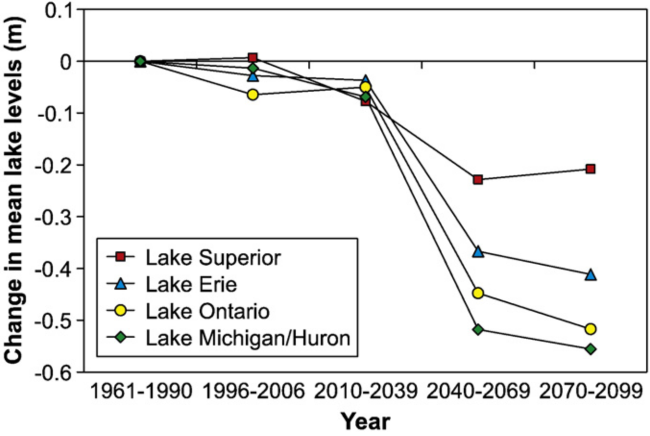
Lake Superior
Lake Michigan and Huron
Lake Erie
Lake Ontario
Water surface elevation (meters)
Total annual over–lake evaporation (mm)
Year
184
183
178
177
176
175
174
173
76
75
74
900
500
900
500
1100
800
900
500
1860
1880
1900
1920
1940
1960
1980
2000


stable
polar
vortex
strong jet
stream
cold air
contained



stable polar vortex
strong jet stream
cold air contained
wavy polar vortex
weak jet stream
cold air moves south
warm air moves north

Outline



Change in mean lake levels (m)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Lake Superior
Lake Erie
Lake Ontario
Lake Michigan/Huron
1961-1990
1996-2006
2010-2039
2040-2069
2070-2099
Year

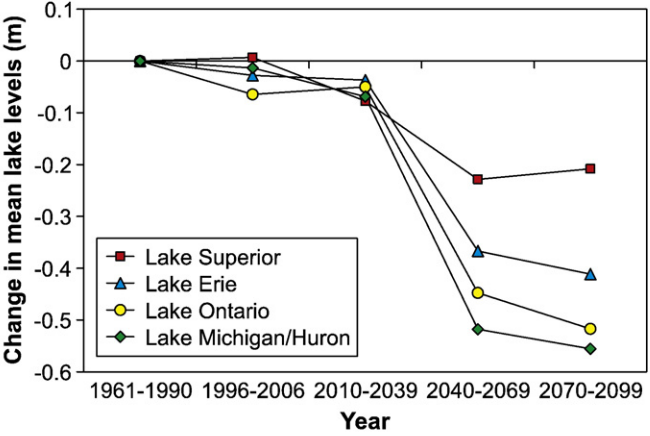
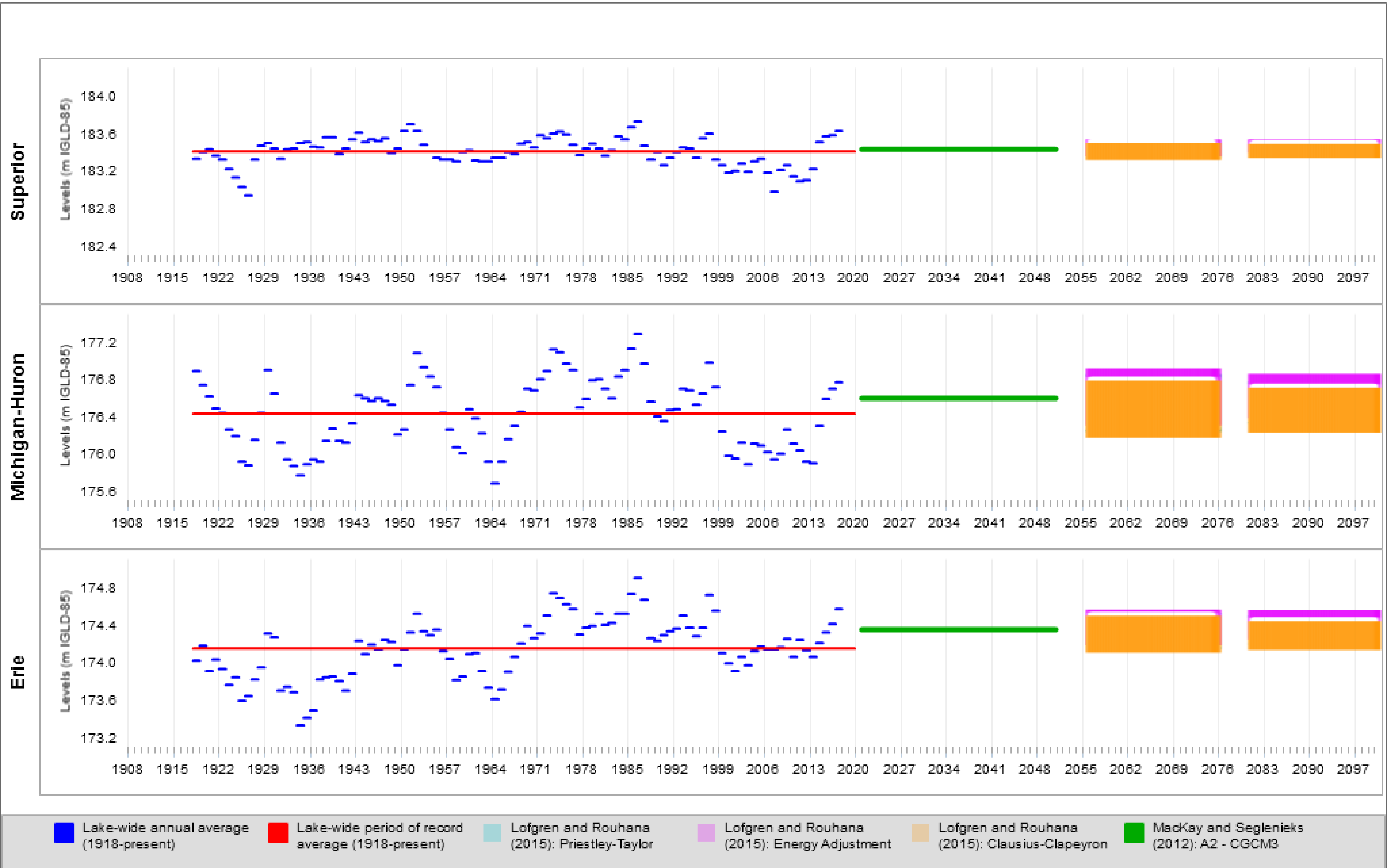


Fig. 10. Average Great Lakes levels depend on the balance between precipitation and corresponding runoff in the Great Lakes Basin and evaporation and outflow. The SRES B1 lower emissions scenario with less warming (not shown) projects little change in lake levels over the coming century. Under the SRES A1fi higher emissions scenario (shown here), decreases on the order of 0.5 up to nearly 2.0 ft are projected towards the end of the century.

Great Lakes water levels

Multi-decadal projections



Generated by the Great Lakes Dashboard: http://www.glerl.noaa.gov/data/gldb

Climatic Change (2015) 130:603–618
DOI 10.1007/s10584-015-1348-8

Present and future Laurentian Great Lakes hydroclimatic conditions as simulated by regional climate models with an emphasis on Lake Michigan-Huron

Biljana Music · Anne Frigon · Brent Lofgren · Richard Turcotte · Jean-François Cyr

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Dynamical Downscaling–Based Projections of Great Lakes Water Levels*,+

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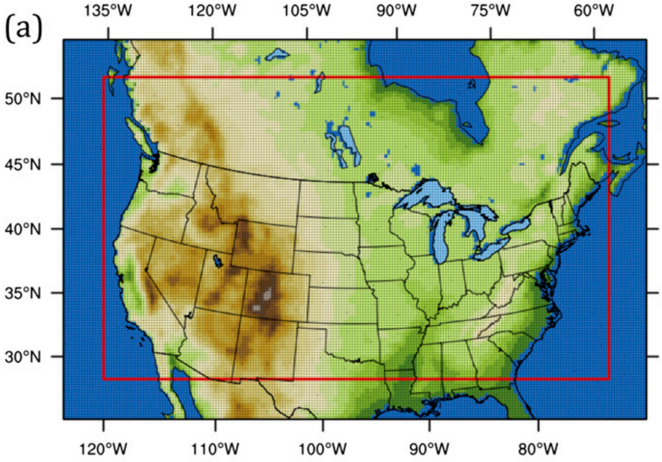
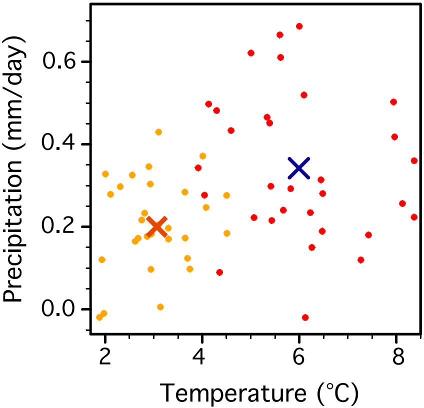
(Manuscript received 11 December 2014, in final form 9 July 2015)

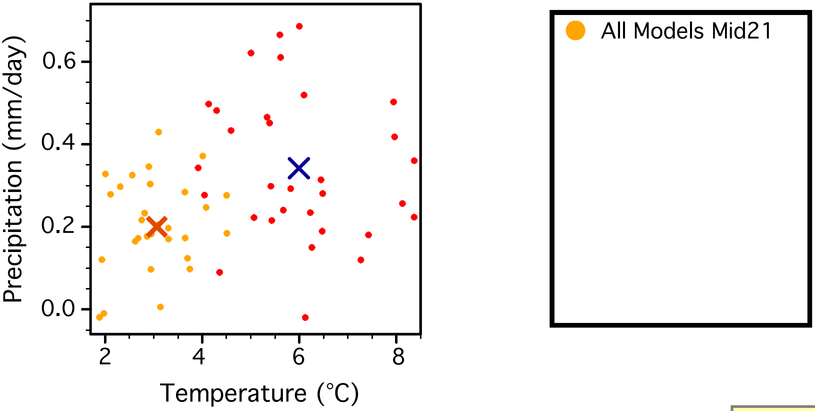
(a)



135°W
120°W
105°W
90°W
75°W
60°W
50°N
45°N
40°N
35°N
30°N
120°W
110°W
100°W
90°W
80°W



Adapted from Notaro et al (2015)



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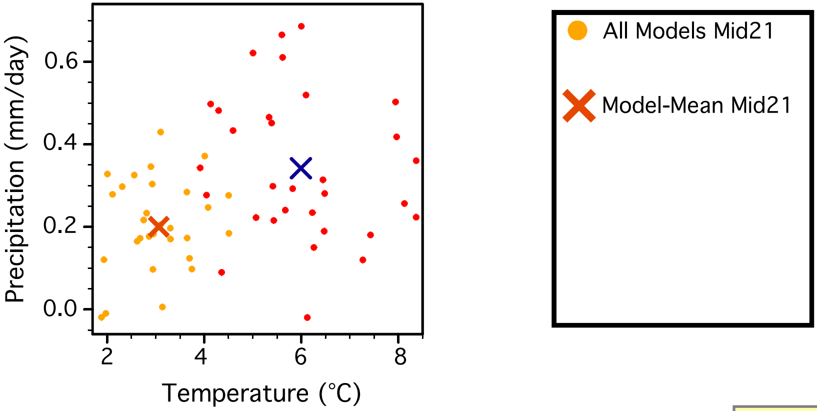
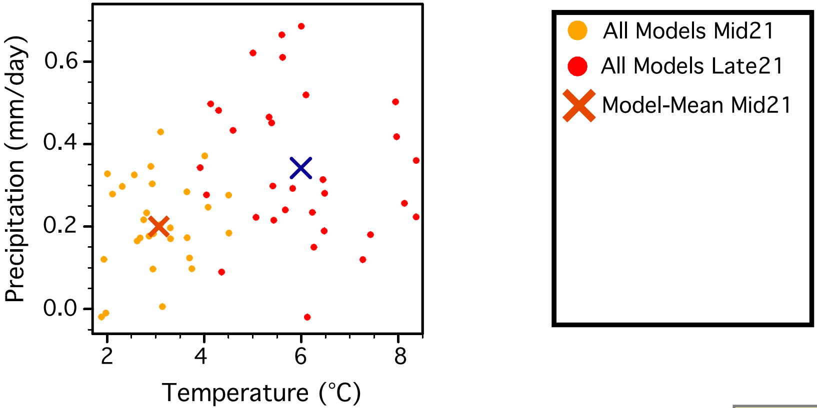
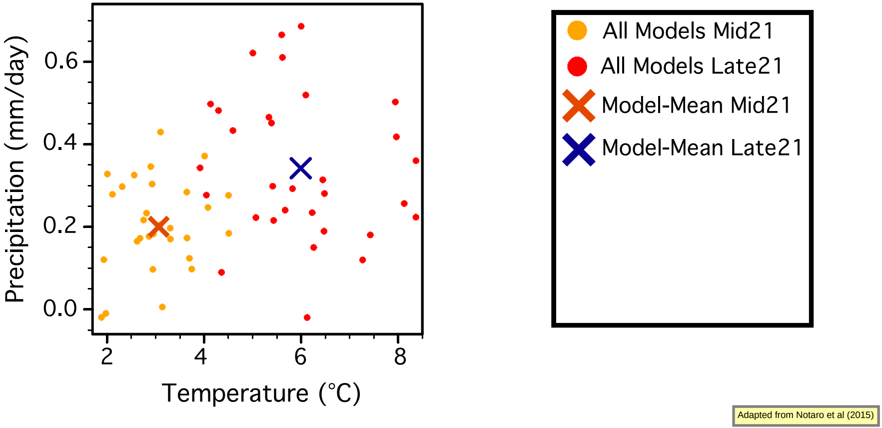


Adapted from Notaro et al (2015)



Adapted from Notaro et al (2015)



0.6
0.4
0.2
0.0
2
4
6
8
Precipitation (mm/day)
Temperature (°C)
All Models Mid21
All Models Late21
Model-Mean Mid21
Model-Mean Late21
Adapted from Notaro et al (2015)

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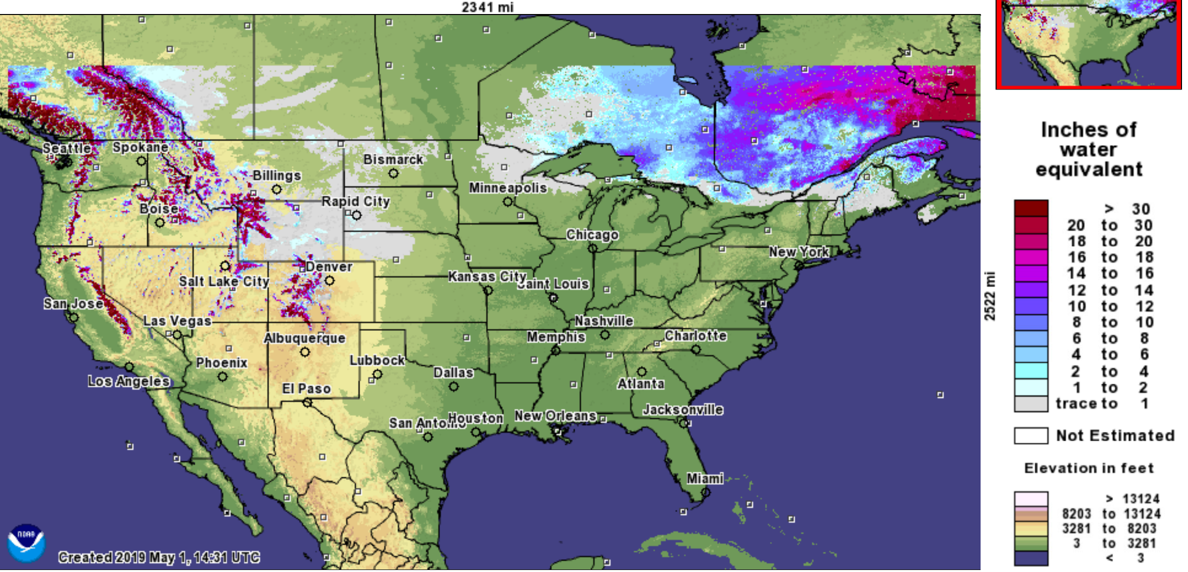
White Shoal Lighthouse: Lake Michigan
Photo courtesy Dick Moehl (Lighthouse Keepers Association)


CANADA STEAMSHIP LINES


Alaska
Pacific
Northwest
Missouri
Basin
North
Central
Northeast
California
Nevada
Colorado
Basin
Ohio
Middle
Atlantic
Arkansas
Red Basin
Southeast
West Gulf
Lower
Mississippi

Modeled Snow Water Equivalent forecasted for 2019 May 2, 14:00 UTC



"2100? IT DOESN'T KEEP ME UP AT NIGHT!"

Lessons for the Next Generation of Climate Assessments

BY LEE TRYHORN AND ART DEGAETANO

Climate change is underway and the impacts are being felt. Assessments of climate change impacts, adaptation, and vulnerability (collectively termed "climate assessments") are being undertaken to inform decision making in this environment of uncertainty (Carter et al. 2007). The urgent need for climate information for management and adaptation decisions has led to an increase in the number of climate assessments being performed across the United States (National Assessment Synthesis Team 2001; New England Regional Assessment Group 2001; Frumhoff et al. 2007; Titus et al. 2009; Jacobson et al. 2009; Moser et al. 2009; Karl et al. 2009; NYSERDA ClimAID Team 2010). Assessment methodologies have gradually evolved and increased in number (Carter et al. 2007), and this trend is likely to continue. In recent years, climate assessments have been progressively propelled from exclusively research-oriented summaries or activities toward analytical frameworks that are designed for practical decision making (Carter et al. 2007). The latest climate assessments (the "new generation") are often required to formulate comprehensive adaptation alternatives or, at the very least, recommendations that will guide the choice of alternatives. This transition is occurring with mixed success, as the aims of research and decision analysis differ somewhat in their treatment of uncertainty (Dessai and Hulme 2004; Rayner et al. 2005). Research seeks to understand and minimize uncertainty, whereas decision analysis aims to manage uncertainty in order to prioritize and carry out actions (Carter et al. 2007).

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In final form 18 November 2010

Despite the increase in assessments that deal with adaptation alternatives, and the increasing recognition that climate impacts and adaptation are unique issues in each community (Miles et al. 2006; Lynch and Brunner 2007; Christoplos et al. 2009; Brunner and Lynch 2010a,b), there has continued to be a lack of practical advice for adaptation decision making at the local level (Arnell 2010). This is particularly true when considering smaller, less urbanized communities. There are a number of examples of larger well-resourced communities taking adaptation action (Lowe et al. 2009; NYC Climate Change Adaptation Task Force), but at smaller scales communities that are proactive with adaptation are a rarity. The attitude is captured by the quote used for the title of this essay from a water supply plant manager when asked about future planning efforts.

The focus of this essay is therefore ways in which assessments can make themselves more socially relevant (i.e., better link climate science to real-world problems being faced by communities) and successfully meet the new demands that are being asked of them. This essay draws on experiences from the 2010 Integrated Assessment for Effective Climate Change

Lisi Pei

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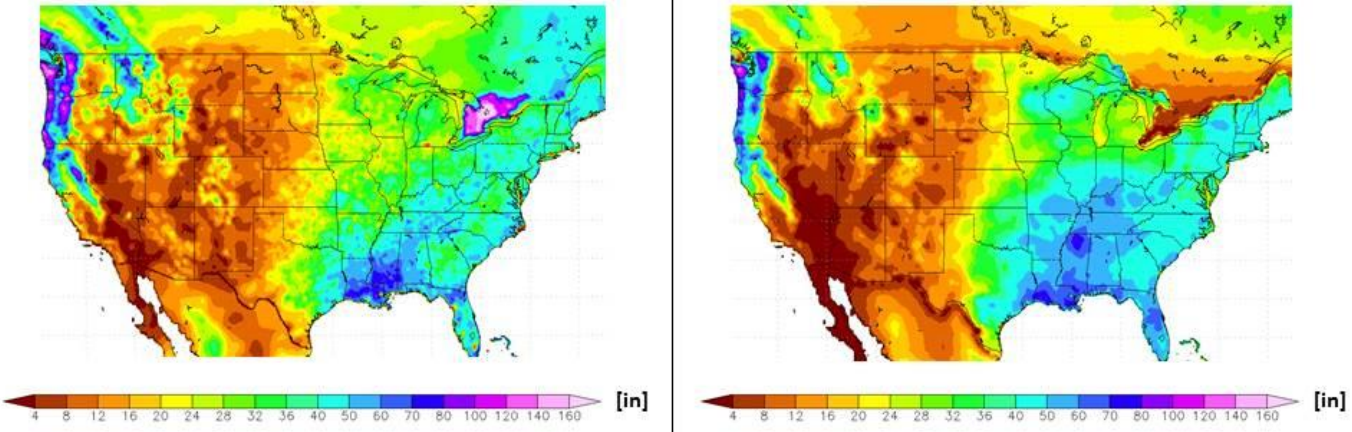
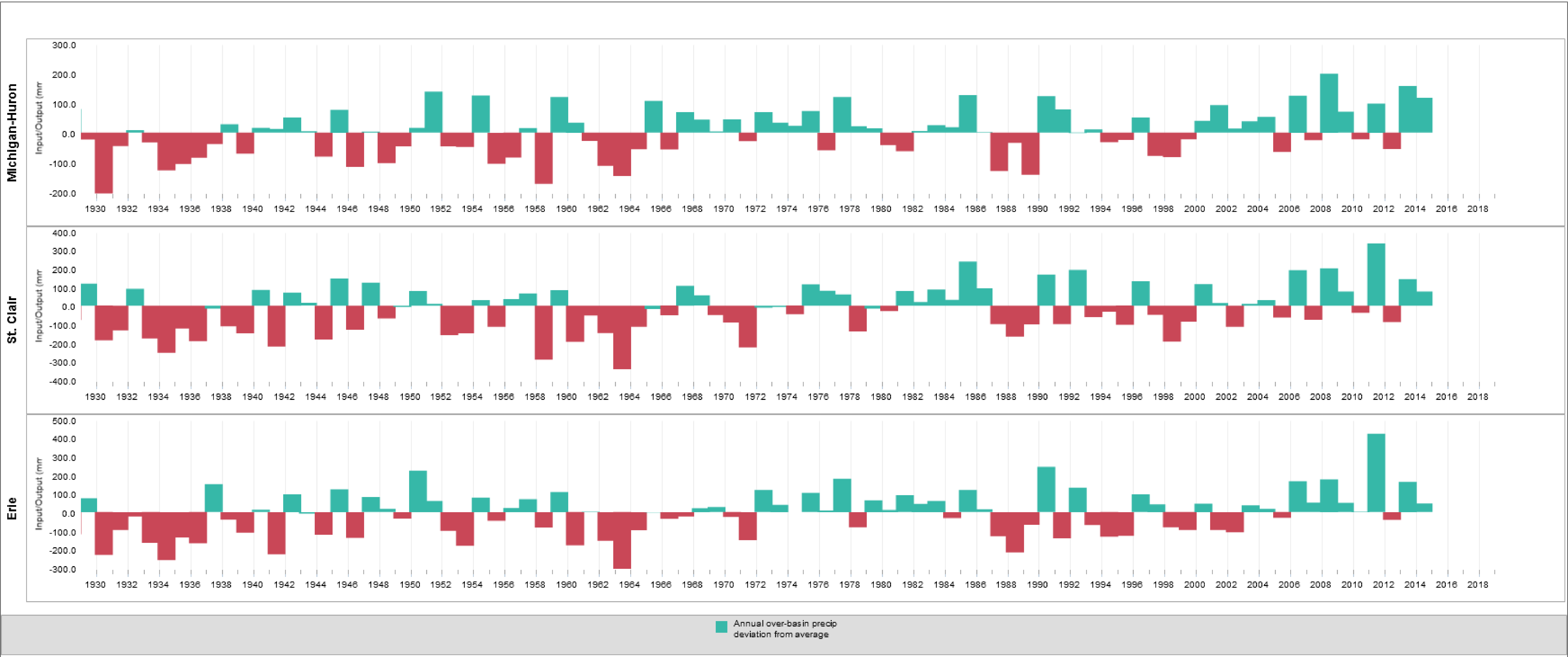


Gronewold et al. (2018), BAMS

Study	Climate data	Grid	Scenario	Projection time period	Run type	Hydrologic model	Projection NBS	Projection lake levels
Cohen (1986)	2 GCMs	6.2° lat × 8.8° lon	$2 \times CO_2$	—	Steady state	Water balance calculations	GL: −4% to −21%	—
Marchand et al. (1988)	1 GCM	4° lat × 5° lon	$2 \times CO_2$	—	Steady state	Great Lakes levels/flow model	—	SUP: −0.21 m and ONT: −0.85 m
Croley (1990)	3 GCMs	5.4° lat × 7.5° lon	$2 \times CO_2$	—	Steady state	GLERL suite	SUP: −26% and ERI: −87%	—
Hartmann (1990)	3 GCMs	5.4° lat × 7.5° lon	$2 \times CO_2$	—	Steady state	GLERL suite	SUP: −26% and ONT: −28%	SUP: −0.47 m and MI–HUR: −1.59 m
Smith (1991)	3 GCMs	5.4° lat × 7.5° lon	$2 \times CO_2$	—	Steady state	GLERL suite	—	SUP: −0.45 m and MI–HUR: −1.58 m
Mortsch and Quinn (1996)	4 GCMs	5.0° lat × 6.6° lon	$2 \times CO_2$	—	Steady state	GLERL suite	—	SUP: −0.39 m and MI–HUR: −1.60 m
Croley et al. (1996)	Transposed observed data	—	—	—	—	GLERL suite	GL: −1% to −54%	—
Chao (1999)	4 GCMs	4.1° lat × 5.2° lon	IPCC Second Assessment Report (AR2)	2050	Transient	GLERL suite	—	SUP: −0.5 m and MI–HUR −0.9 m
Mortsch et al. (2000)	2 GCMs	3.1° lat × 3.8° lon	$+1\%\ CO_2\ yr^{-1}$	2050	Transient	GLERL suite	—	SUP: −0.16 m and MI–HUR: −0.49 m
Lofgren et al. (2002)	2 GCMs	3.1° lat × 3.8° lon	$+1\%\ CO_2\ yr^{-1}$	2090	Transient	GLERL suite	—	SUP: −0.16 m and MI–HUR −0.52 m
Hayhoe et al. (2010)	3 CMIP3 GCMs	2.4° lat × 2.8° lon	SRES A1FI	2070–99	Transient	GLERL suite	—	SUP: −0.2 m and MI–HUR: −0.55 m
Angel and Kunkel (2010)	23 CMIP3 GCMs	2.5° lat × 2.8° lon	SRES B1, A1B, and A2	2080–94	Transient	GLERL suite	—	MI–HUR: −0.25 m for B1 to −0.41 m for A2
MacKay and Seglenieks (2013)	1 RCM	22.5 km	SRES A2	2021–50	Transient	RCM hydrologic components and CGLRRM	ERI: −9% and SUP: +1%	SUP: −0.03 m and ERI: −0.06 m
Music et al. (2015)	3 RCMs	45–50 km	SRES A2	2041–70	Transient	RCM hydrologic components	MI–HUR: +1%	—

Great Lakes Hydrologic Cycle

Basin-wide precipitation



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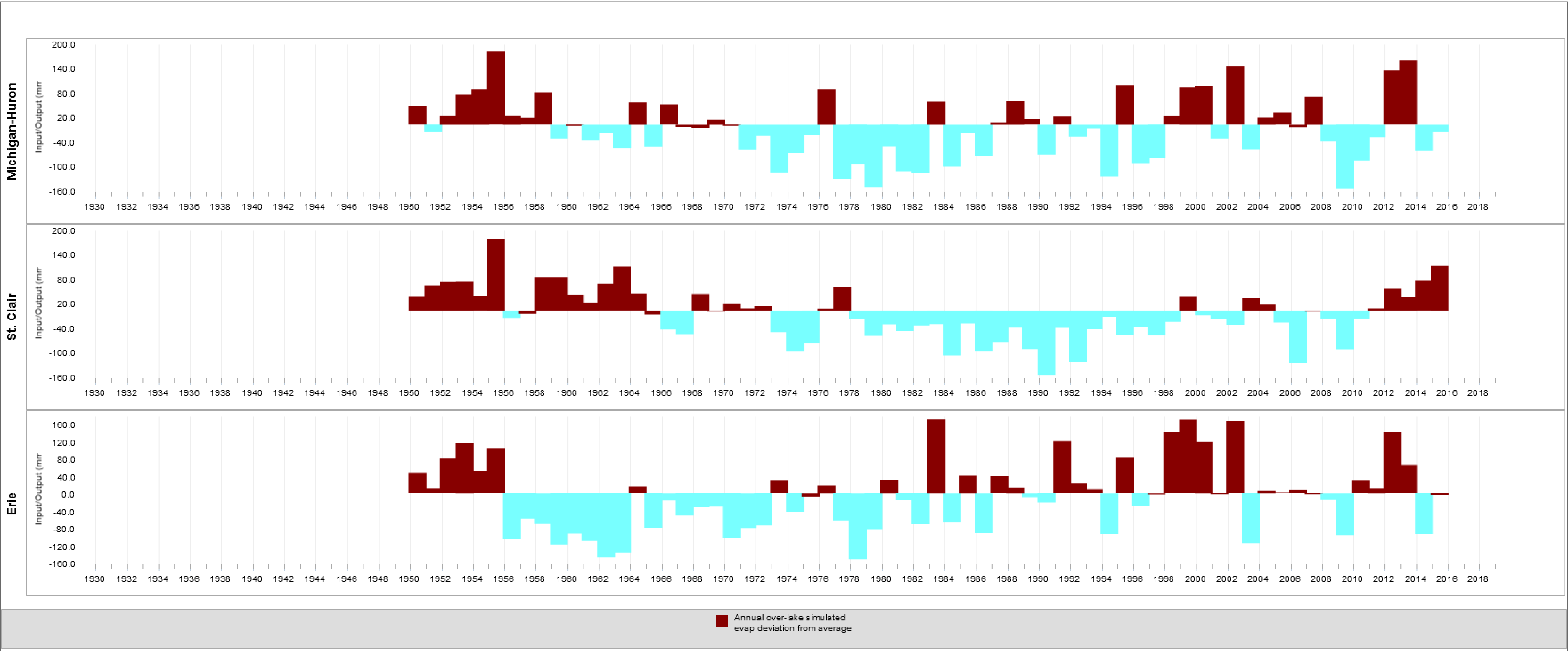
Great Lakes Hydrologic Cycle

Lake evaporation



Generated by the Great Lakes Dashboard: http://www.glerl.noaa.gov/data/gldb

Eddy-covariance system installed March 2017 on Whitefish Bay (courtesy Peter Blanken)

Resolving Hydrometeorological Data Discontinuities along an International Border

Andrew D. Gronewold, Vincent Fortin, Robert Caldwell, and James Noel

Monitoring, understanding, and forecasting the hydrologic cycle of large river and lake basins often require a broad suite of data and models ranging from in situ and satellite-derived measurements of (among other variables) precipitation, air and surface water temperature, energy fluxes, and soil moisture (Rodell et al. 2004; Trenberth et al. 2007) to conceptual and process-based models applied across varying time and space scales (Loaiciga et al. 1996; Silberstein 2006). Many North American (and other continental) hydrologic datasets and models, however, are susceptible to variations in monitoring infrastructure and data dissemination protocols when watershed, political, and jurisdictional boundaries do not align. This is a challenge facing hydrologic science professionals studying any freshwater basin that intersects an international boundary.