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Future Great Lakes climatology and water levels simulated using Regional Climate Models

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Environment Canada

The St. Clair River Symposium
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Summary

- Great Lakes hydroclimatology changes
- Previous future climate studies
- RCM downscaling
- RCM downscaling – future climate
- RCM downscaling – future lake levels
- Take home messages

Great Lake climatology changes

First step was to look at past trends in climate.

Best tool available to examine climate trends on the Great Lakes is the dashboard from the Great Lakes Environmental Research Laboratory (GLERL) run by NOAA in Ann Arbor, Michigan.

To find it search for: glerl hydro climate dashboard

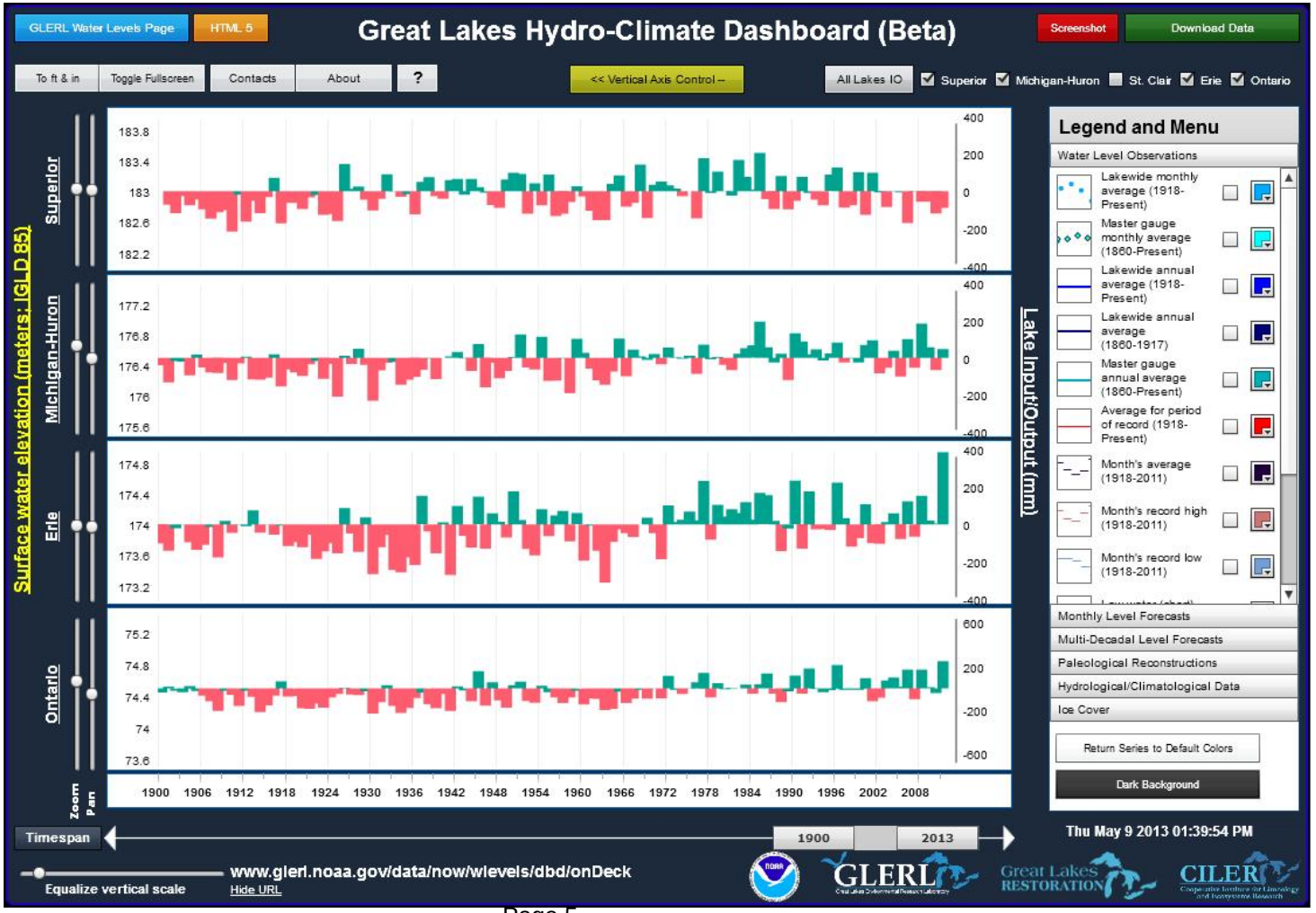
A very nice interface to plot lake levels, precipitation, evaporation, runoff, ice cover, etc. from time periods going from paleo reconstructions to future climate scenarios.

Great Lake climatology changes

Lake levels

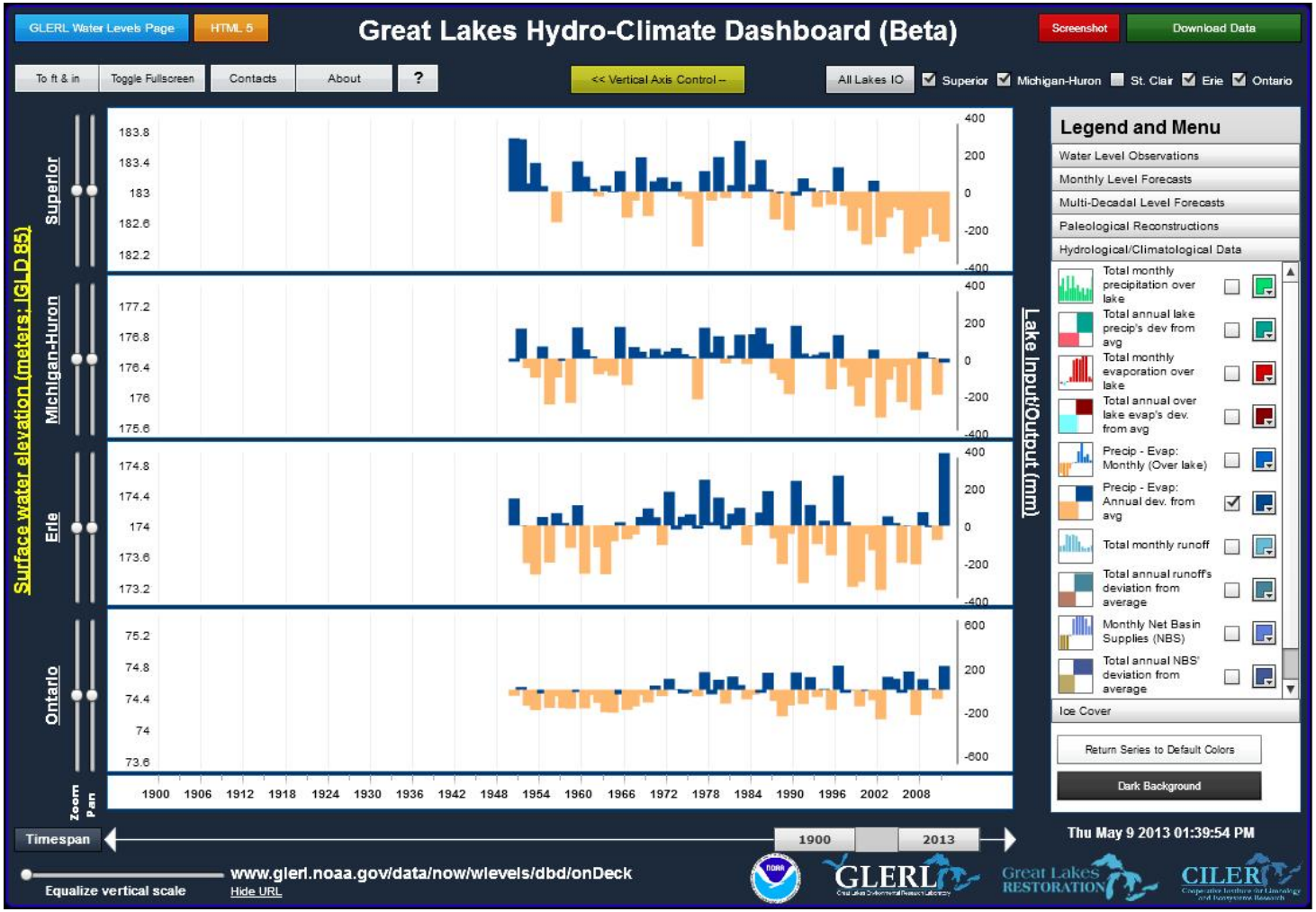
Great Lake climatology changes

Lake Precip



Great Lake climatology changes

Lake Evap



Great Lake climatology changes

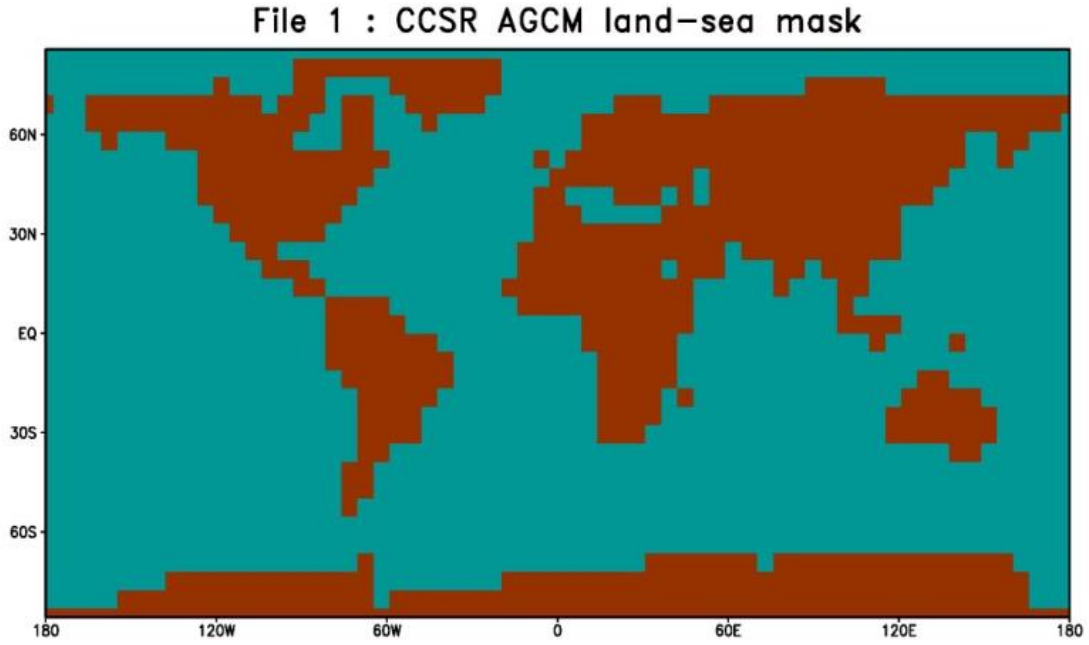
Very general overall trends:

- Decrease in lake levels for a recent 15 year period for Lake Superior and Michigan/Huron (increased in the last 1.5 years), large variations also seen in the past
- Slight increase in precipitation over some lakes in the past 15 years (Lake Superior neutral or lower)
- Runoff is similar to precipitation
- (according to AHPS model) Large increase in evaporation in Lakes Superior and Michigan/Huron in the past 15 years, less of increase in Lakes Erie and Ontario

Previous future climate studies

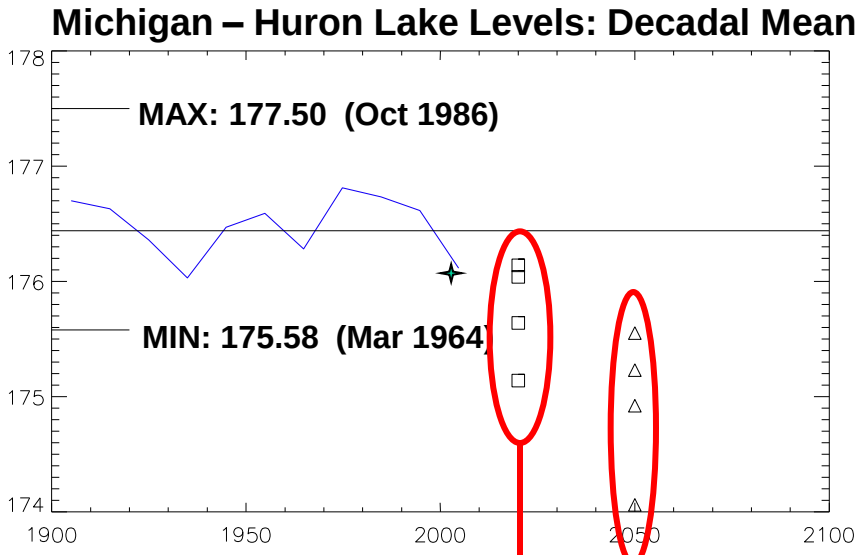
All methods use output data from Global Circulation Models (GCMs) based on various future carbon scenarios (A1B, A2, etc.).

Unfortunately the GCMs have poor resolution, most don't even see the lakes and therefore no lake processes are included.



Previous future climate studies

Lake level predictions made using GCM data resulted in estimates for much lower lake levels:



Lofgren *et al.* 2002 — early transient runs (GFTR2, HCTR2, MOTR2, CCTR2)

Mortsch *et al.* 2000 — early 2XCO2 runs (GISS, GFDL, OSU, CCC1)

Previous future climate studies

This has been repeated often in the media:

October 2, 2009: Chesterton Tribune.

Study reports Indiana Dunes National Lakeshore threatened by climate change

“Scientists project that Great Lake levels could fall by as much as several feet by 2090.”

Kansas City infoZine® Greater Kansas City's User-Driven News Source Online Since 1994

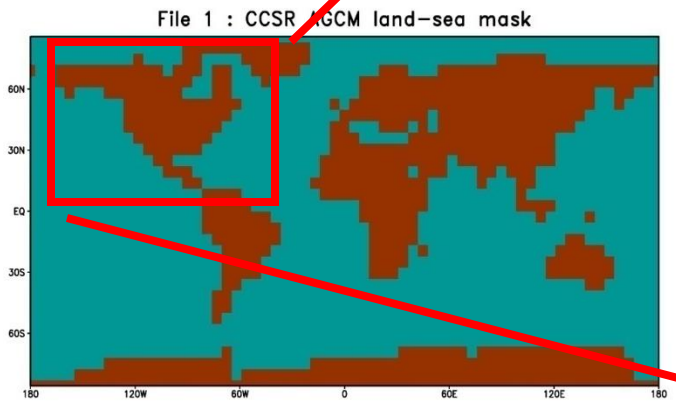
November 28, 2008

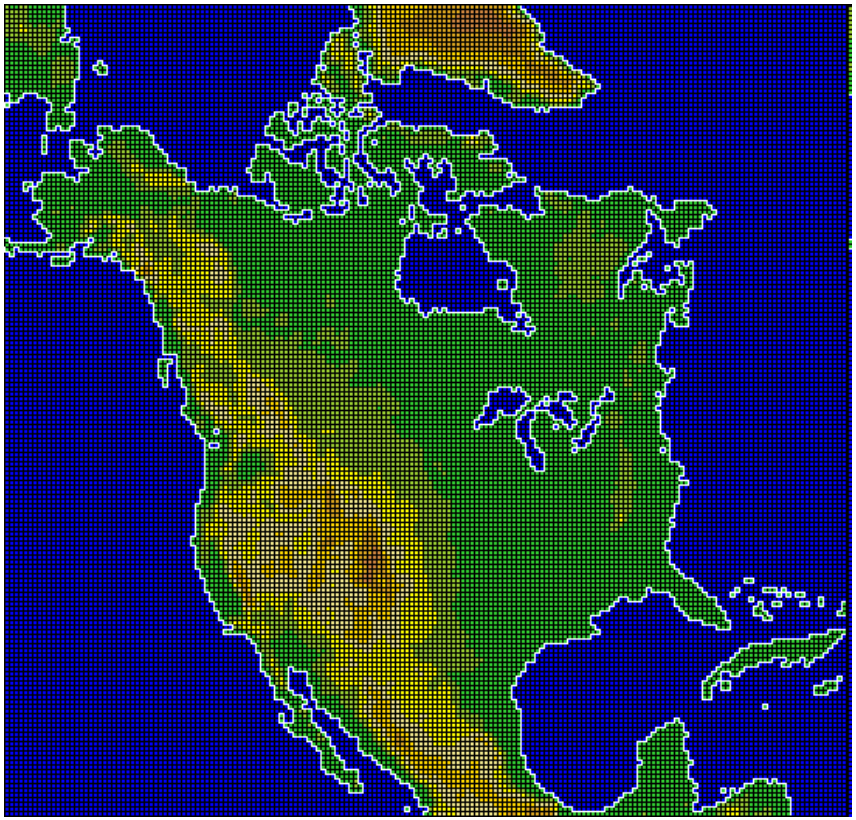
Climate Change, Water Sharing Could Damage Great Lakes

“Most climate models predict that the water levels in the Great Lakes will fall …. Lake Huron could drop by as much as 4.5 feet.

RCM dynamical downscaling

- RCMs are grid forced around the outside with GCM data.





RCM dynamical downscaling

Regional Climate Models (RCMs) reproduces the main characteristics of the climate system based on dynamical and thermodynamic equations

The outside boundary conditions are supplied by the various future climate results of the GCMs, this process is called dynamical downscaling.

The smaller resolution of RCMs allow processes such as lake effect precipitation and precipitation recycling to be modelled (~45 km instead of ~200+ km).

Future climate results for one run are also available on a much smaller time step (15 min instead of monthly)

RCM dynamical downscaling

Two sets of RCM data were analyzed, runs of the Canadian Regional Climate Model (CRCM) done by the Ouranos consortium in Montreal and results from the NARCCAP project for the 2050 time slice.

A total of eight CRCM runs were performed using a different members from 3 different driving GCMs.

- CGCM – 5 members
- ECHAM5 – 2 members
- CNRM-CM3.3- 1 member

A total of six runs were used from the NARCCAP project using different combinations of 4 GCMs and 3 RCMs.

CRCM-cgcm3	CRCM-ccsm
HRM3-gfdf	HRM3-hadcm3
WFRG-cgcm3	WFRG-ccsm

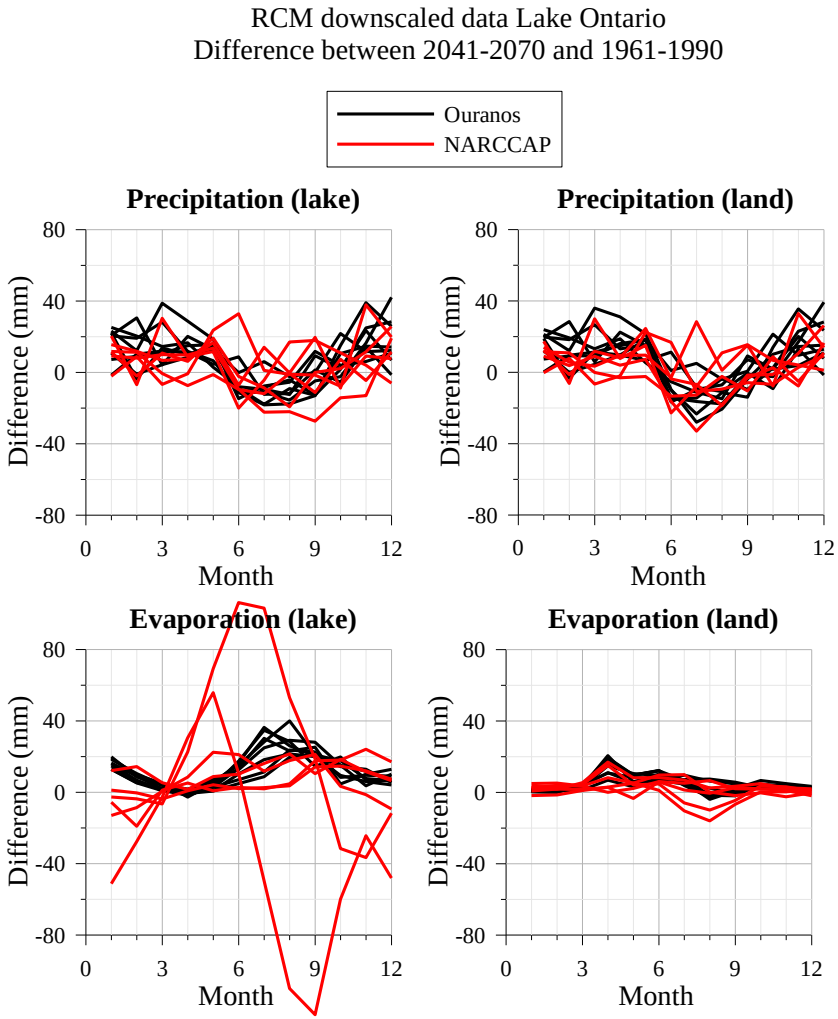
RCM downscaling – future climate

Annual total of differences for each component (positive numbers indicate higher future values).

Component	Lake	RCM diff (2071-2041) - (1970-2000)	GLERL diff (1961-1990) - (1950-2010)	GLERL diff (1971-2000) - (1950-2010)	GLERL diff (1981-2010) - (1950-2010)
		Modelled	Measured	Measured	Measured
Lake Precipitaton	Superior	68.7	10.6	23.1	3.0
(mm over lake)	Michigan/Huron	68.2	-3.7	16.2	21.1
	Erie	55.8	6.1	34.2	23.5
	Ontario	67.9	-11.1	31.8	34.5
Lake Evaporation	Superior	101.0	-15.0	18.7	55.0
(mm over lake)	Michigan/Huron	125.4	-43.6	-8.7	41.4
	Erie	133.3	-38.5	4.3	39.7
	Ontario	97.0	-16.2	-1.9	8.5
Runoff	Superior	16.6	26.6	2.7	-35.1
(mm over land)	Michigan/Huron	21.0	0.3	36.0	33.3
	Erie	12.7	-23.7	30.3	54.7
	Ontario	20.3	-71.8	65.2	78.9

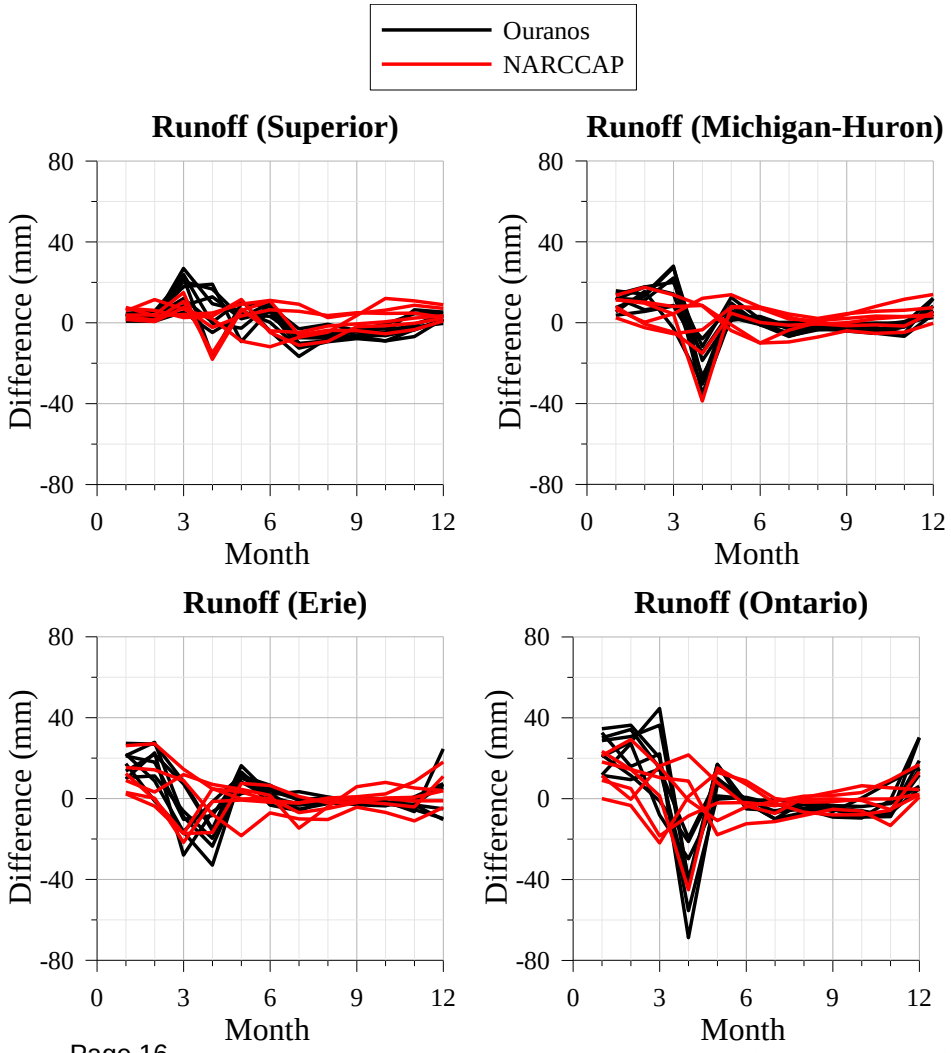
RCM downscaling – future climate

- Lake Ontario
- Large differences seen in seasonal patterns.
- Generally wetter in the winter/spring and drier in the summer/early fall.

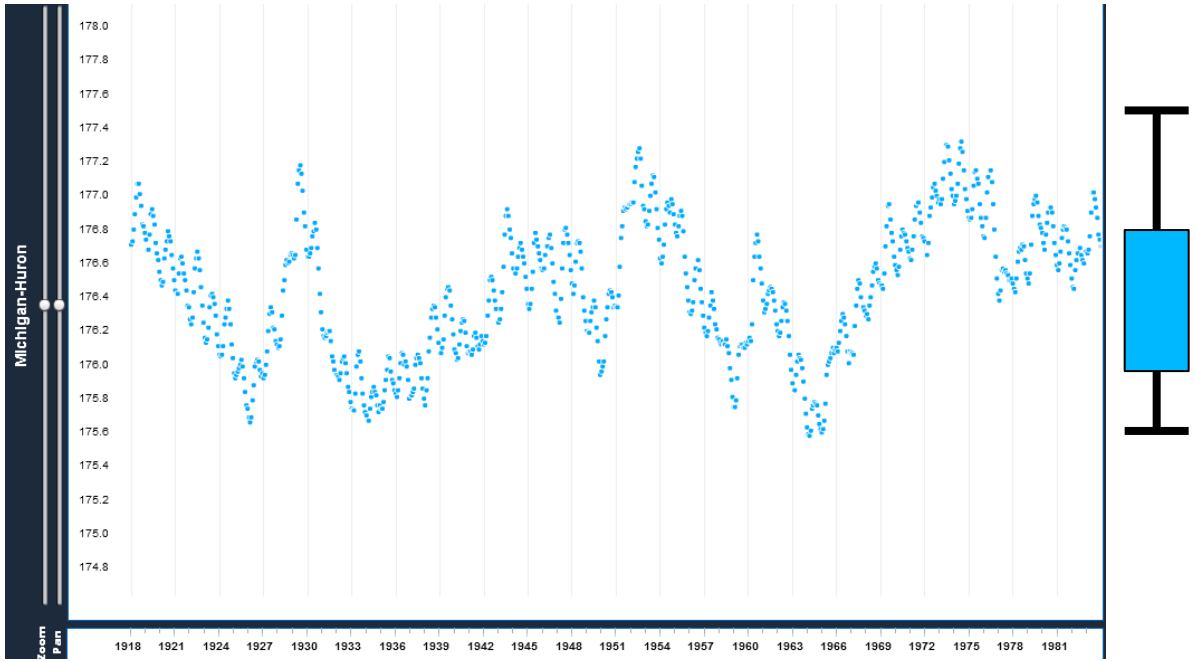


RCM downscaling – future climate

- More runoff during the winter, large reduction in spring melt peak, slight reduction in summer/fall.



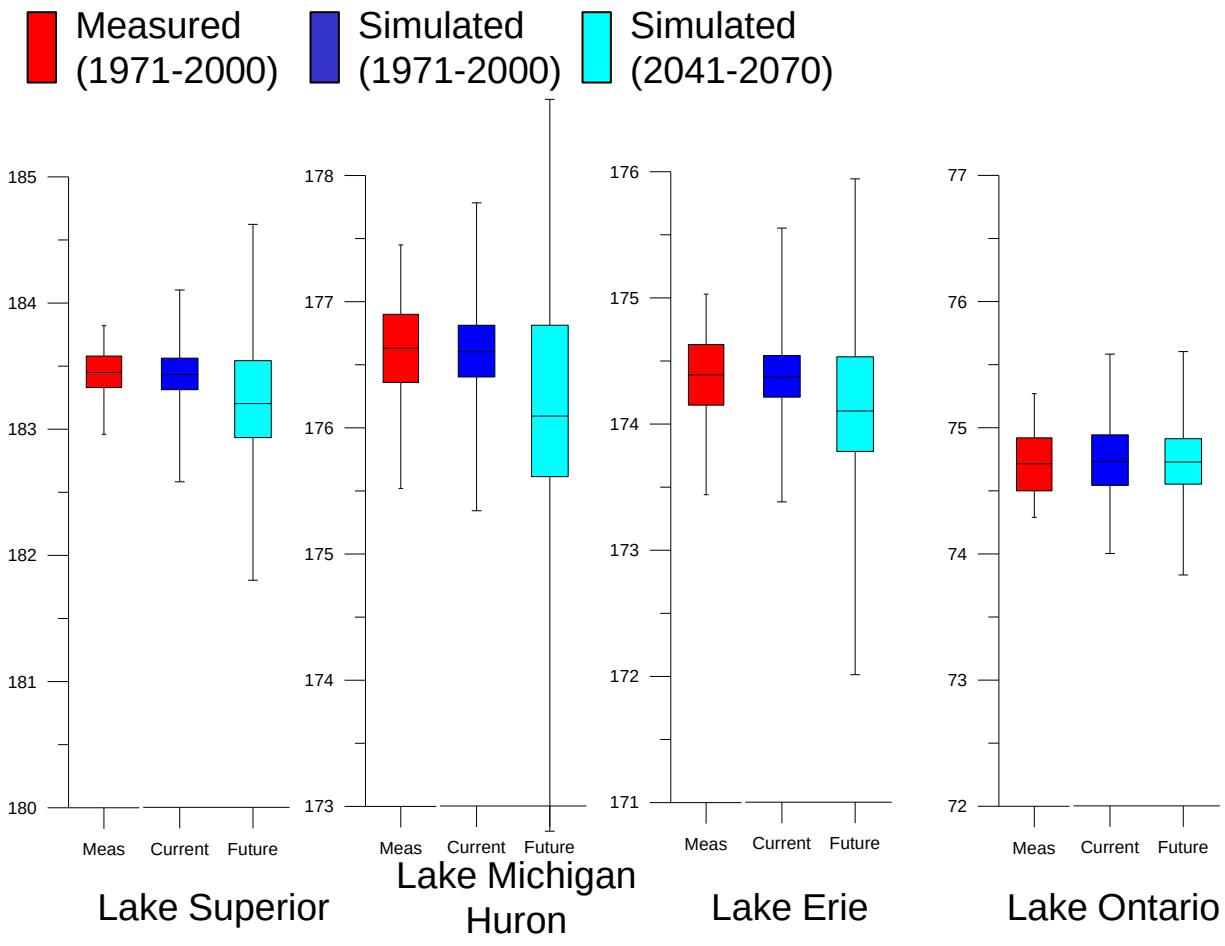
RCM downscaling – future lake levels



- What would have been the best estimate for the next 30 years in 1983?

RCM downscaling – future lake levels

- Lake levels calculated using the Coordinated Routing and Regulation Model.
- Results show lower median levels and larger range



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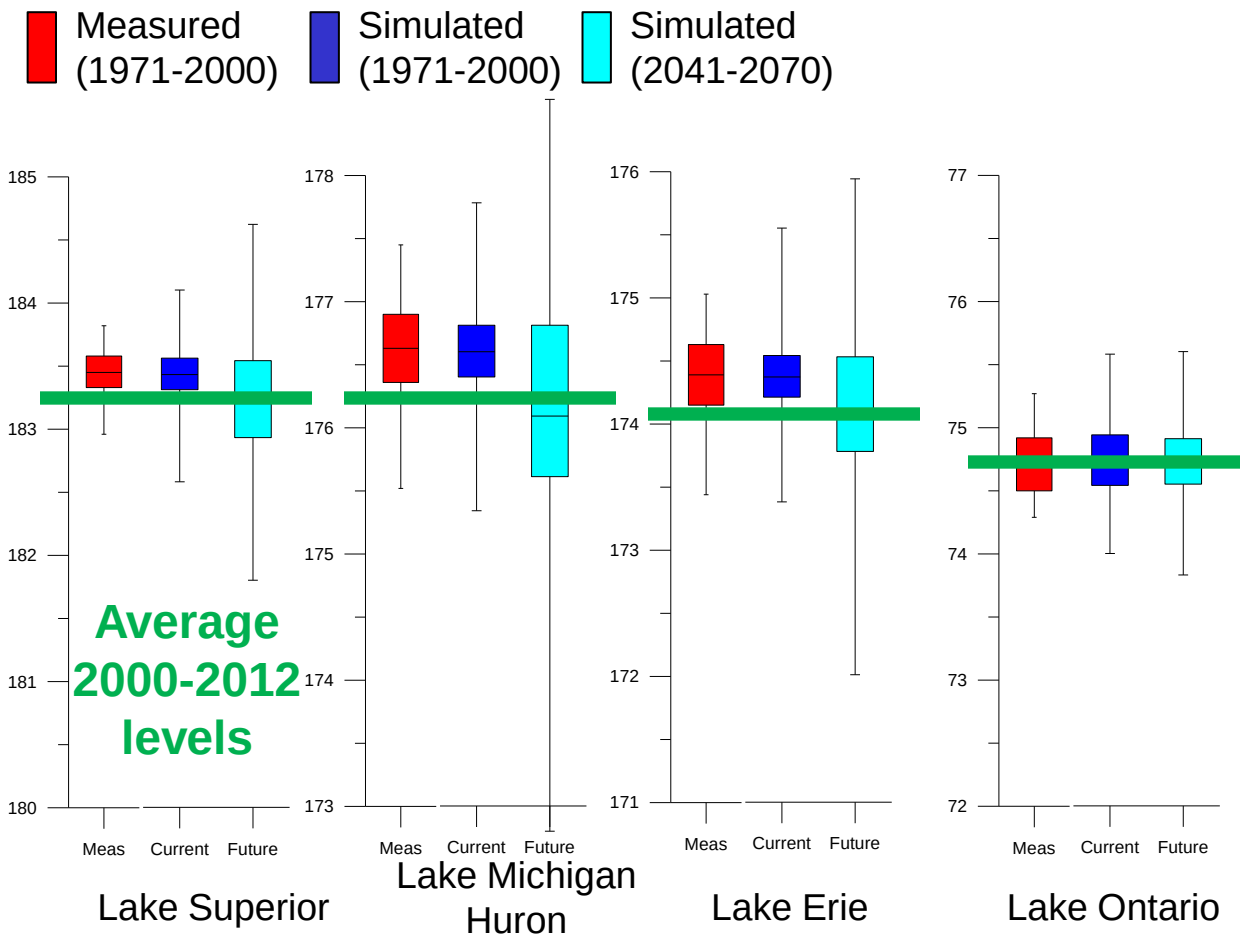
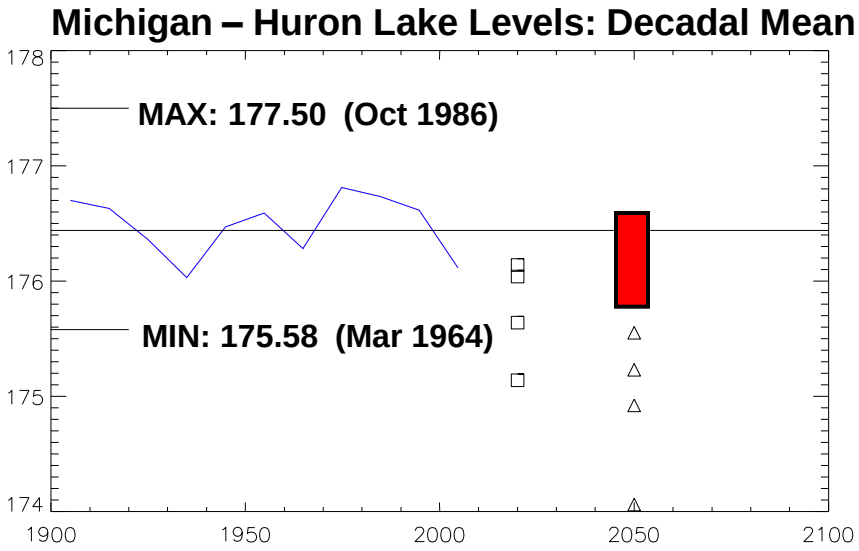


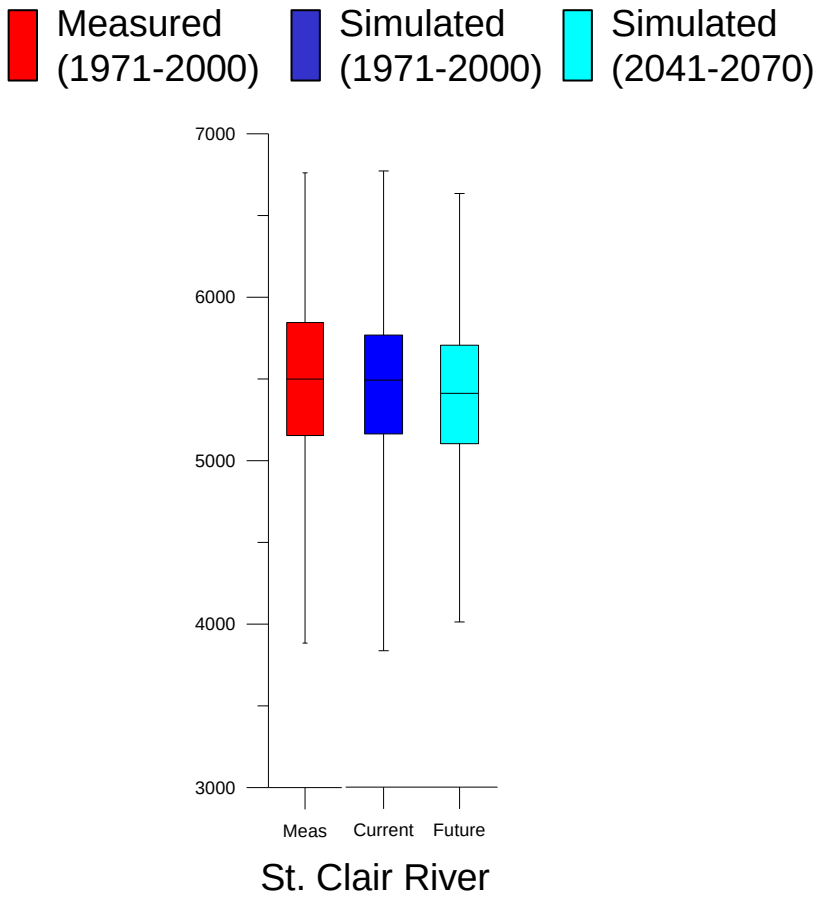
RCM downscaling – future lake levels

- Not as dramatic a change in lake level as seen in earlier studies using GCM results directly.



RCM downscaling – future lake levels

- Slight reduction in the median value of St. Clair River flows



St. Clair River

Take home messages

- We have seen recent decadal changes in lake level, precipitation, and evaporation that are different from previous relationships
- In general, the future projections based on climate models sees a continuation of the trends seen the last decade
- Although future projections show lower median water levels, they also show larger range of levels (ie. does not project that there will never be high or low levels)
- Have to be prepared for a wide range of future water levels and flows