Great Lakes Economies and Ecosystems: will extreme low water levels leave them high and dry?

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National Oceanic and Atmospheric Administration

[1]Center for Operational Oceanographic Products and Services (COOPs)
[2]Great Lakes Environmental Research Laboratory (GLERL)

NOAA Central Library Brown Bag Seminar
Silver Spring, MD
April 23, 2013

Outline

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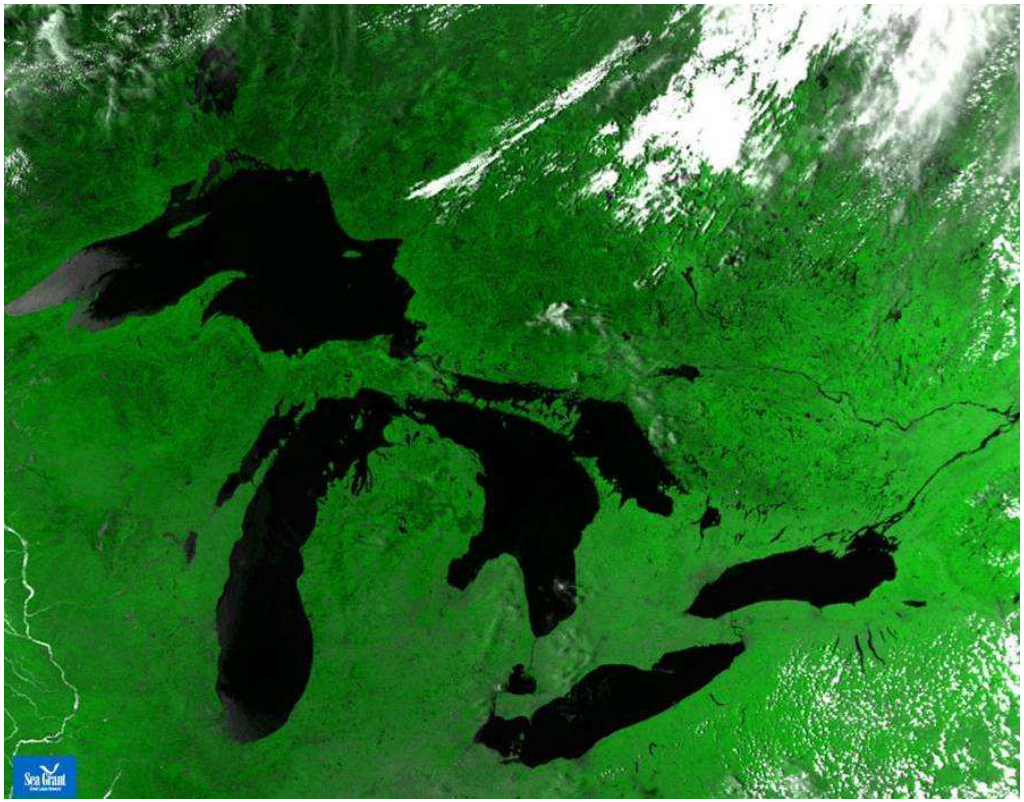
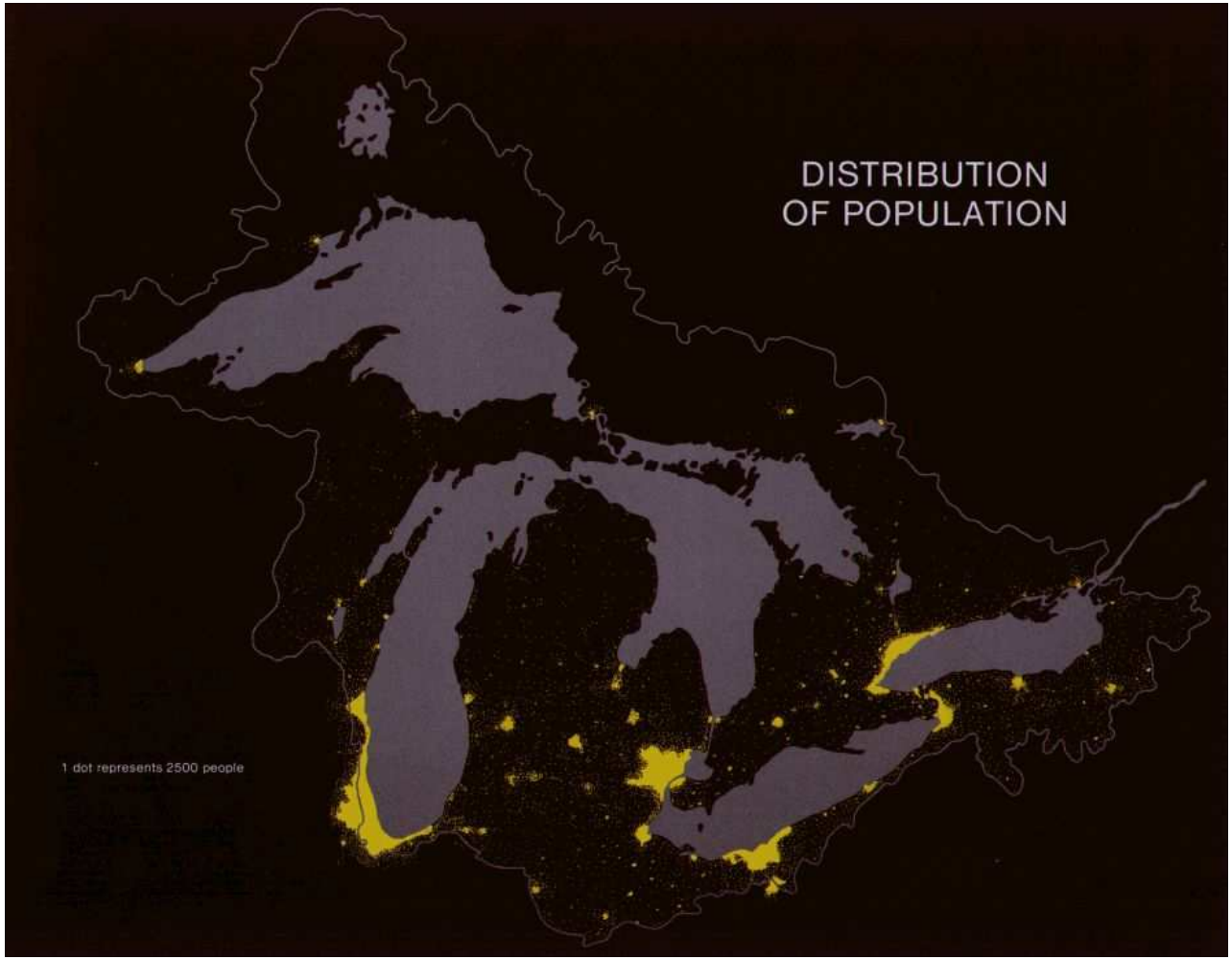
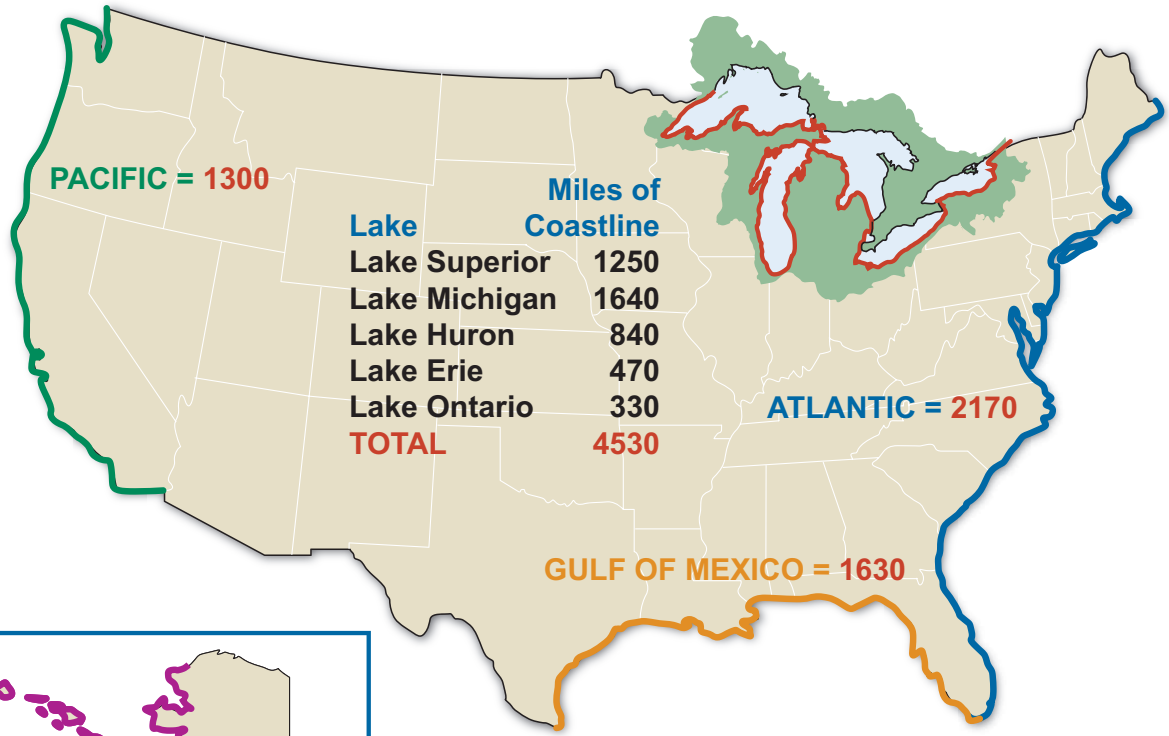

Sea Grant

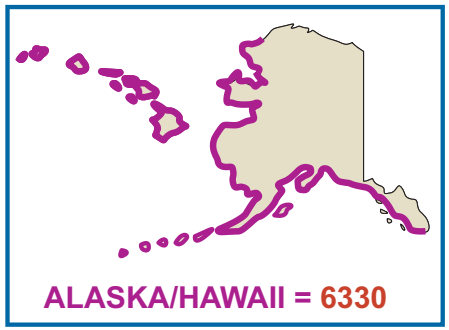


From: USEPA, Great Lakes Atlas

U.S. Great Lakes Coastline Comparison

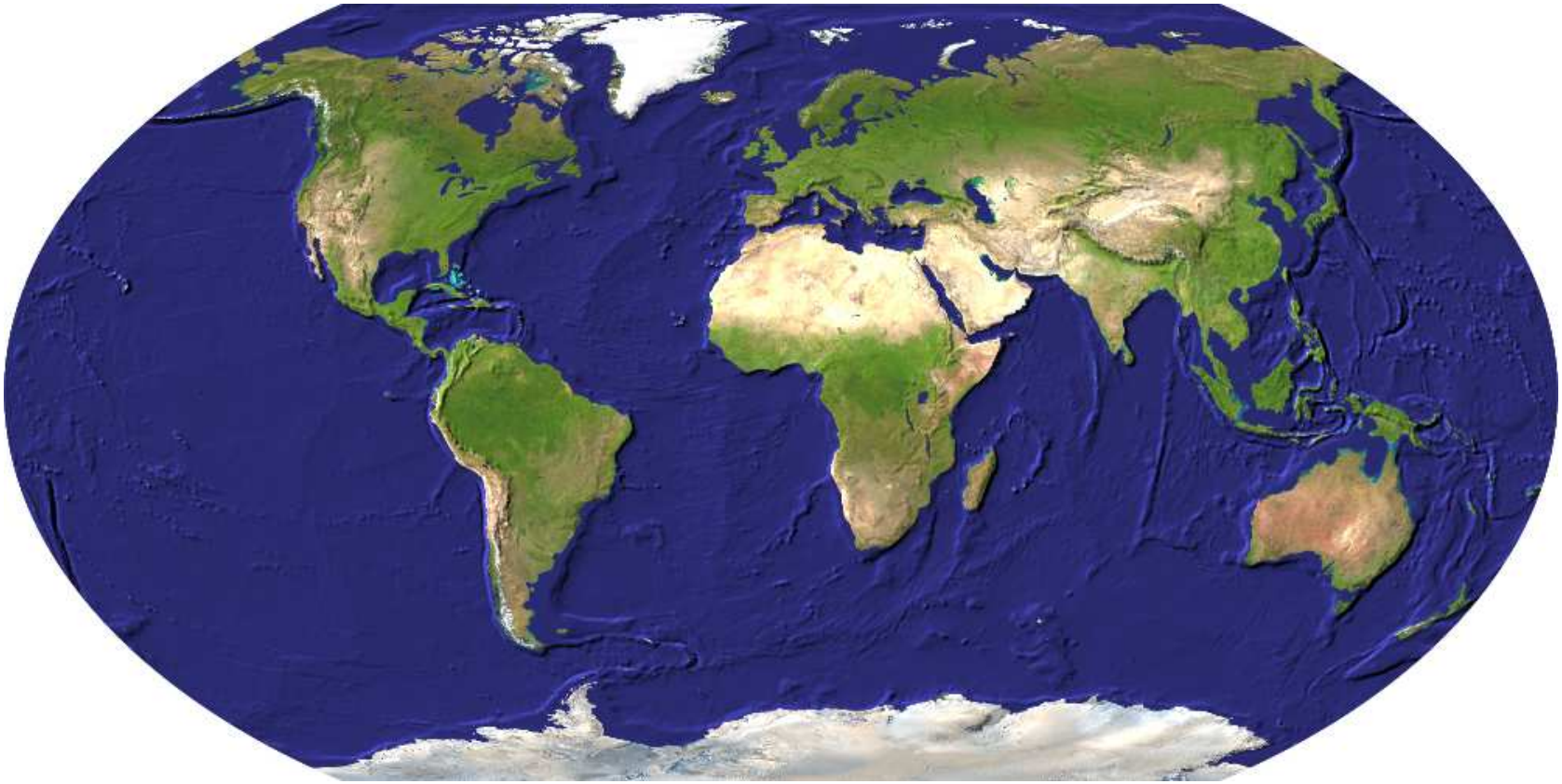


Lake	Miles of Coastline
Lake Superior	1250
Lake Michigan	1640
Lake Huron	840
Lake Erie	470
Lake Ontario	330
TOTAL	4530



*All numbers rounded to the nearest 10 miles.

Source: The Coastline of the United States. U.S. Dept. of Commerce, NOAA, NOAA/PA 71046 (Rev. 1975).



Name	Country	Surface area		Volume	
		(km^2)	(mi^2)	(km^3)	(mi^3)
Michigan–Huron	U.S. and Canada	117,702	45,445	8,458	2,029
Superior	U.S. and Canada	82,414	31,820	12,100	2,900
Victoria	Multiple	69,485	26,828	2,750	660
Tanganyika	Multiple	32,893	12,700	18,900	4,500
Baikal	Russia	31,500	12,200	23,600	5,700
Great Bear Lake	Canada	31,080	12,000	2,236	536
Malawi	Multiple	30,044	11,600	8,400	2,000
Great Slave Lake	Canada	28,930	11,170	2,090	500
Erie	U.S. and Canada	25,719	9,930	489	117
Winnipeg	Canada	23,553	9,094	283	68
Ontario	U.S. and Canada	19,477	7,520	1,639	393

Table: Water volume and surface area of the earth's highest surface area unfrozen fresh water bodies.

Name	Country	Surface area (km^2)	Surface area (mi^2)	Volume (km^3)	Volume (mi^3)
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Introduction: Great Lakes take home messages

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- Earth's largest (by surface area) unfrozen freshwater system

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- Earth's largest (by surface area) unfrozen freshwater system
- Significant human population, ecosystem, and economy
- Collectively managed and utilized by two nations
- NOAA plays critical role in collaborative monitoring and modeling

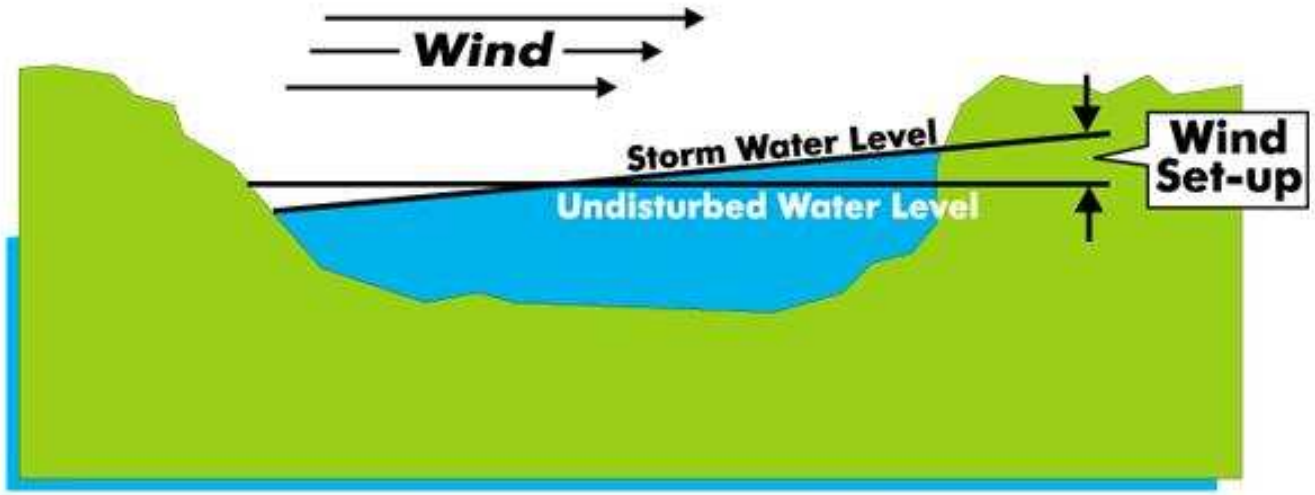
Outline


PRIMARY WIND
BACKUP WIND
RELATIVE HUMIDITY
AIR TEMPERATURE
CORS (GPS)
GOES ANTENNA
NOT VISIBLE:
BAROMETRIC PRESSURE (in building)
WATER TEMPERATURE (in water)
WATER LEVEL (in sump)
MACKINAW CITY, TYPICAL WATER, METEOROLOGICAL & GPS
SENSOR CONFIGURATION

Source: Great Lakes information network (GLIN)

Water levels: drivers and dynamics (short-term)

Water levels: drivers and dynamics (short-term)



Lake profile showing wind set-up

Courtesy *Living with the Lakes*, copyright 2000
USACE-Detroit District and Great Lakes Commission

Water levels: drivers and dynamics (short-term)

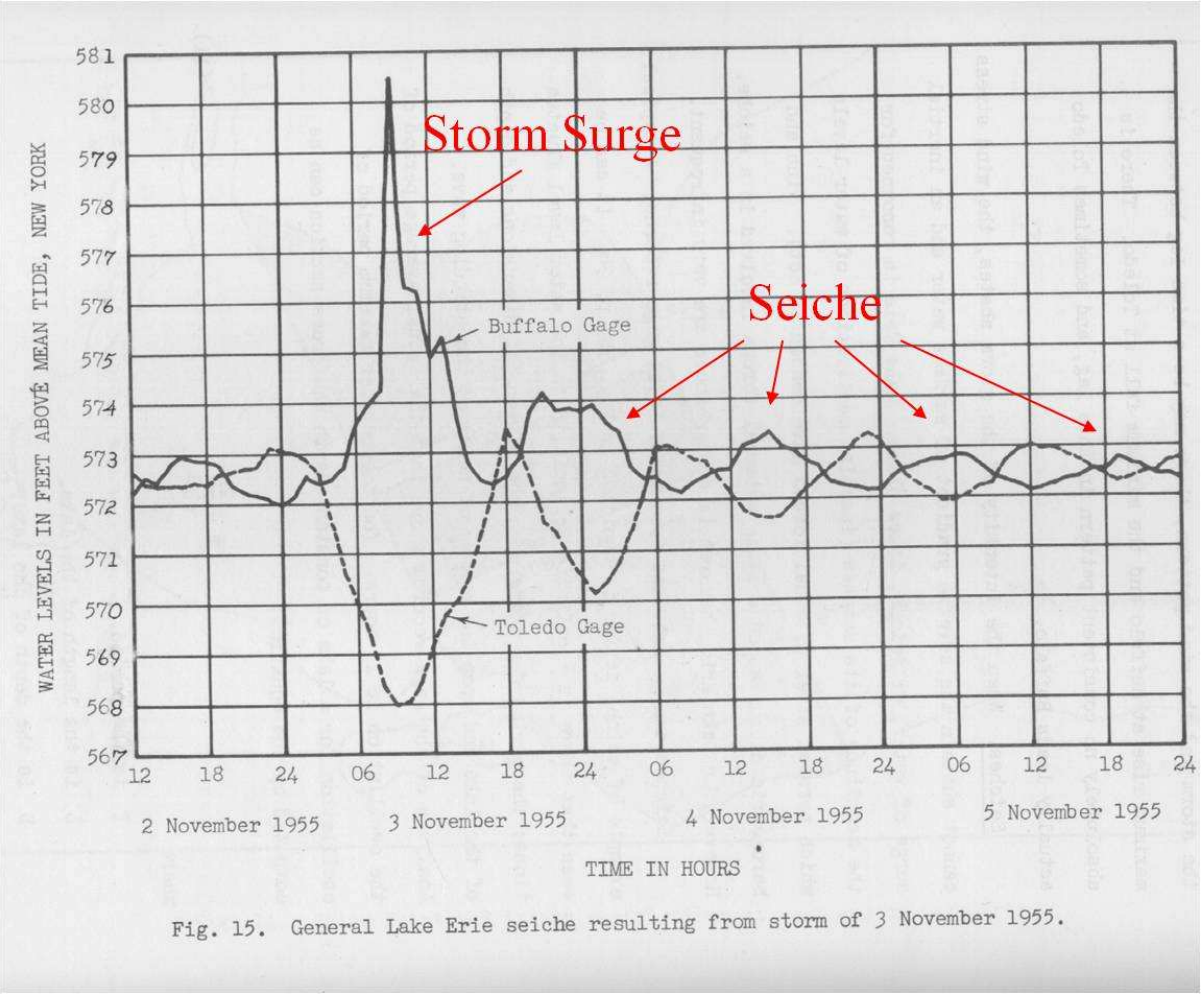


Fig. 15. General Lake Erie seiche resulting from storm of 3 November 1955.

Water levels: drivers and dynamics (mid-term)

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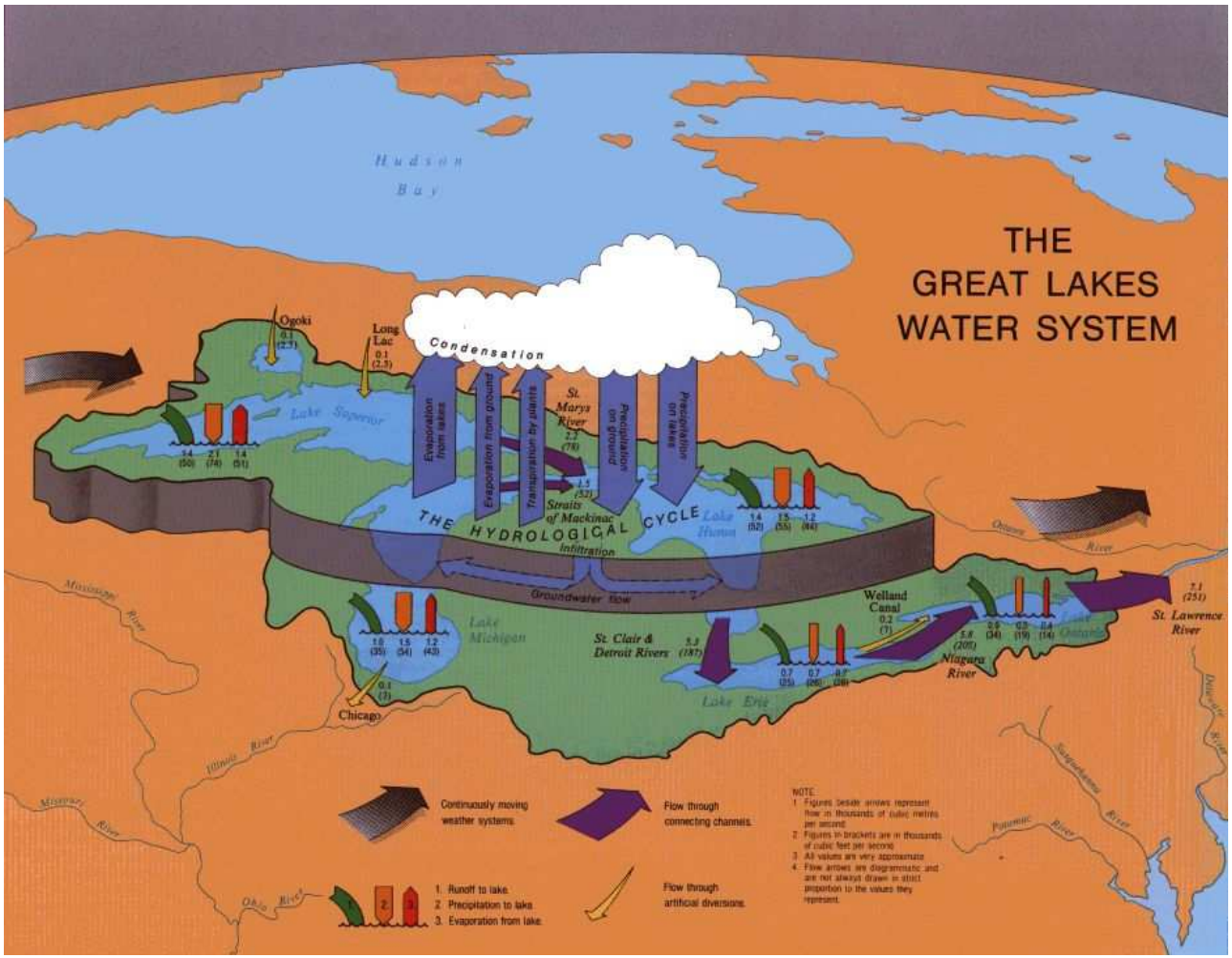

From: USEPA, Great Lakes Atlas

Water levels: drivers and dynamics (long-term)

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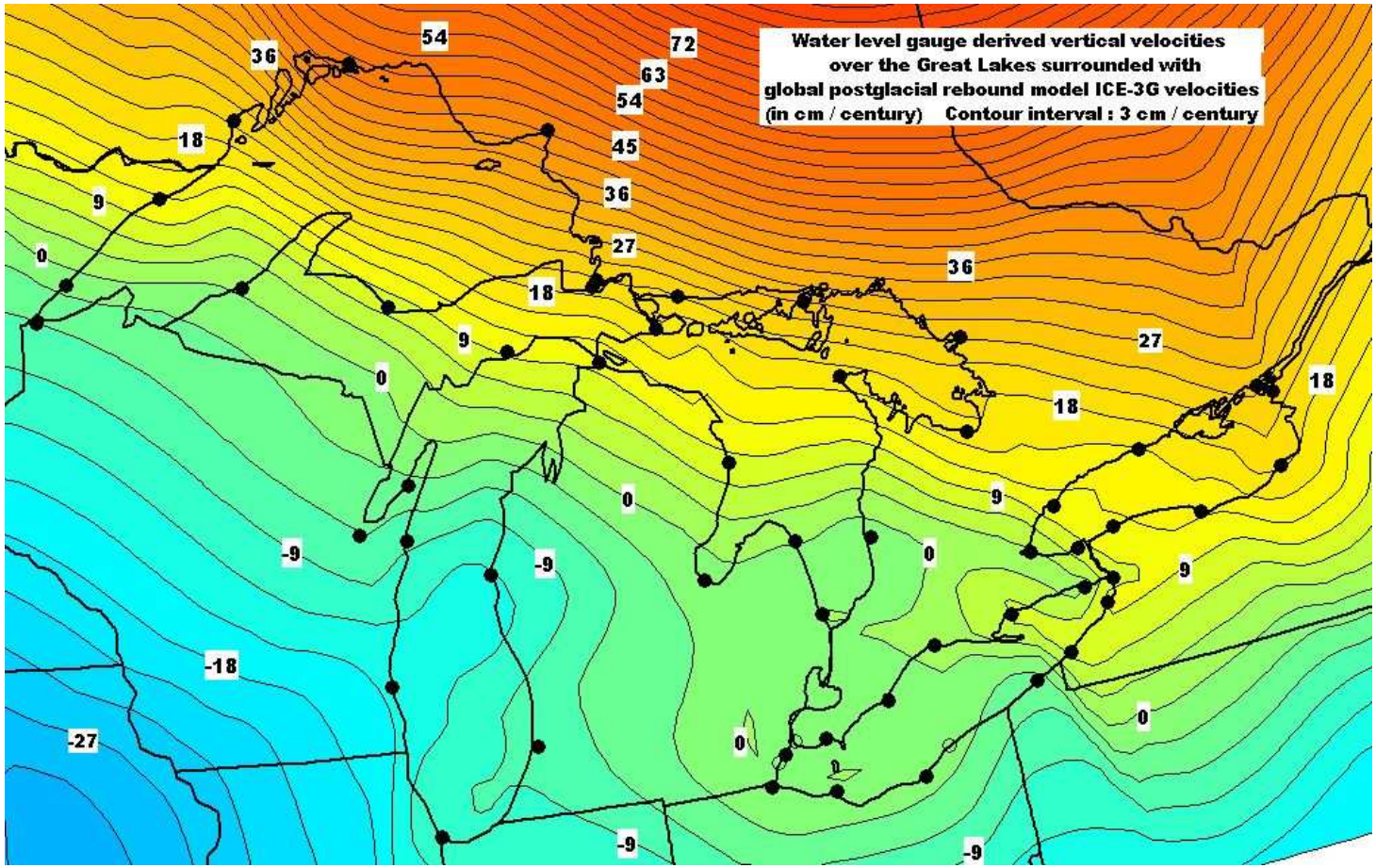

From: Mainville & Craymer, 2005

Water levels: data (long-term)

GLERL Water Levels Page | HTML 5

Great Lakes Hydro-Climate Dashboard (Beta)

Screenshot | Download Data

To fit & in | Toggle Fullscreen | Contacts | About | ?

Superior | Michigan-Huron | St. Clair | Erie | Ontario

Surface water elevation (meters; IGLD 85)

Superior
184.4
184
183.6
183.2
182.8
182.4
182

Michigan-Huron
177.4
177
176.6
176.2
175.8
175.4
175

http://www.glerl.noaa.gov/data/now/wlevels/levels.html

Erie
175.2
174.8
174.4
174
173.6
173.2
172.8

Ontario
75.8
75.4
75
74.6
74.2
73.8
73.4

1918 1921 1924 1927 1930 1933 1936 1939 1942 1945 1948 1951 1954 1957 1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011

Zoom
Pan

Legend and Menu

Water Level Observations

- Lakewide monthly average (1918-Present)
- Master gauge monthly average (1860-Present)
- Lakewide annual average (1918-Present)
- Lakewide annual average (1860-1917)
- Master gauge annual average (1860-Present)
- Average for period of record (1918-Present)
- Month's average (1918-2011)
- Month's record high (1918-2011)
- Month's record low (1918-2011)

Monthly Level Forecasts

Multi-Decadal Level Forecasts

Paleological Reconstructions

Hydrological/Climatological Data

Ice Cover

Return Series to Default Colors

Dark Background

Timespan 1918 2013

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Equalize vertical scale

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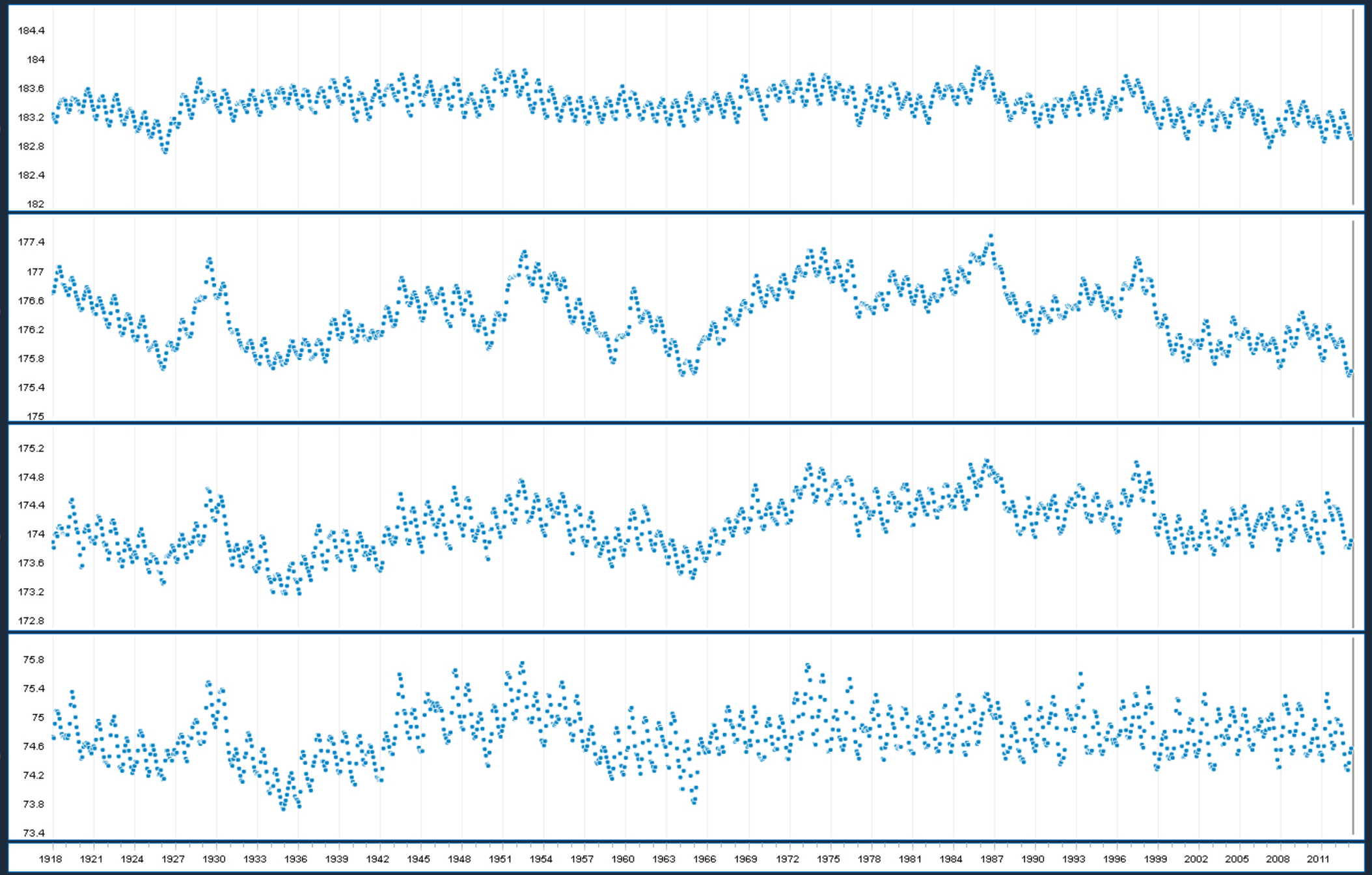

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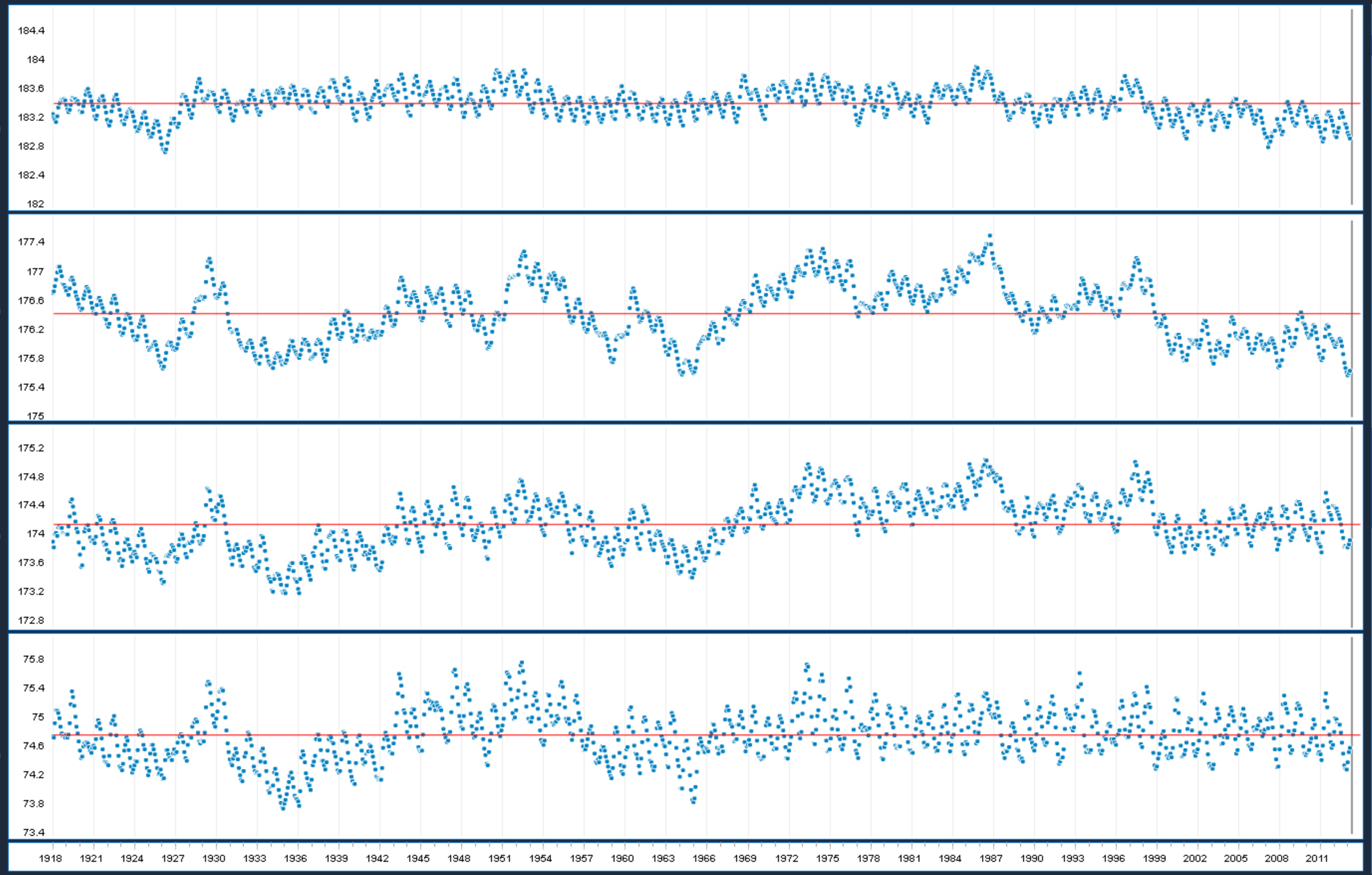

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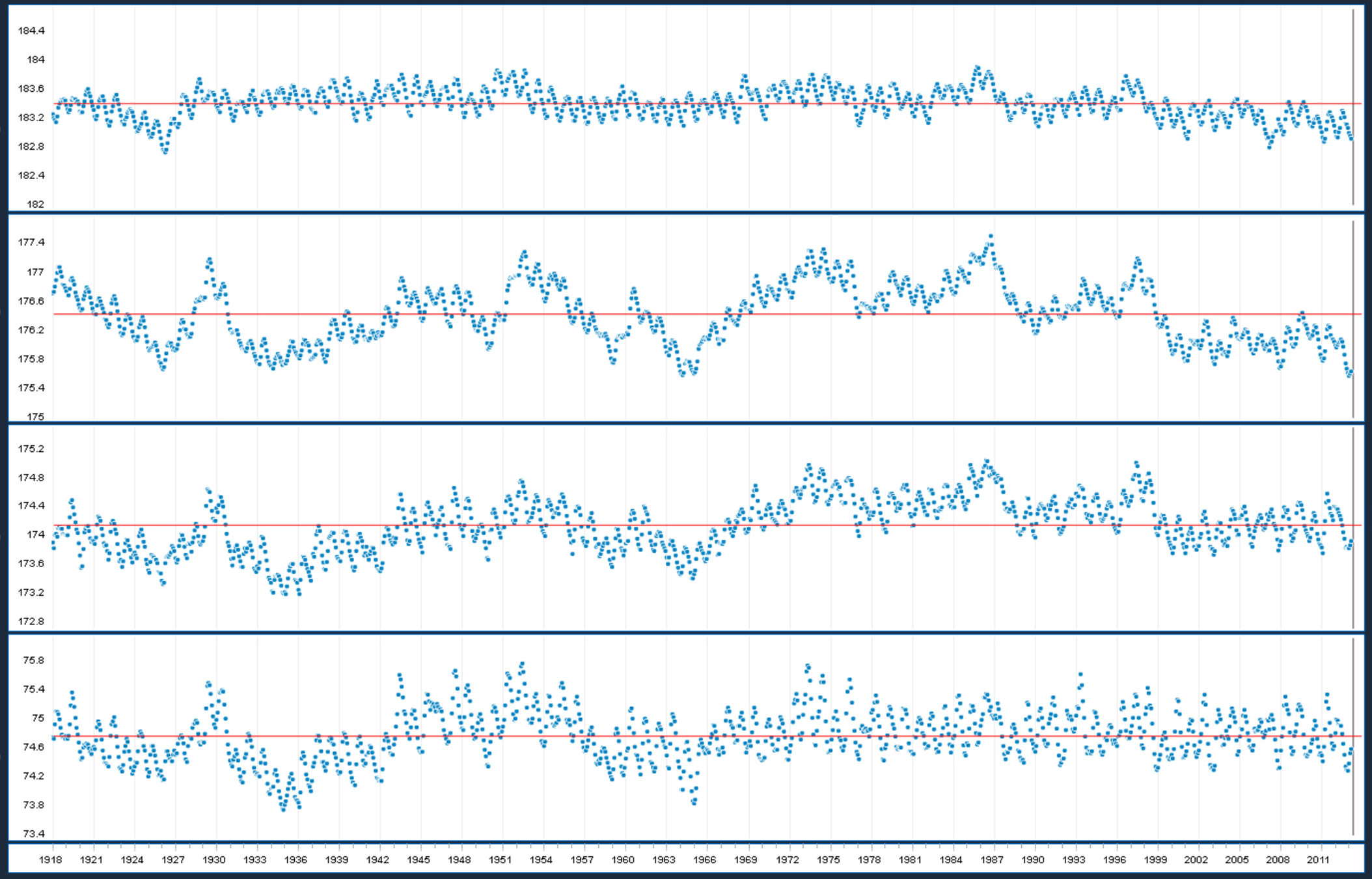

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<< Vertical Axis Control --

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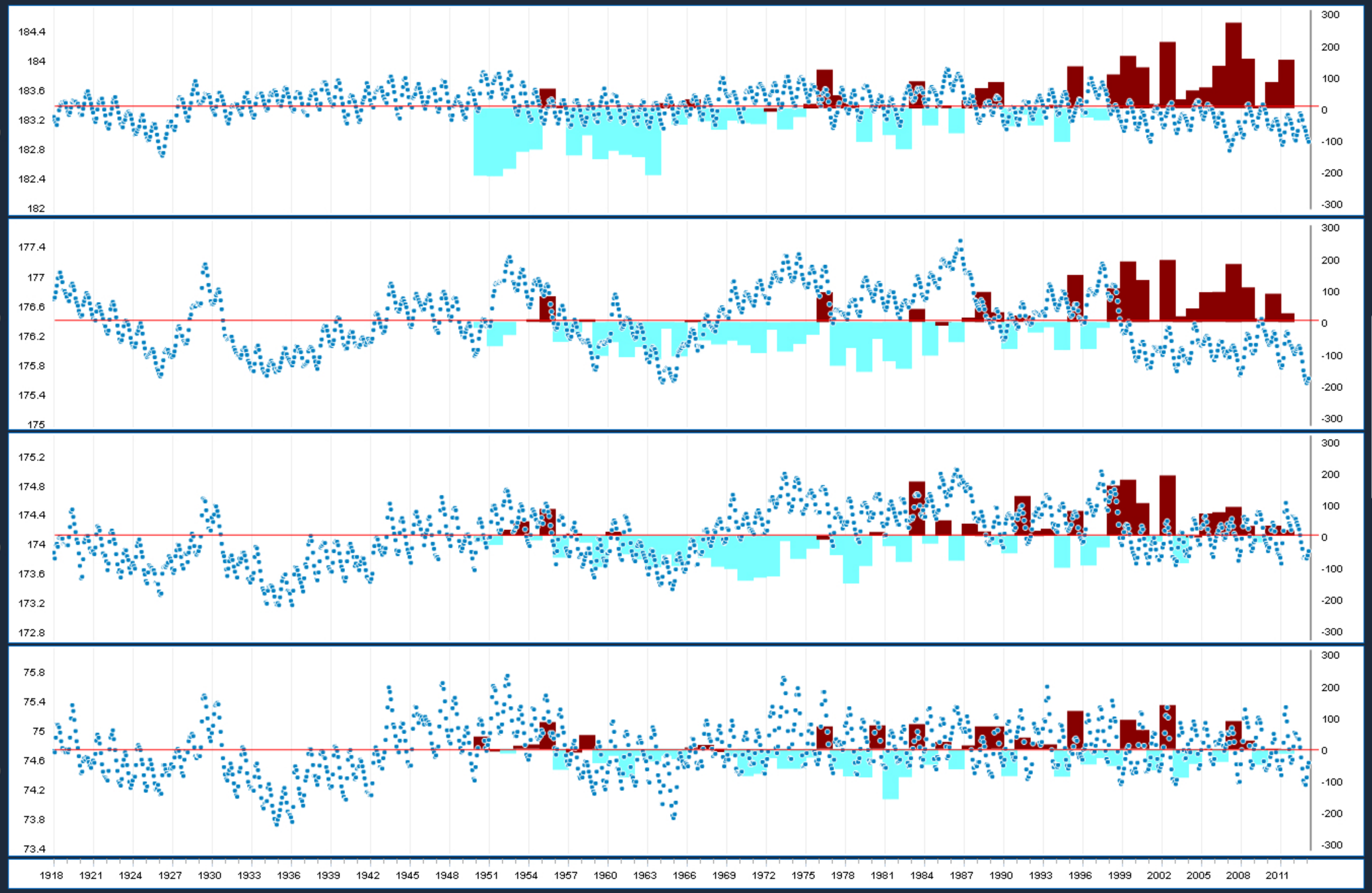

Zoom
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Lake Input/Output (mm)

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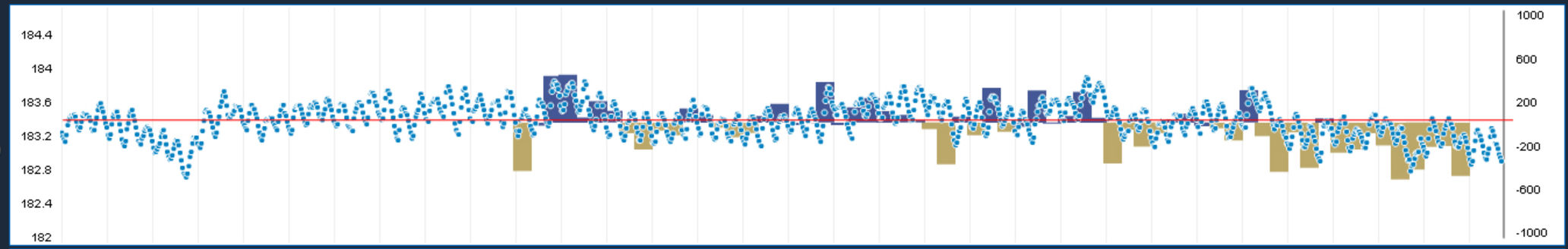

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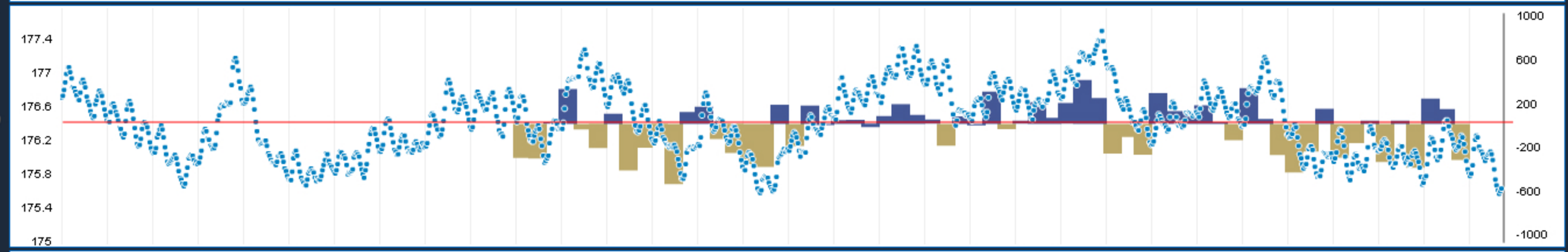
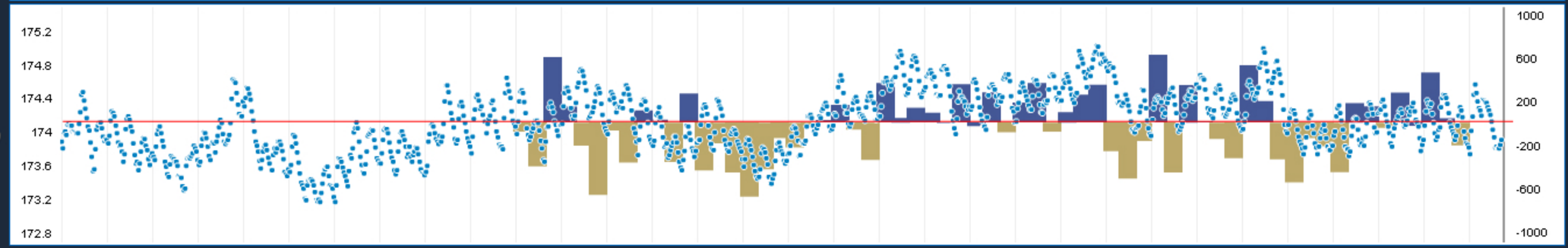
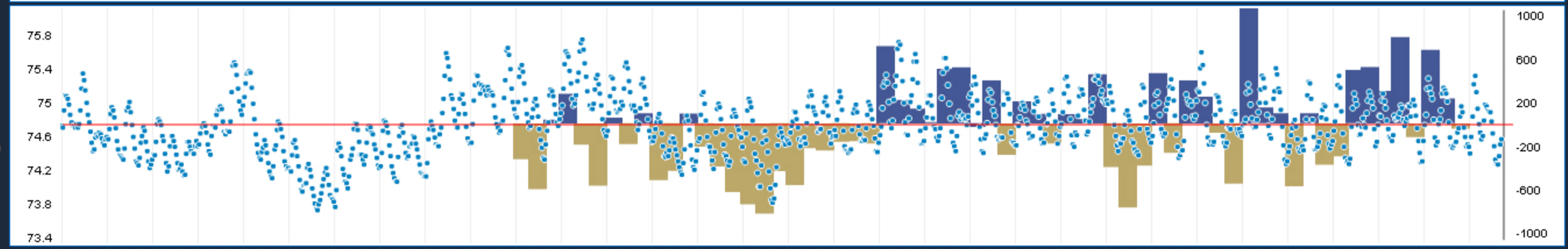


Erie



Ontario



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Water levels: take home messages

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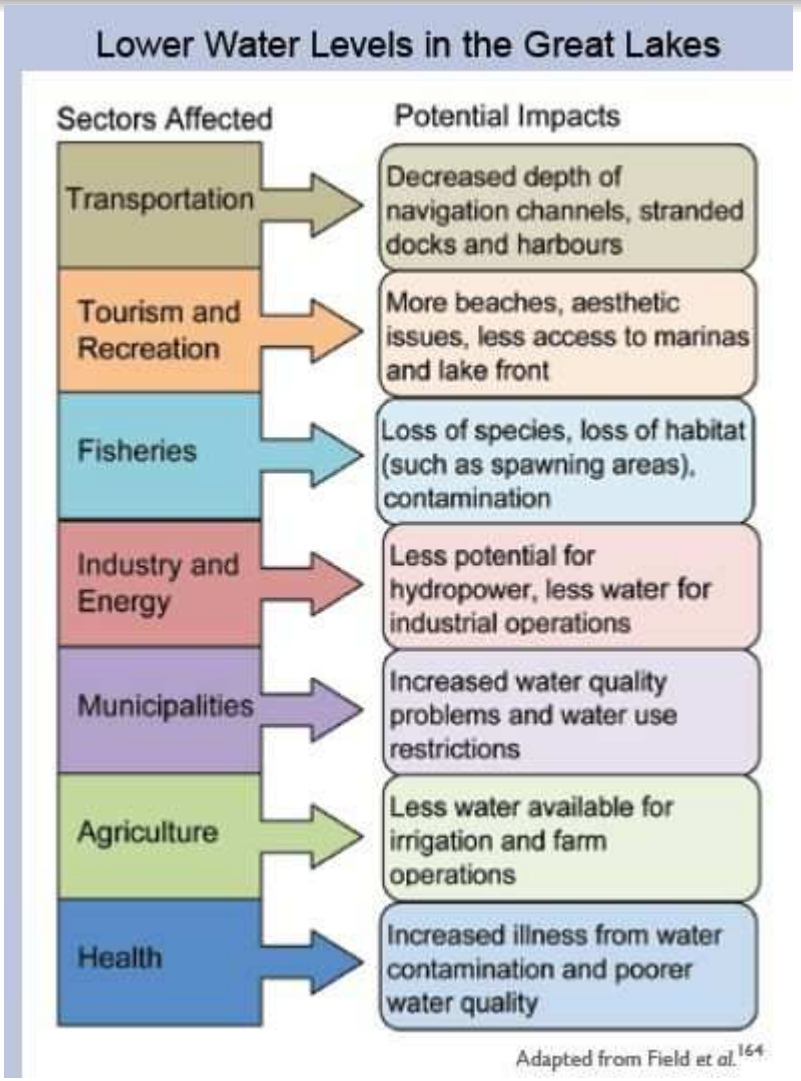
4. NOAA (and partners): water level and water budget monitoring
5. Multi-agency and international frameworks:
   - IJC, CCGLBHHD, IWRSS, NACSP, GLWQA (among others)

Outline

Great Lakes economy and ecosystems



Great Lakes economy and ecosystems: commerce overview

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- 50% of U.S. steel-making capacity

Source: Great Lakes Maritime Task Force 2013

Great Lakes economy and ecosystems: commerce overview

- 50% of U.S. steel-making capacity
- 70% of U.S. auto manufacturing

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Great Lakes economy and ecosystems: commerce overview

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Great Lakes economy and ecosystems: commerce overview

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- Shipping is an integral component. . .

Source: Great Lakes Maritime Task Force 2013

Great Lakes economy and ecosystems: shipping

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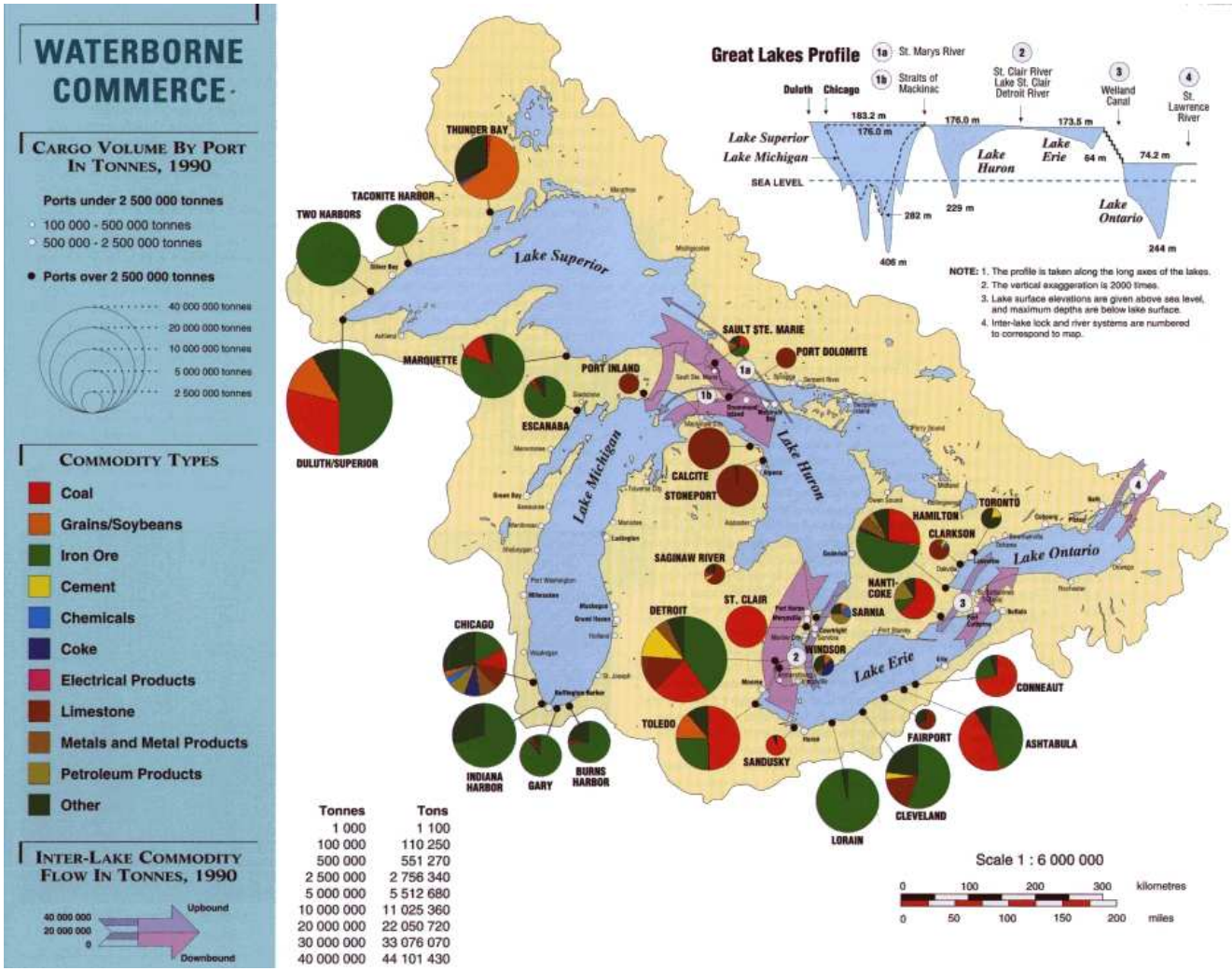
- $33.5 billion in business revenue
- $14.1 billion in annual personal income
- $6.4 billion in local purchases
- $4.6 billion in tax revenue
- $3.6 billion in transportation rate savings

Source: Great Lakes Maritime Task Force 2013

Great Lakes economy and ecosystems: shipping



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Oceangoing or “salty” trade - 17 million tons:

- Import specialty and finished steel products

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Oceangoing or “salty” trade - 17 million tons:

- Import specialty and finished steel products
- Export grain

Great Lakes economy and ecosystems: shipping

U.S.-flag trade = 115 million tons:

- Mostly U.S. to U.S. within the upper four Lakes
- Cargo typically includes iron ore, coal, and limestone

Canadian-flag trade = 65 million tons:

- Trade between Duluth/Superior and Sept Iles
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Source: Great Lakes Maritime Task Force 2013

Great Lakes economy and ecosystems: shipping

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Every inch counts:

Great Lakes economy and ecosystems: shipping

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- 56 “Lakers” are enrolled in Lake Carriers Association (LCA)

Great Lakes economy and ecosystems: shipping

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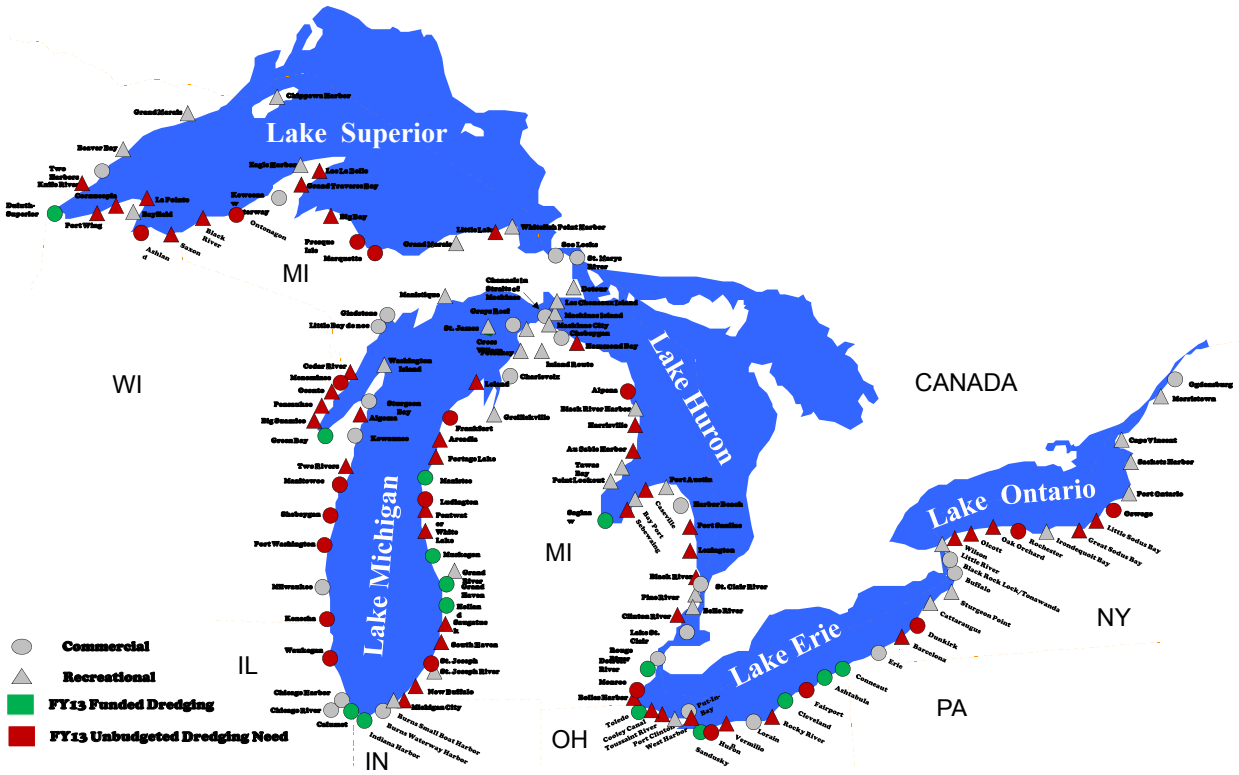
Source: Great Lakes Maritime Task Force 2013

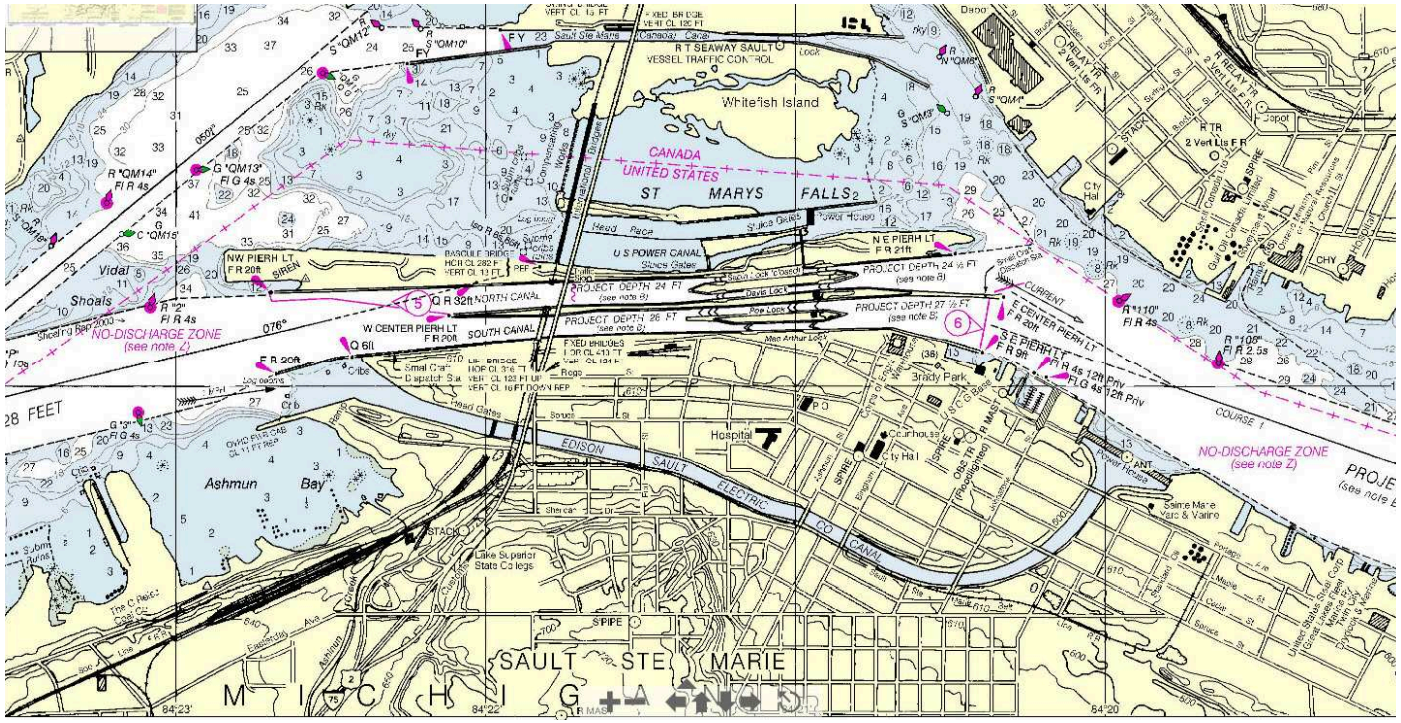
Great Lakes economy and ecosystems: shipping

FY13 Dredging Requirements



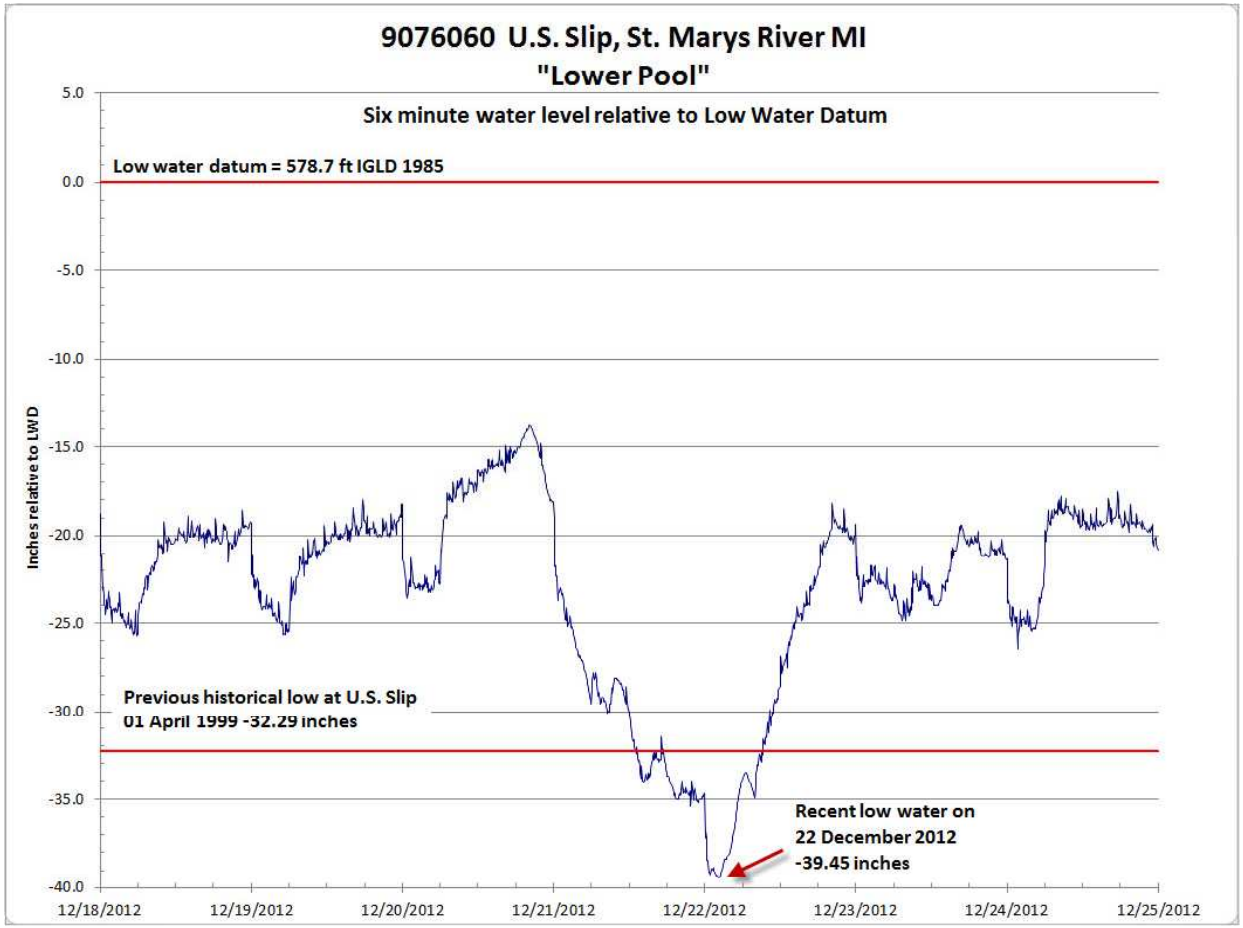
Source: Great Lakes Maritime Task Force 2013

Great Lakes economy and ecosystems: shipping

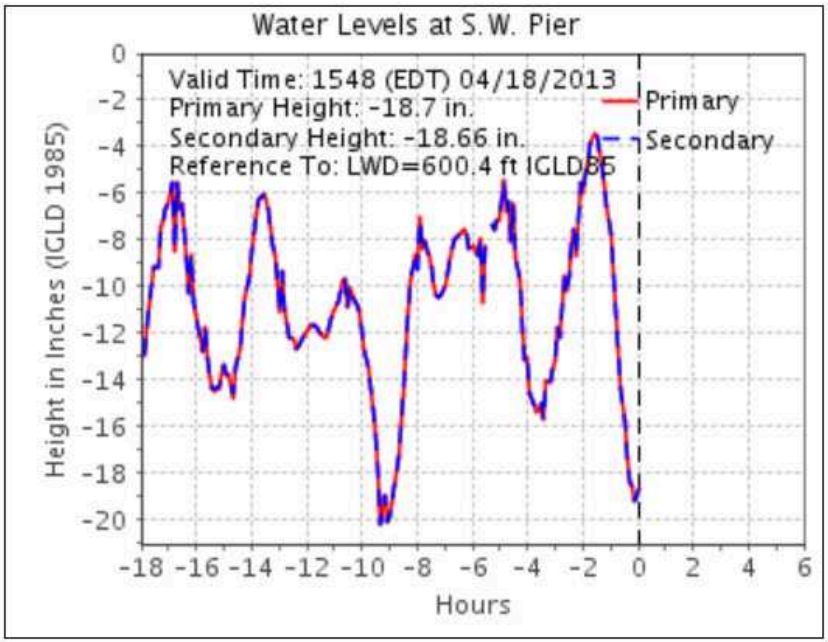


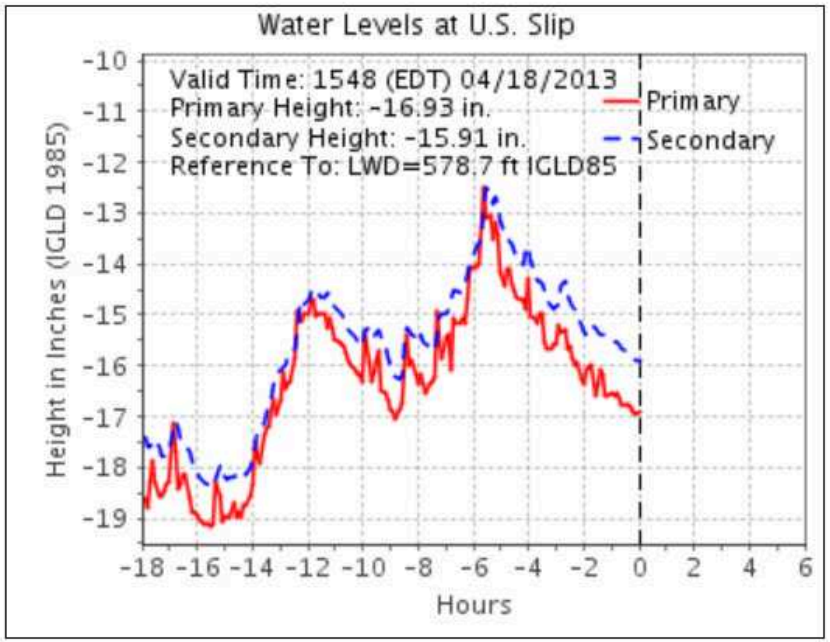
- Levels below Chart Datum could limit use of Sault St. Marie for deep draft vessels
- Maximum project depths are 28 feet

Great Lakes economy and ecosystems: shipping



Great Lakes economy and ecosystems: shipping





Present conditions: locks at St. Marys Falls canal (levels below chart datum)

Source: NOAA NOS COOPs physical oceanographic real-time system (http://tidesandcurrents.noaa.gov)

Great Lakes economy and ecosystems: nearshore habitat

Great Lakes economy and ecosystems: nearshore habitat

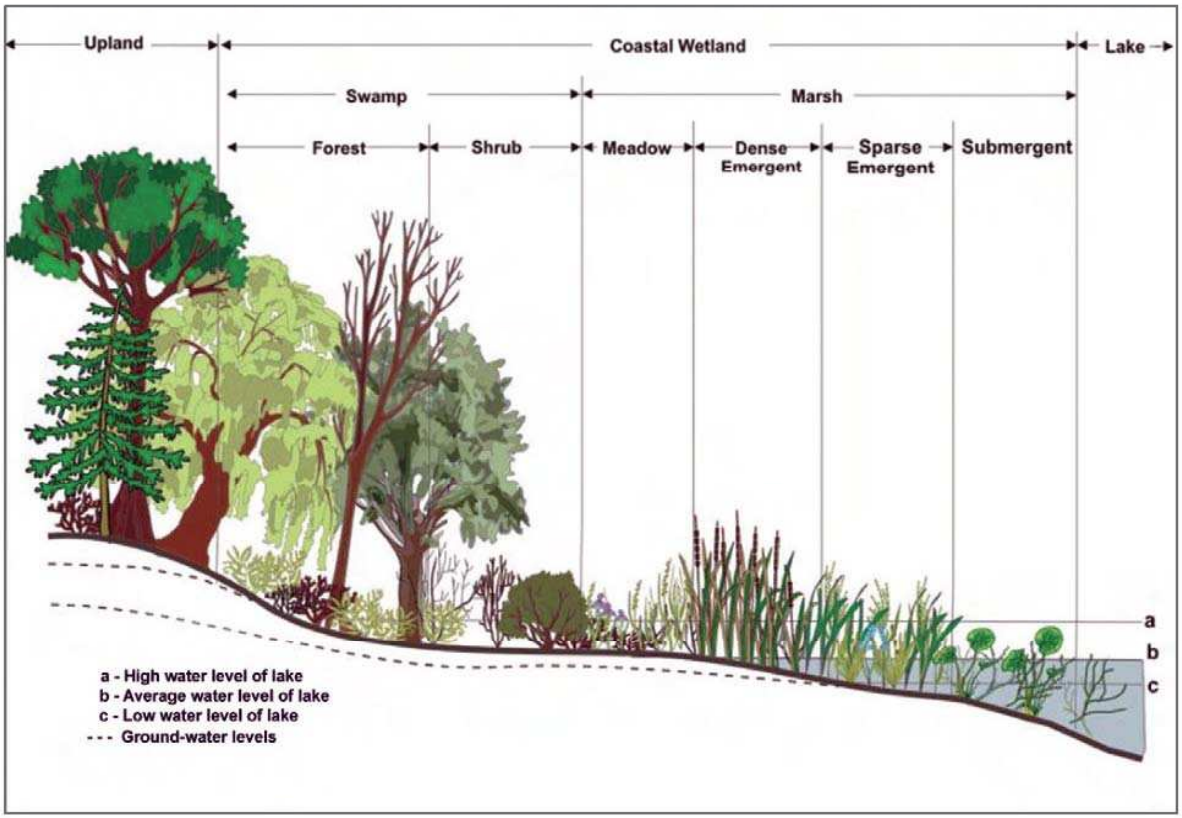


Figure 12. Profile of a typical coastal marsh from lake to upland showing changes in plant communities related to lake-level history (from Environment Canada, 2002).

Source: USGS Circular 1311 Lake –Level Variability and Water Availability in the Great Lakes

Great Lakes economy and ecosystems: nearshore habitat

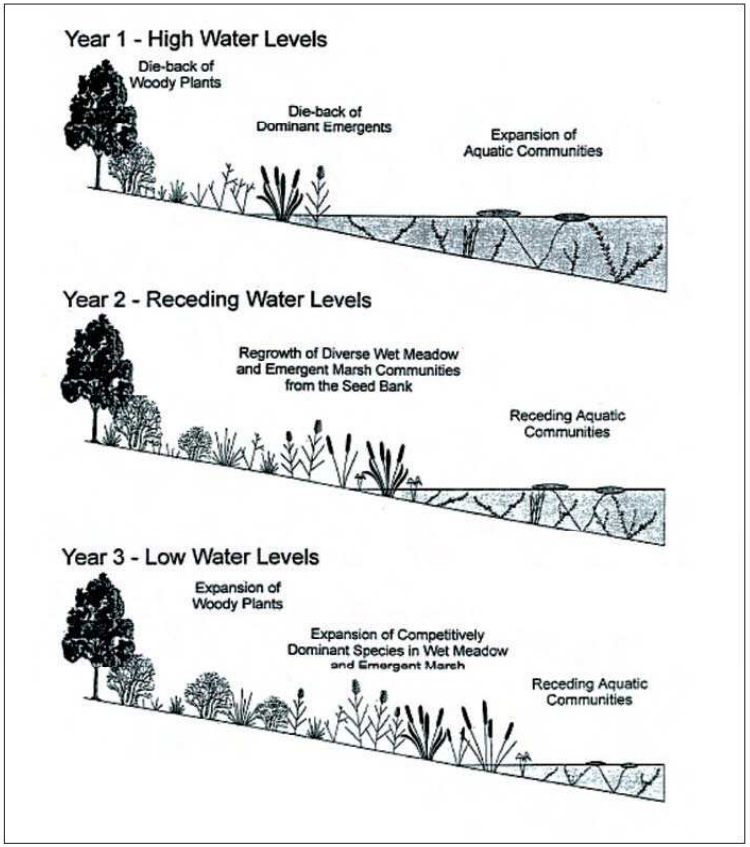


Figure 11. Simplified diagram of the effects of water-level fluctuations on coastal wetland plant communities (from Maynard and Wilcox, 1997).

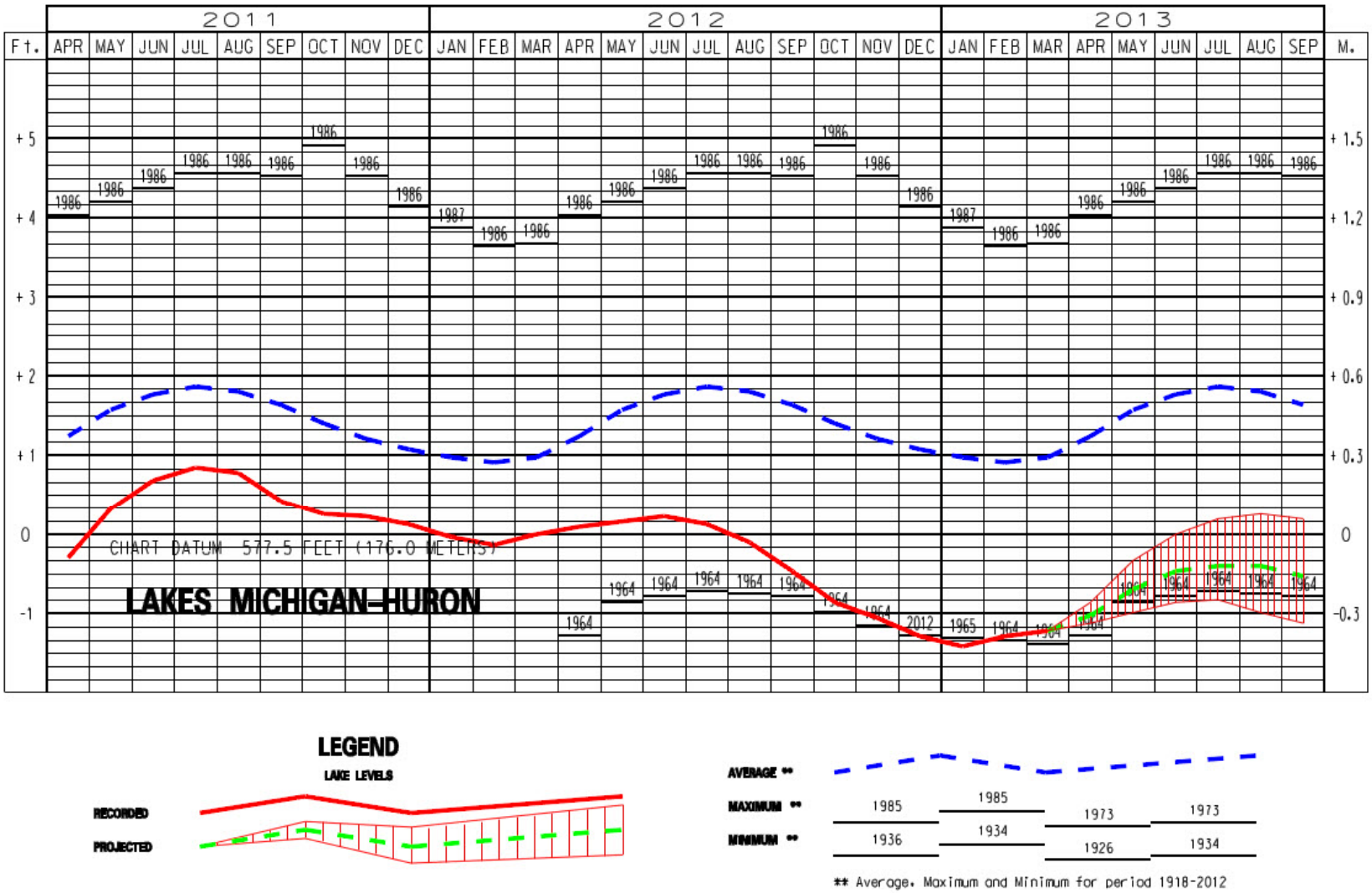
Great Lakes economy and ecosystems: property and recreation

Great Lakes economy and ecosystems: property and recreation

Source: IJC adaptive management task team

Outline

Water Level models (seasonal)



http://www.lre.usace.army.mil/Missions/GreatLakesInformation/GreatLakesWaterLevels/WaterLevelForecast/MonthlyBulletinofGreatLakesWaterLevels.aspx

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Superior | Michigan-Huron | St. Clair | Erie | Ontario

Surface water elevation (meters; IGLD 85)

Superior

184.2
183.8
183.4
183
182.6
182.2
181.8

Michigan-Huron

177.4
177
176.6
176.2
175.8
175.4

Erie

175.2
174.8
174.4
174
173.6
173.2
172.8

1996 1998 2000 2002 2004 2006 2008 2010 2012 2014

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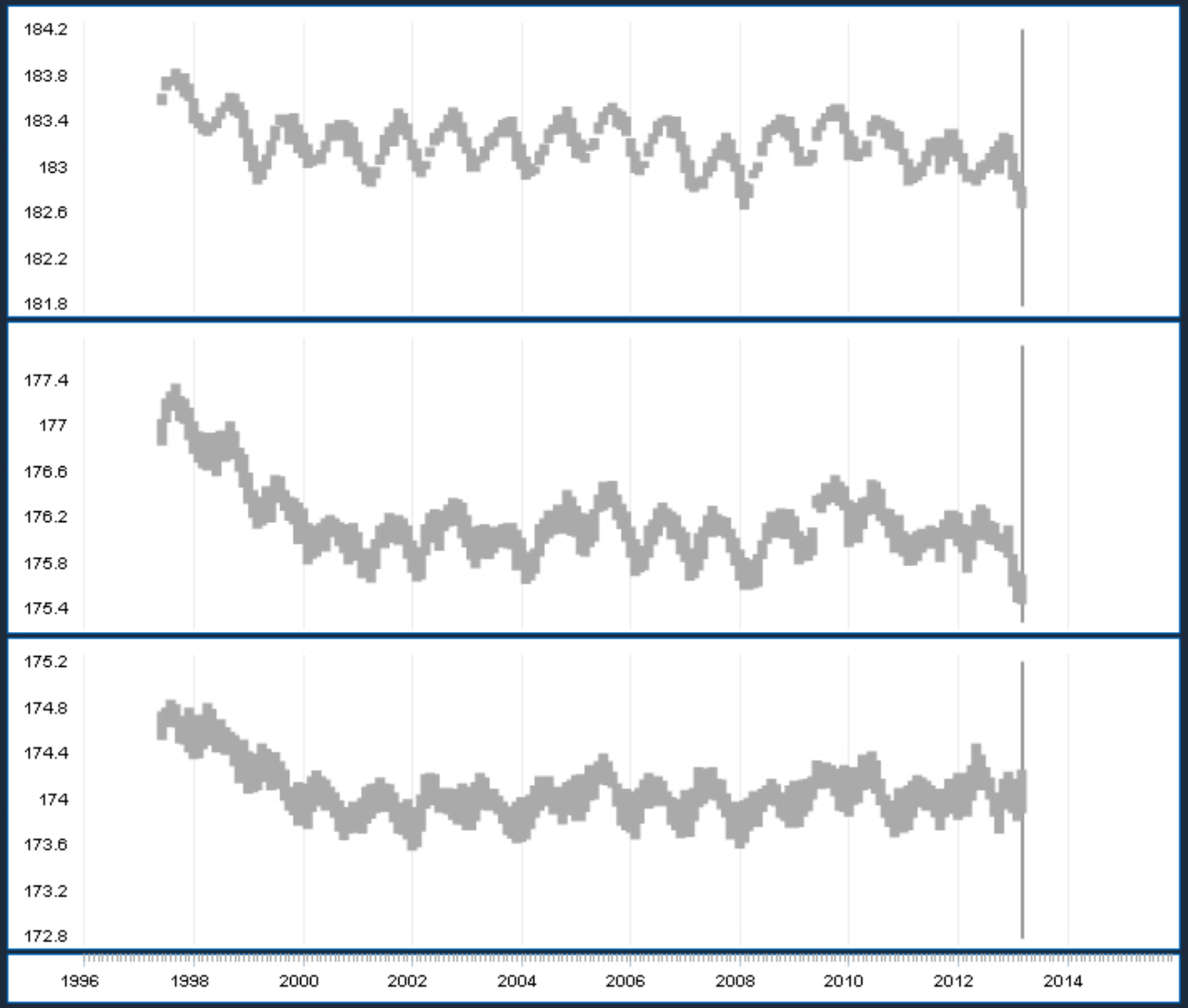

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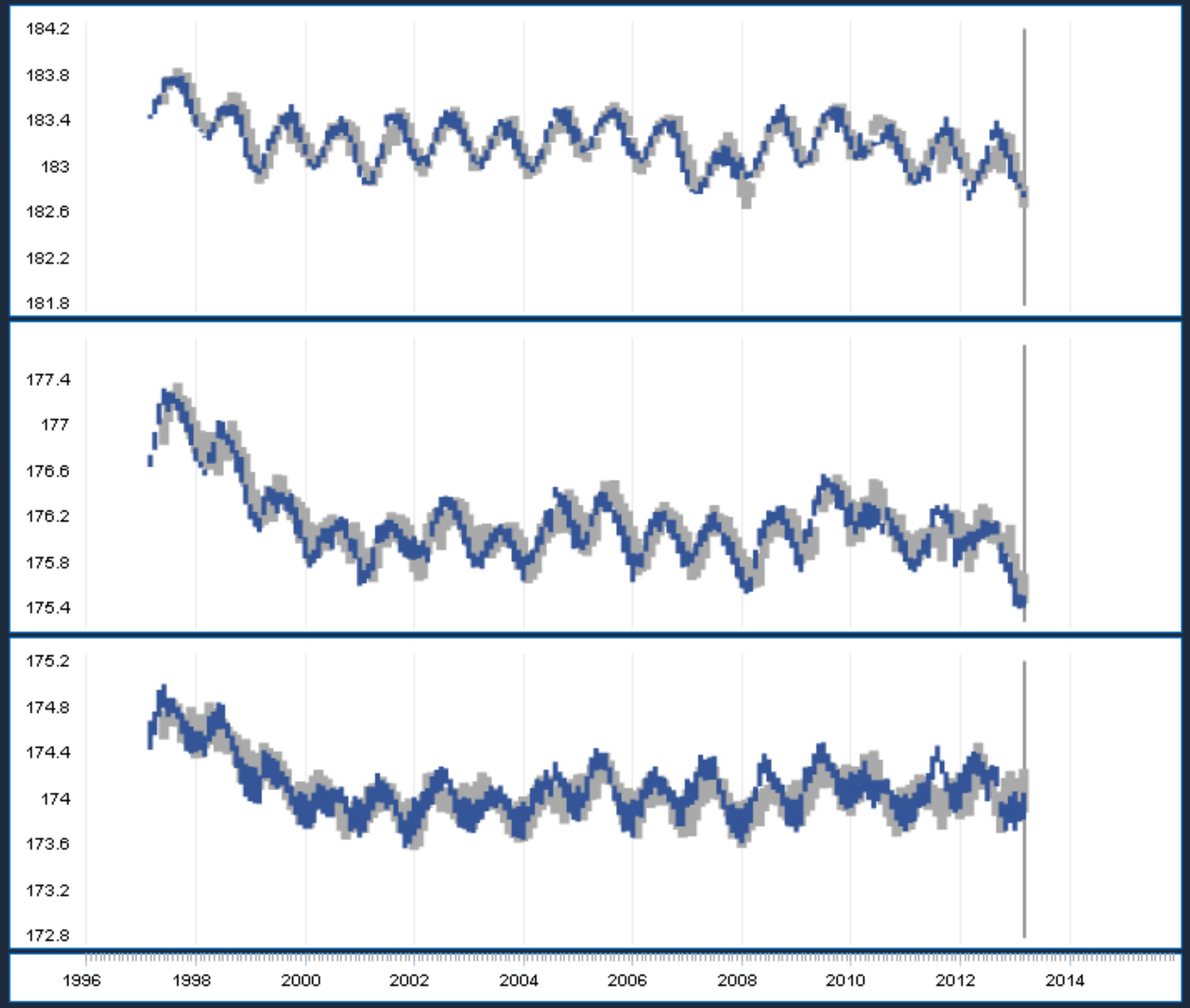

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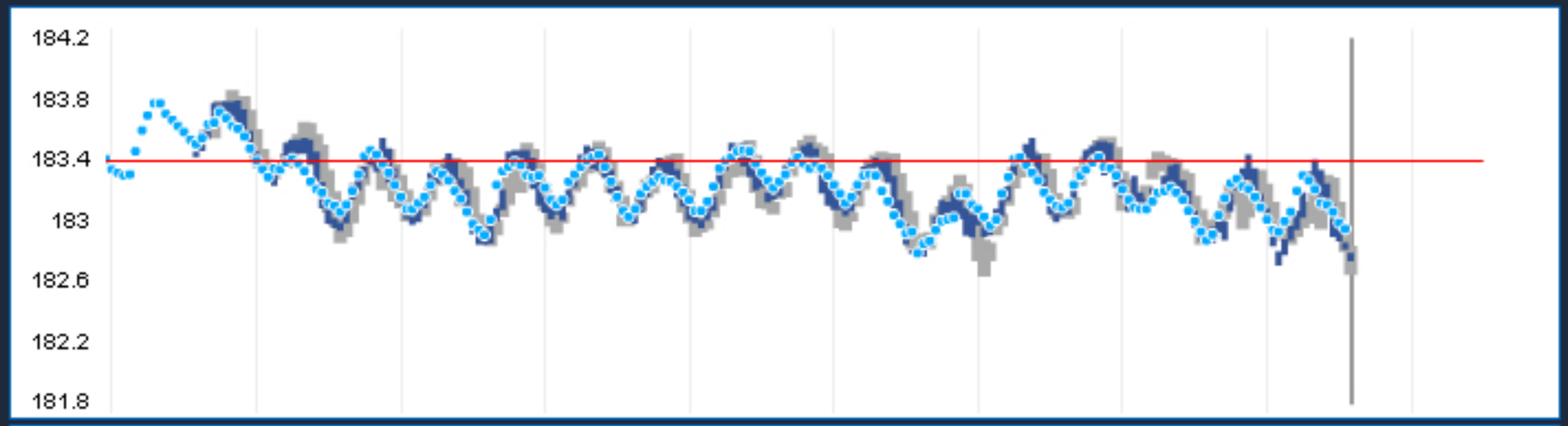
Superior



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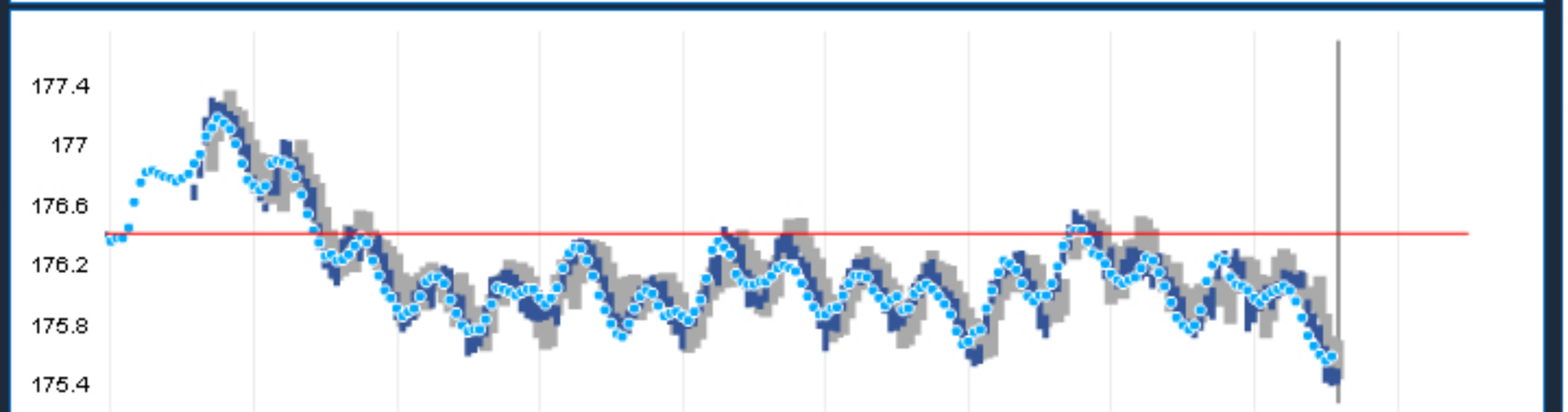

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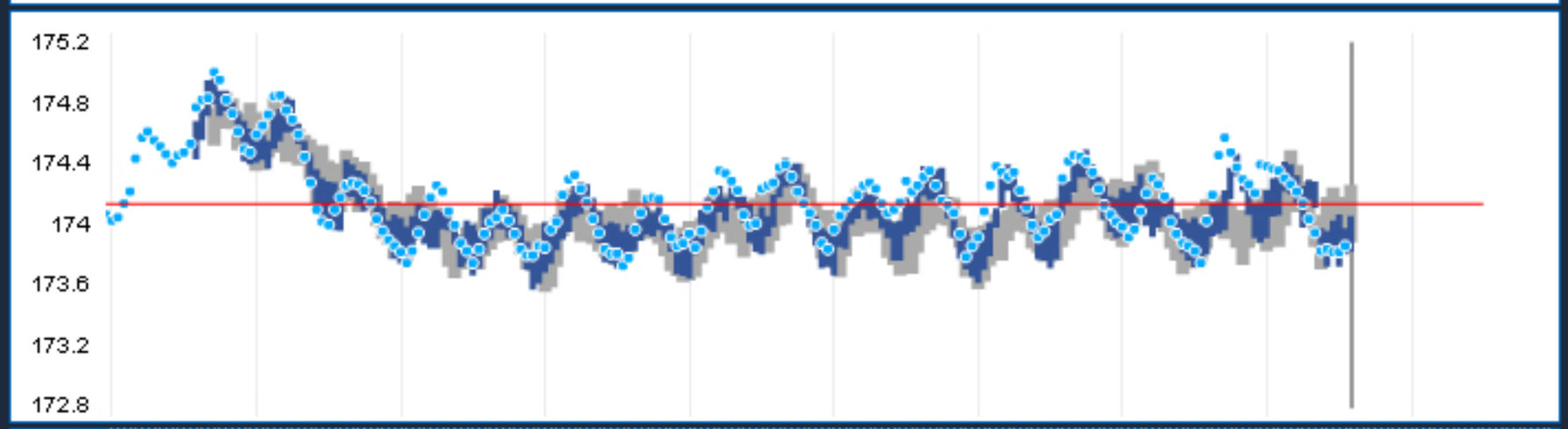

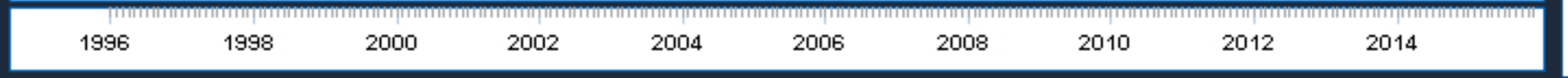

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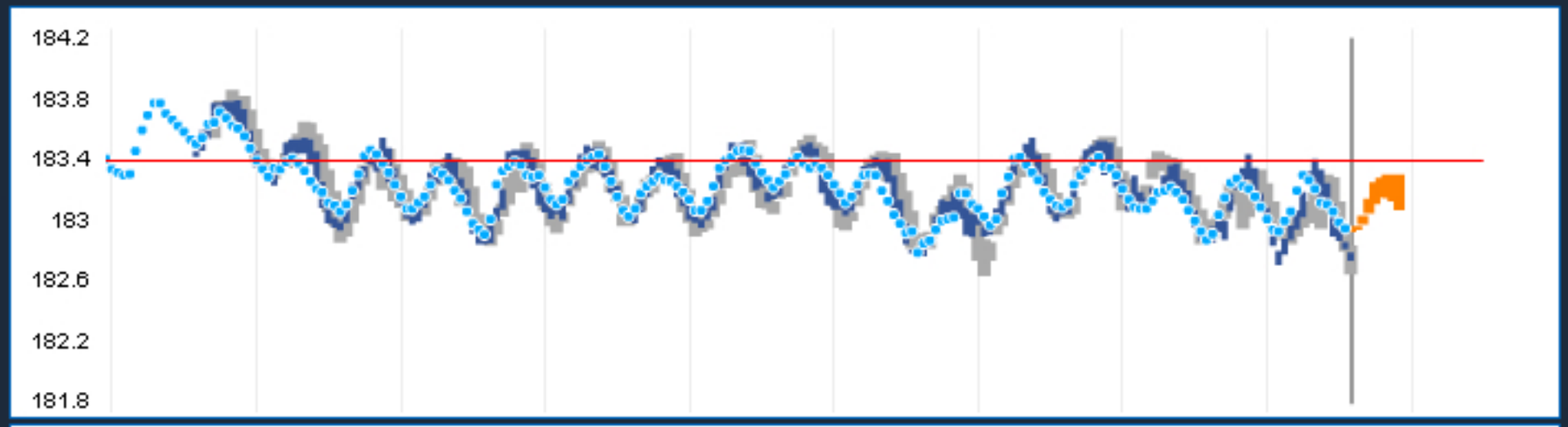

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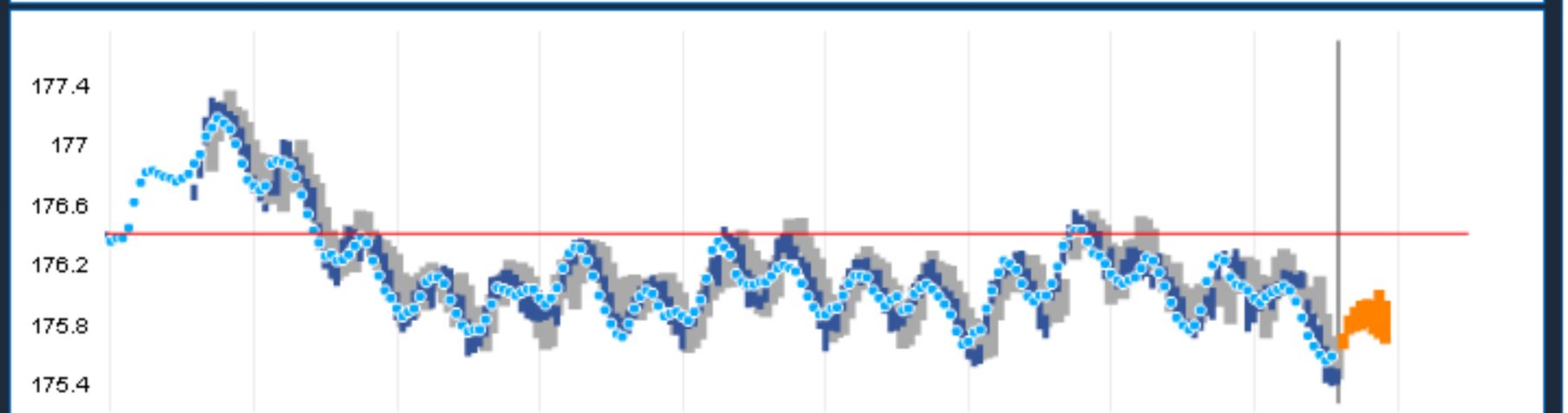

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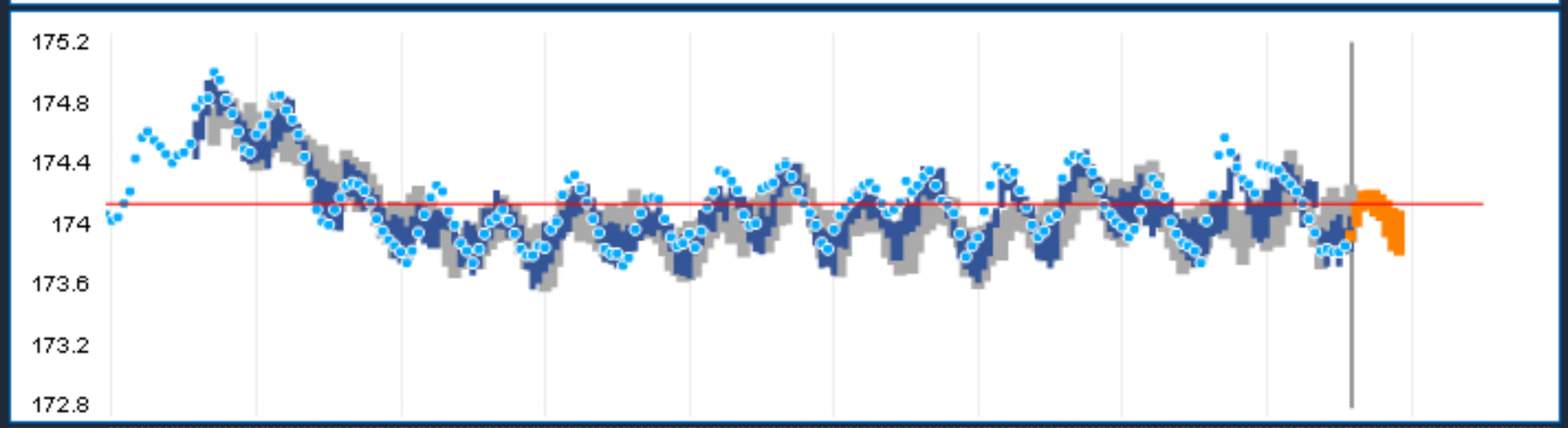

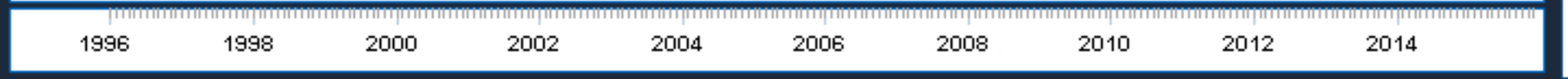

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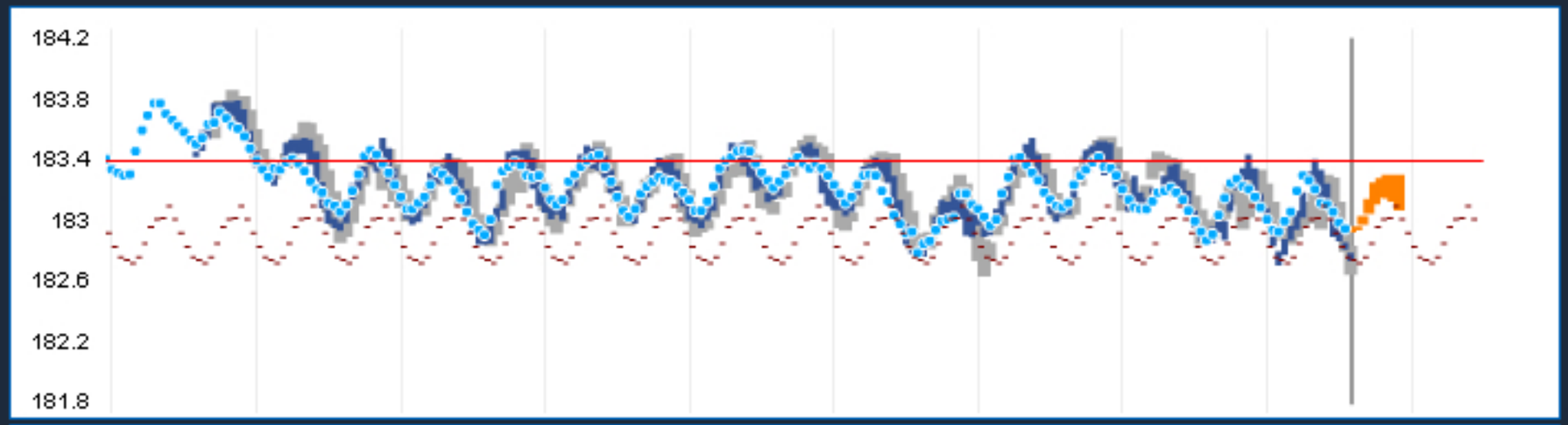

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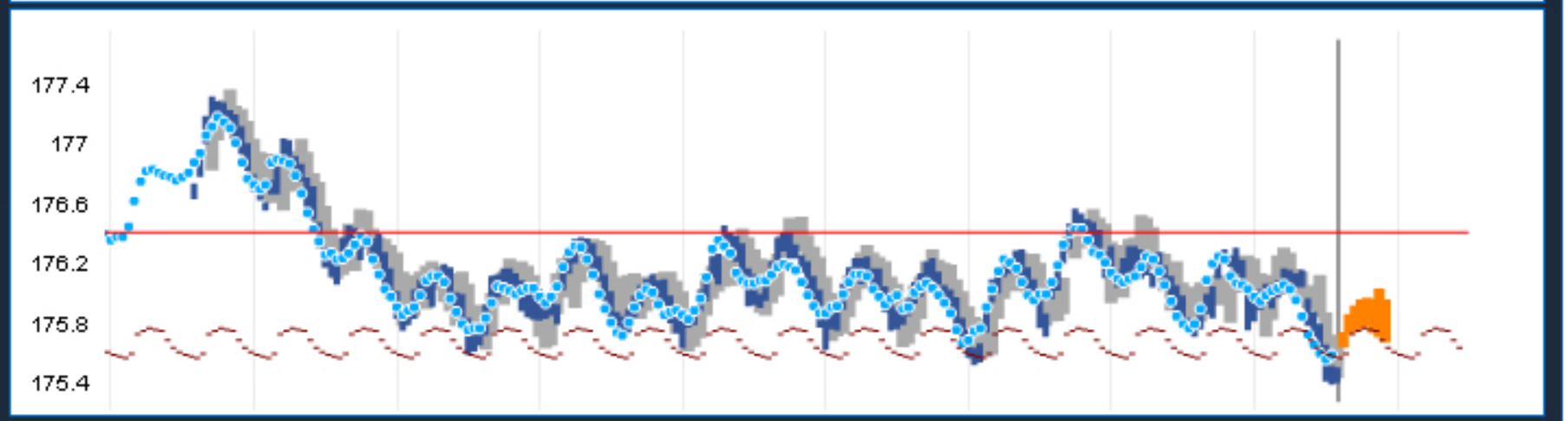

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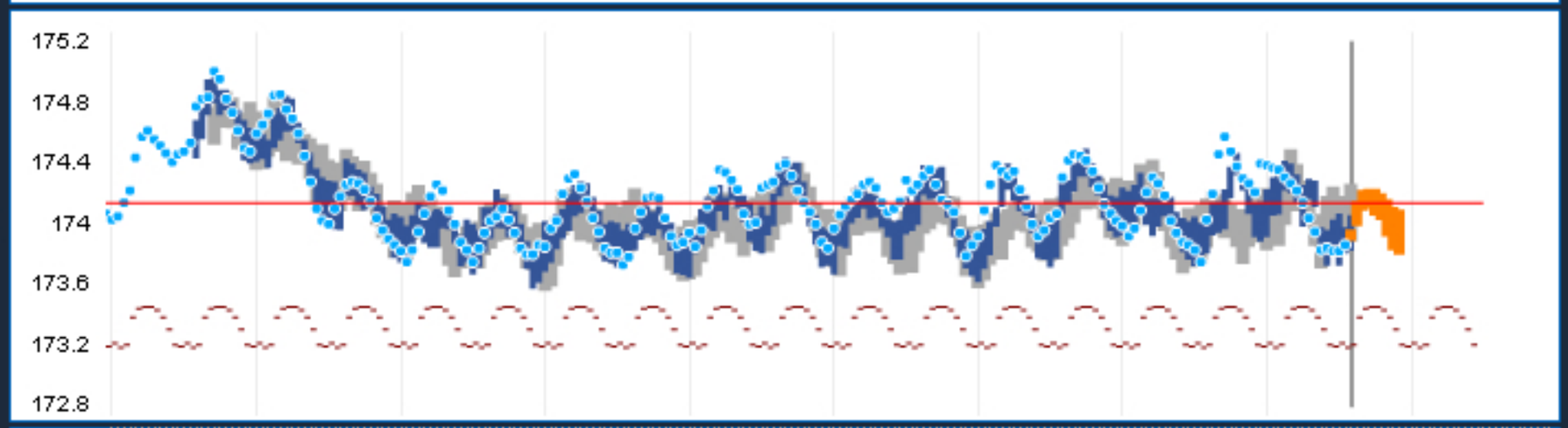

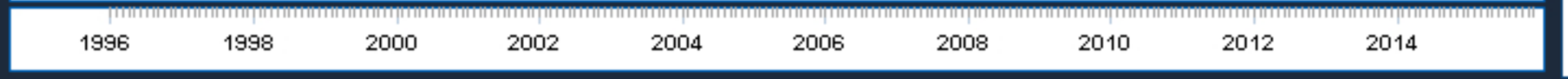

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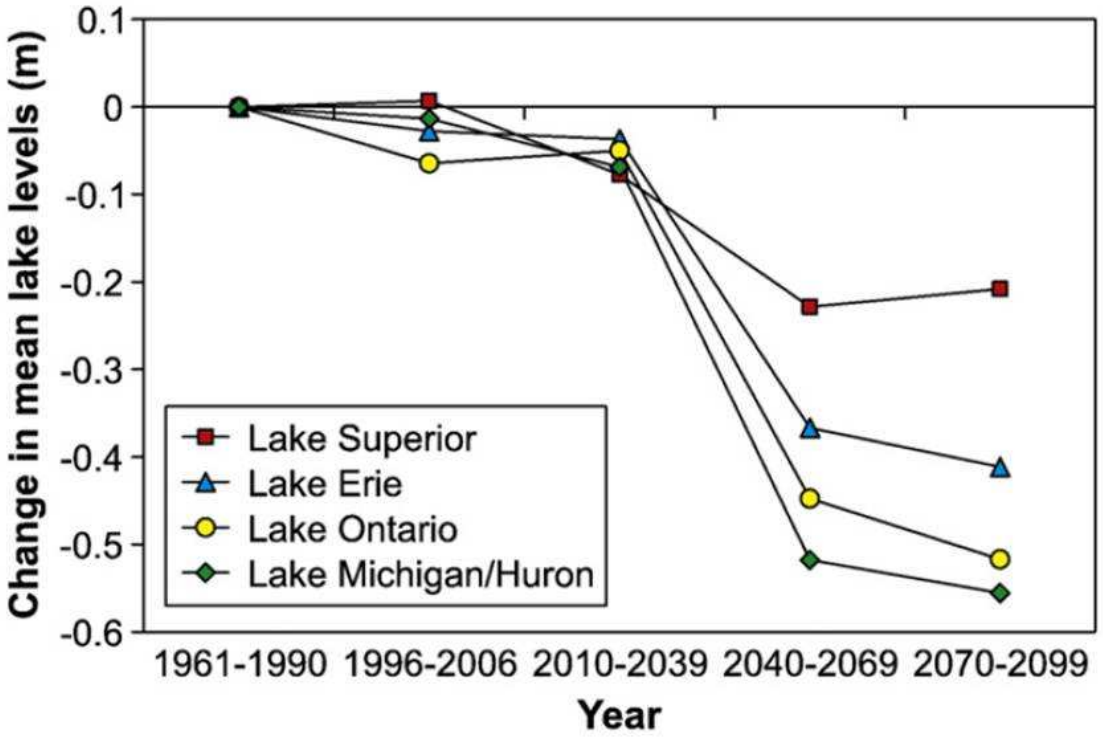
Water level models (multi-decadal forecasts)



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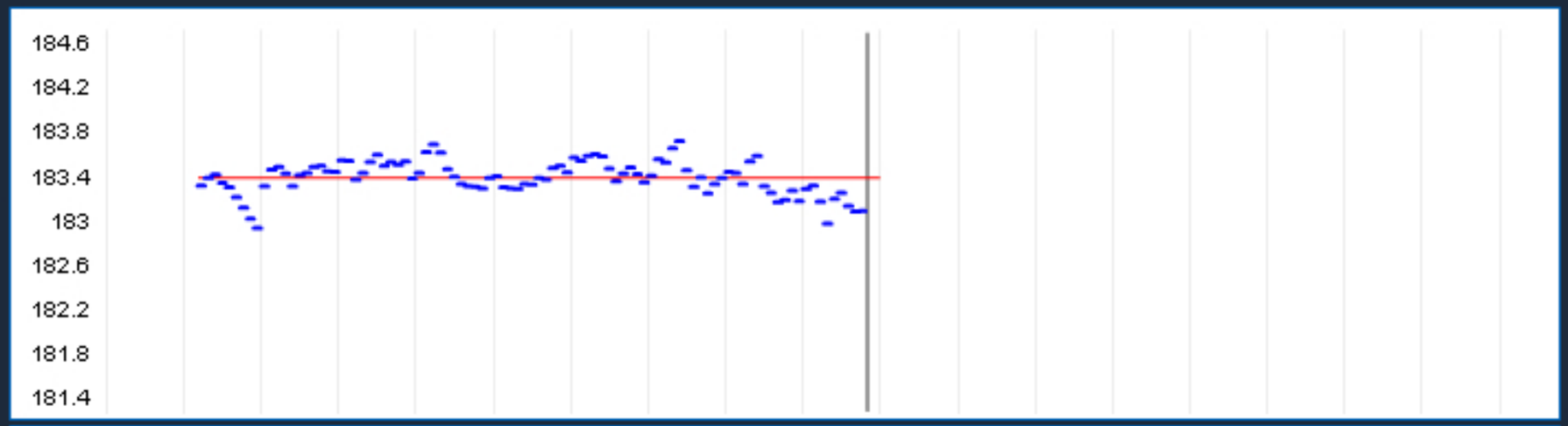
Superior



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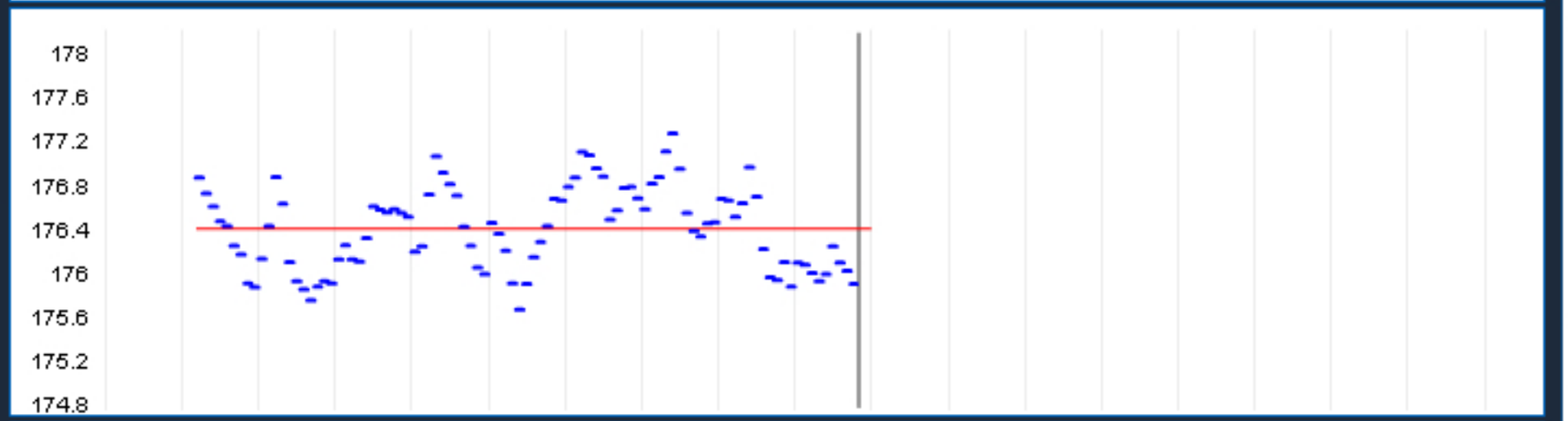

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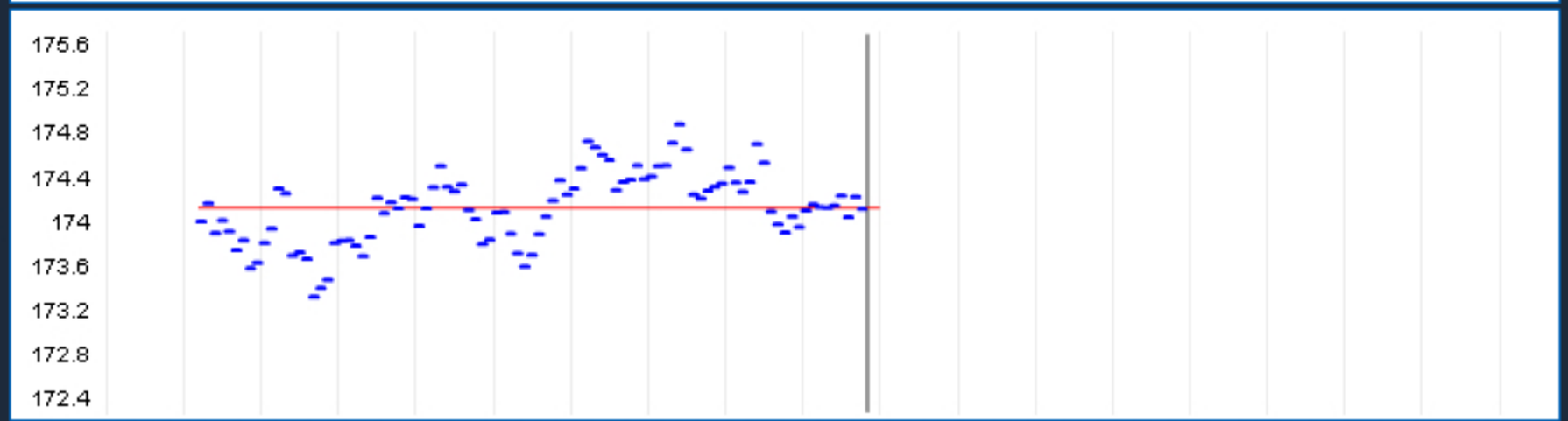

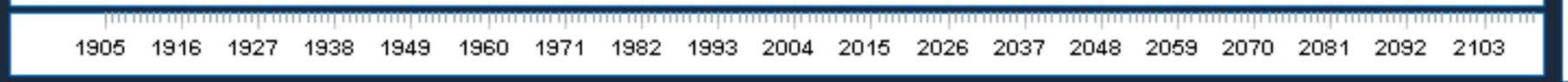

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- Lofgren et al. (2011): A2 - CGCM3 - TA
- Lofgren et al. (2011): A2 - CGCM3 - EA
- Lofgren et al. (2011): A1B - GFDL20 - TA
- Lofgren et al. (2011): A1B - GFDL20 - EA
- MacKay and Seglenieks (2012): A2 - CGCM3

Lofgren series are from same paper. Click info button below for details.

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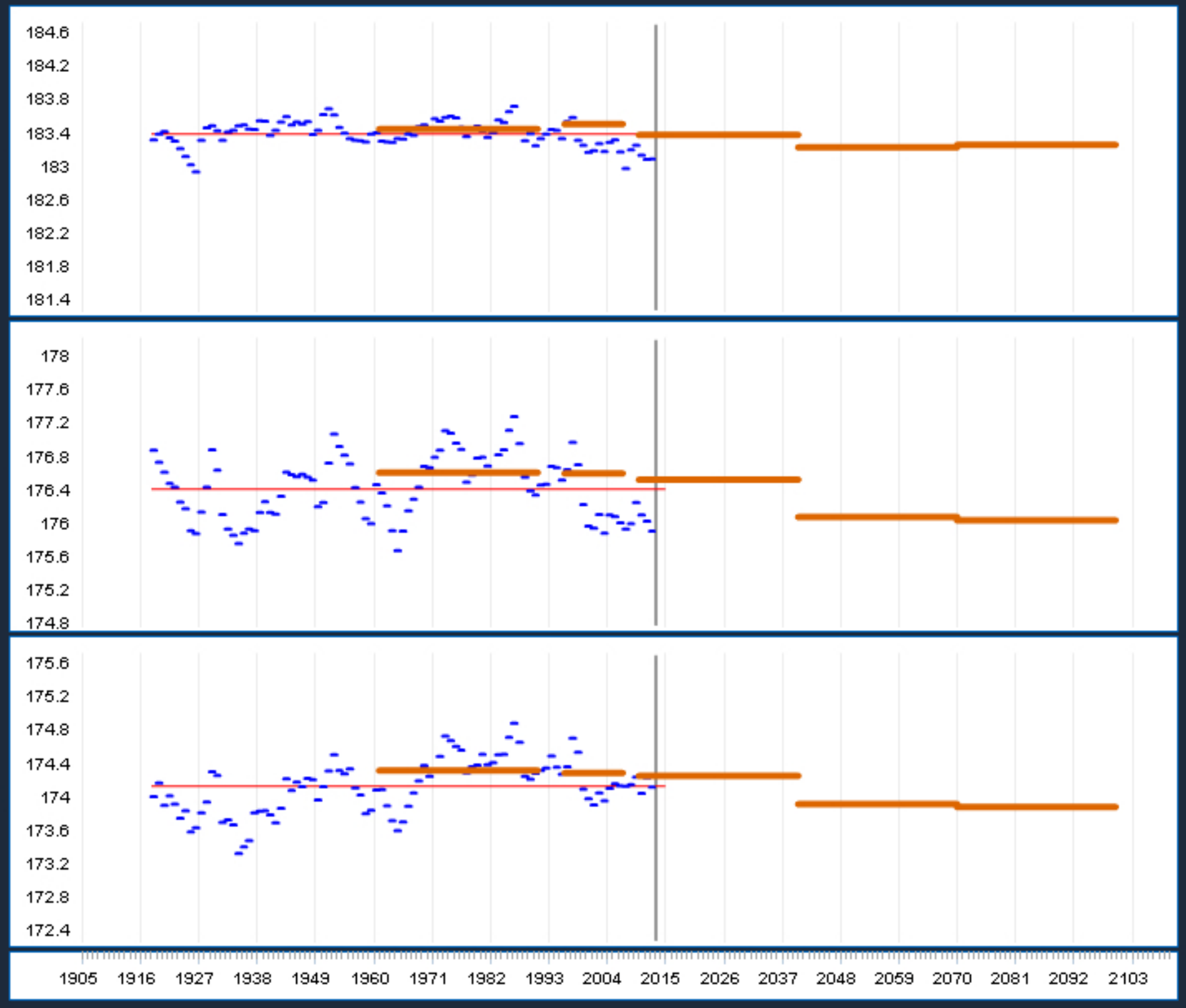

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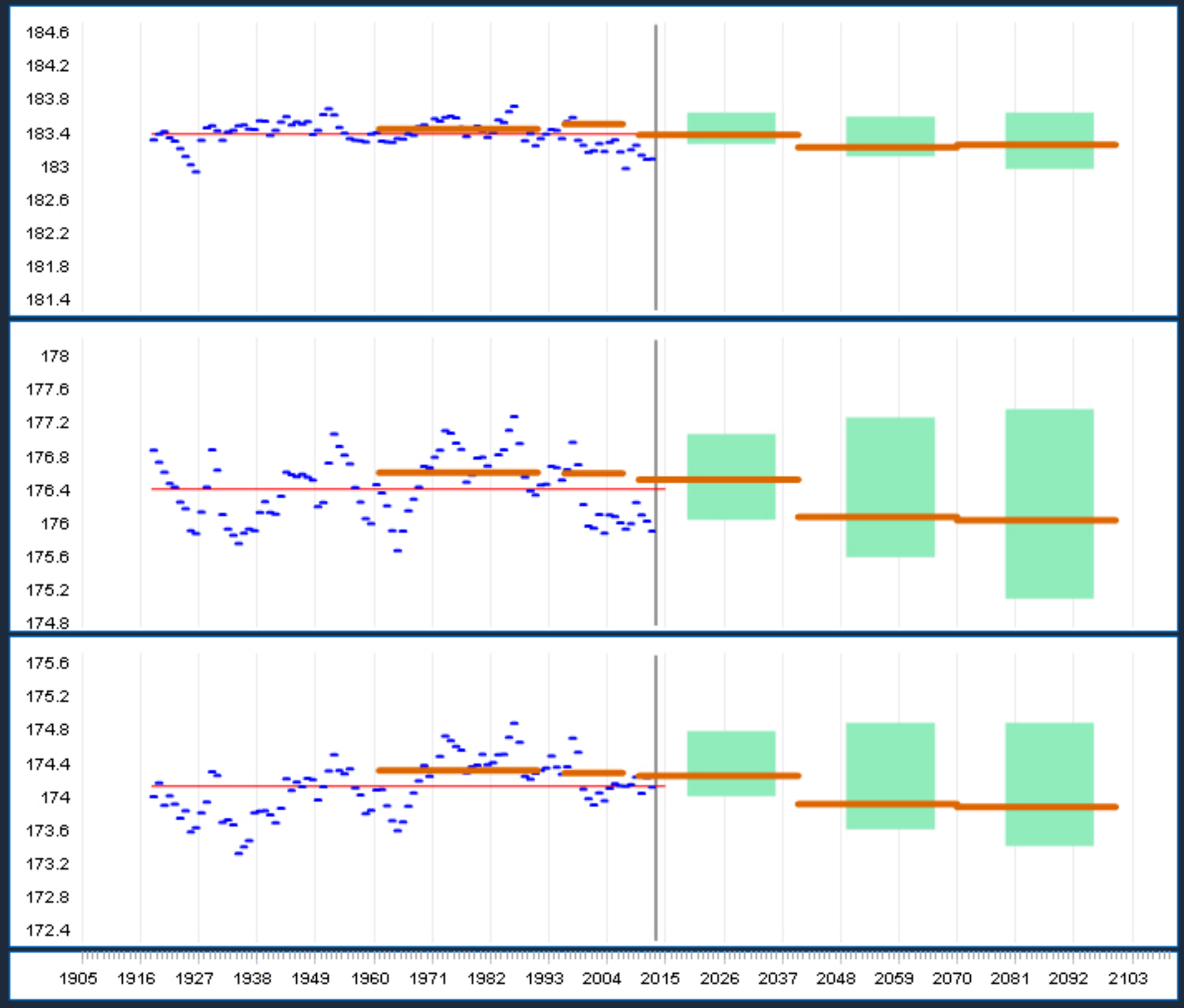

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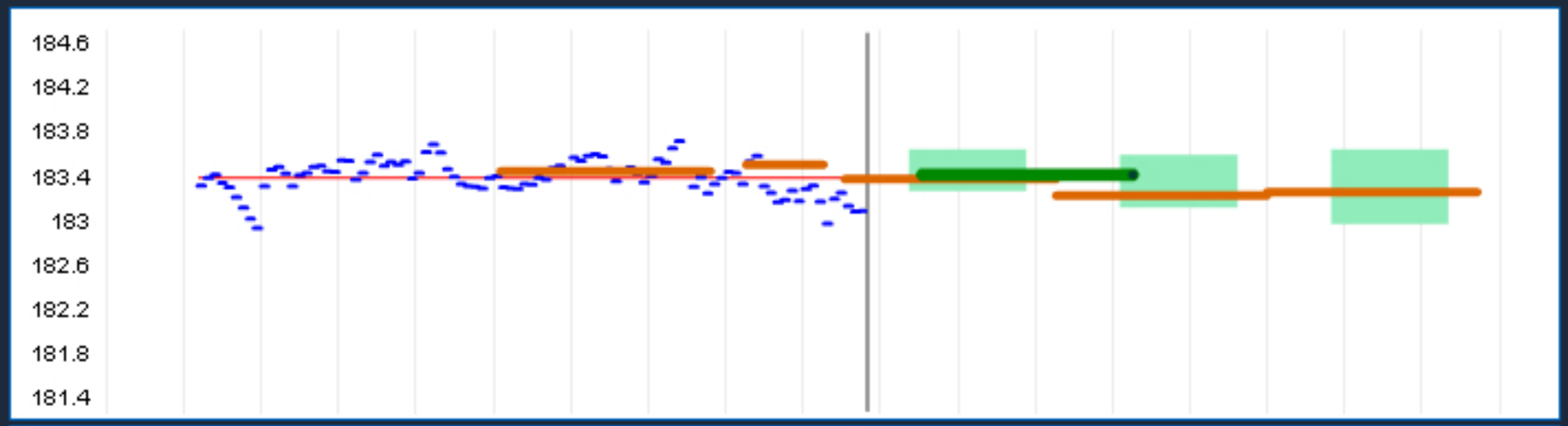
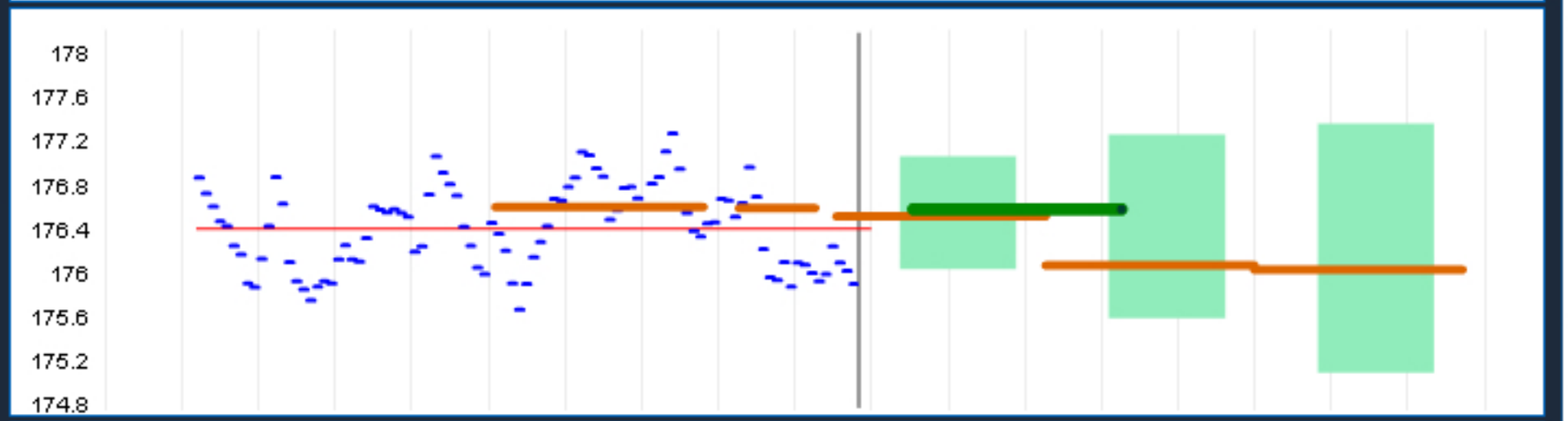
Surface water elevation (meters; IGLD 85)

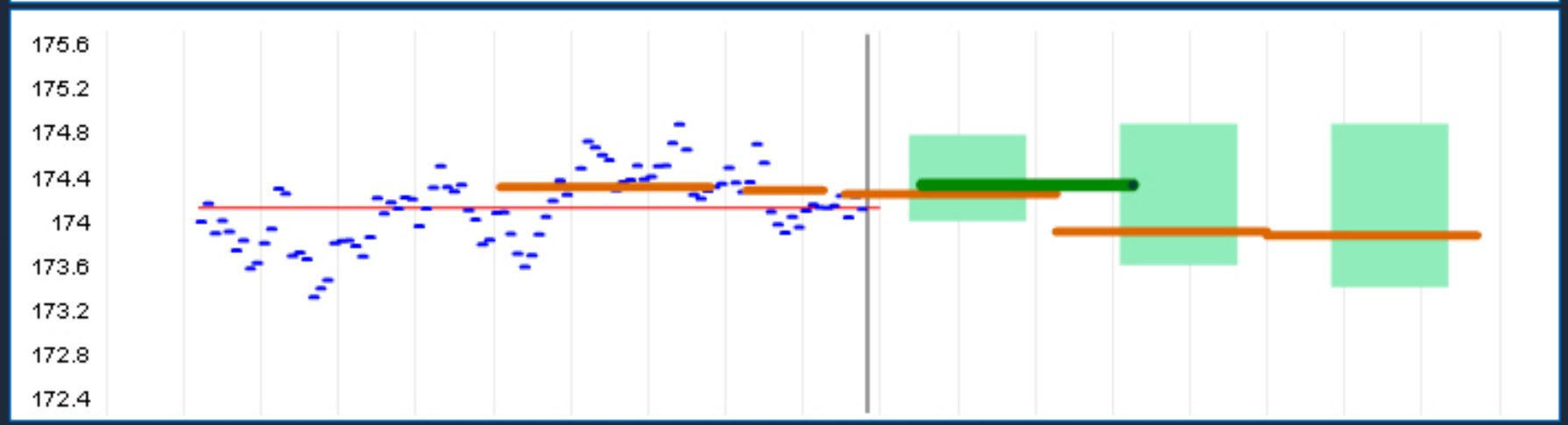
Superior

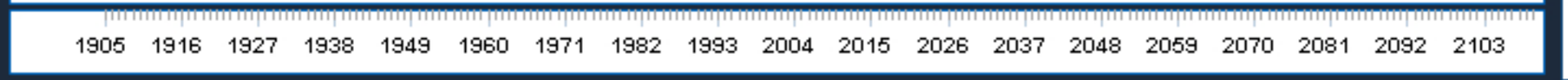


Michigan-Huron



Erie





Zoom | Pan

Legend and Menu

- Water Level Observations
- Monthly Level Forecasts
- Multi-Decadal Level Forecasts

- Angel et al. (2010) A2 - Multi-GCM
- Hayhoe et al. (2010): A1fi - AOGCM
- Lofgren et al. (2011): Base Case
- Lofgren et al. (2011): A2 - CGCM3 - TA
- Lofgren et al. (2011): A2 - CGCM3 - EA
- Lofgren et al. (2011): A1B - GFDL20 - TA
- Lofgren et al. (2011): A1B - GFDL20 - EA
- MacKay and Seglenieks (2012): A2 - CGCM3

Lofgren series are from same paper. Click info button below for details.

Info on multi-decadal forecasts

- Paleological Reconstructions
- Hydrological/Climatological Data
- Ice Cover

Return Series to Default Colors

Dark Background

Timespan | 1905 | 2110

Tue Mar 5 2013 03:28:58 AM

Equalize vertical scale

NOAA | GLERL Great Lakes Environmental Research Laboratory | Great Lakes RESTORATION | CILER Cooperative Institute for Limnology and Ecosystems Research

GLERL Water Levels Page | HTML 5

Great Lakes Hydro-Climate Dashboard (Beta)

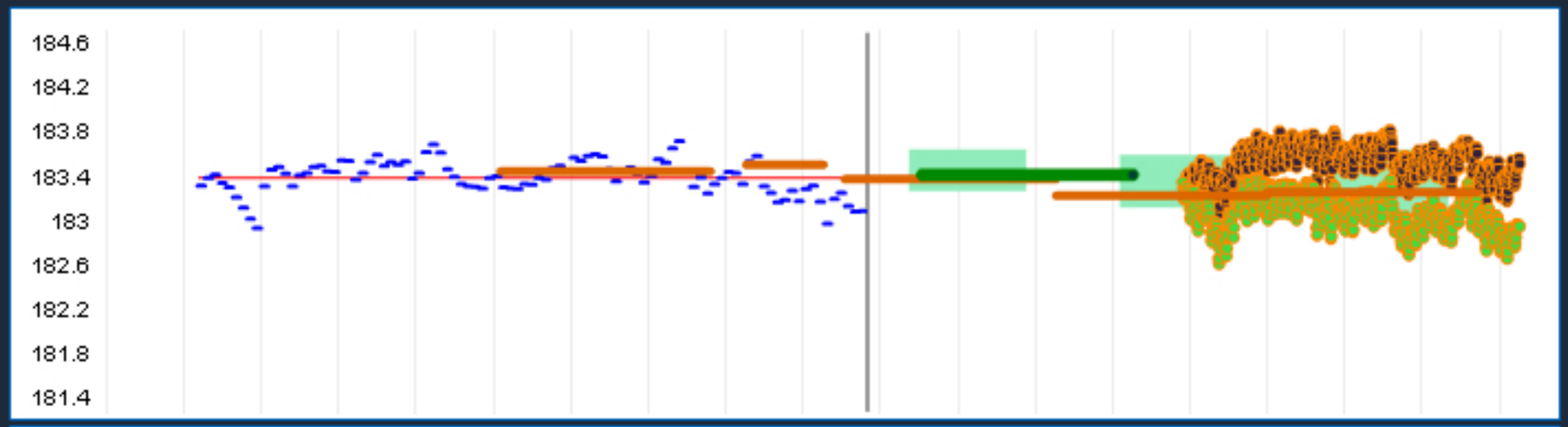
Screenshot | Download Data

To fit & in | Toggle Fullscreen | Contacts | About | ?

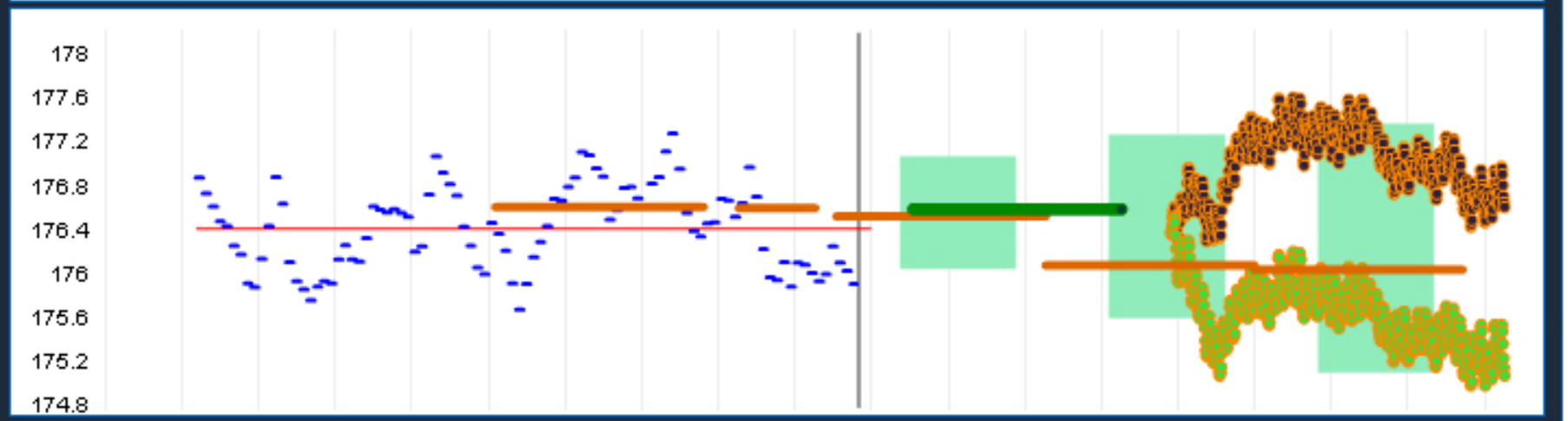
Superior | Michigan-Huron | St. Clair | Erie | Ontario

Surface water elevation (meters; IGLD 85)

Superior



Michigan-Huron



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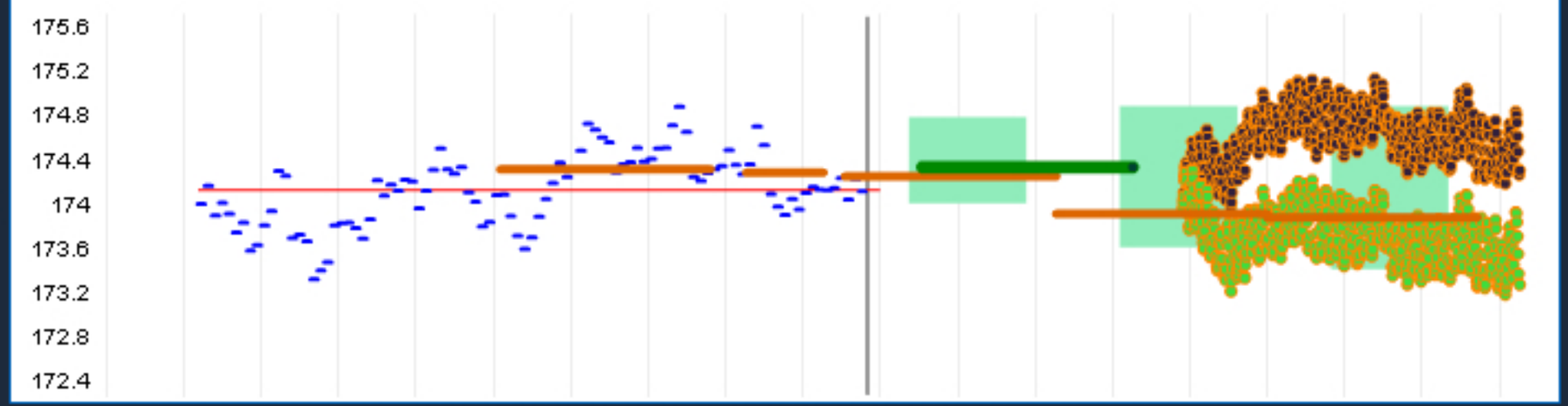

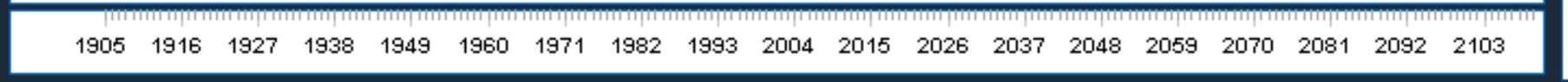

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Models and forecasting: take home messages

Models and forecasting: take home messages

- Continuous model skill assessment and improvements

Models and forecasting: take home messages

- Continuous model skill assessment and improvements
- Maintain and expand monitoring infrastructure

Models and forecasting: take home messages

- Continuous model skill assessment and improvements
- Maintain and expand monitoring infrastructure
- Multiple models, multiple model inputs - range of results

Conclusions

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- Current low water levels: economic and ecosystem impacts

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- Lots of variability (and uncertainty) in long-term forecasts

Conclusions

- Current low water levels: economic and ecosystem impacts
- Lots of variability (and uncertainty) in long-term forecasts
- More at “glerl.noaa.gov” and “tidesandcurrents.noaa.gov”

Acknowledgements

Acknowledgements

- NOAA-GLERL: T. Hunter, A. Clites, J. Smith, F. Quinn, M. Lansing

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- USEPA (GLRI), USGS, USACE, and EC

Great Lakes Economies and Ecosystems: will extreme low water levels leave them high and dry?

Steve Gill[1], Drew Gronewold[2], and Thomas Landon[1]
stephen.gill@noaa.gov, drew.gronewold@noaa.gov, thomas.landon@noaa.gov

National Oceanic and Atmospheric Administration

[1]Center for Operational Oceanographic Products and Services (COOPs)
[2]Great Lakes Environmental Research Laboratory (GLERL)

NOAA Central Library Brown Bag Seminar
Silver Spring, MD
April 23, 2013

Water levels: observations (paleo)

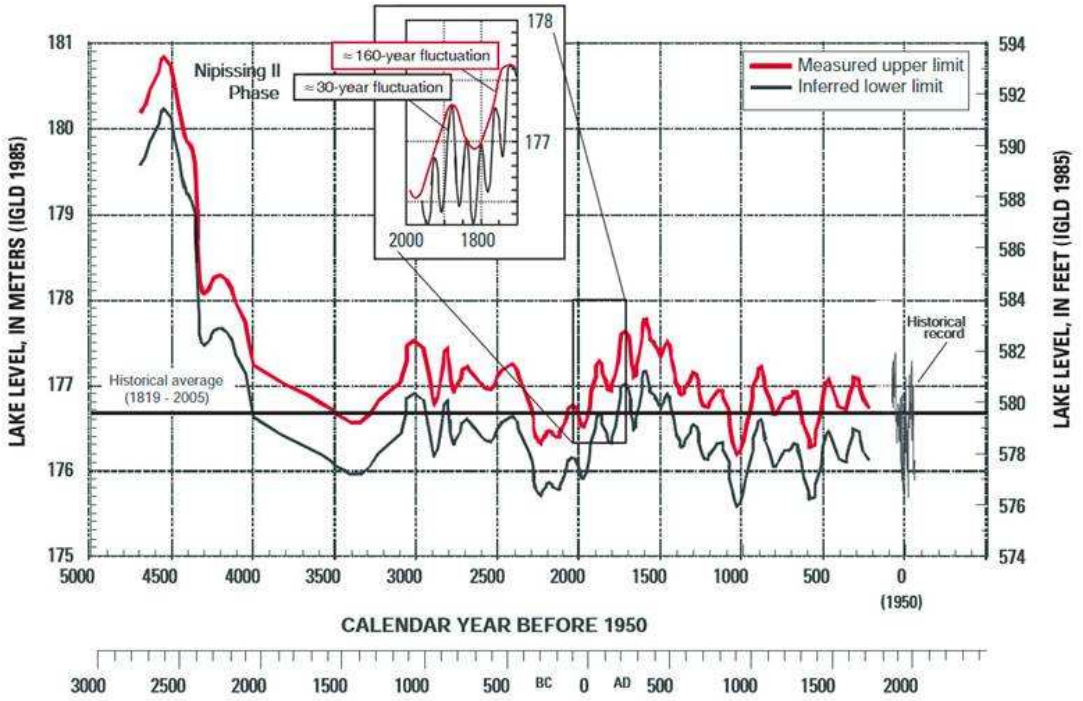


Figure 8. Hydrograph of late Holocene lake level and historical lake level for Lake Michigan-Huron. The red line is interpreted from beach-ridge studies, whereas the lower black line is an inferred lower limit using the range of the historical record as a guide.

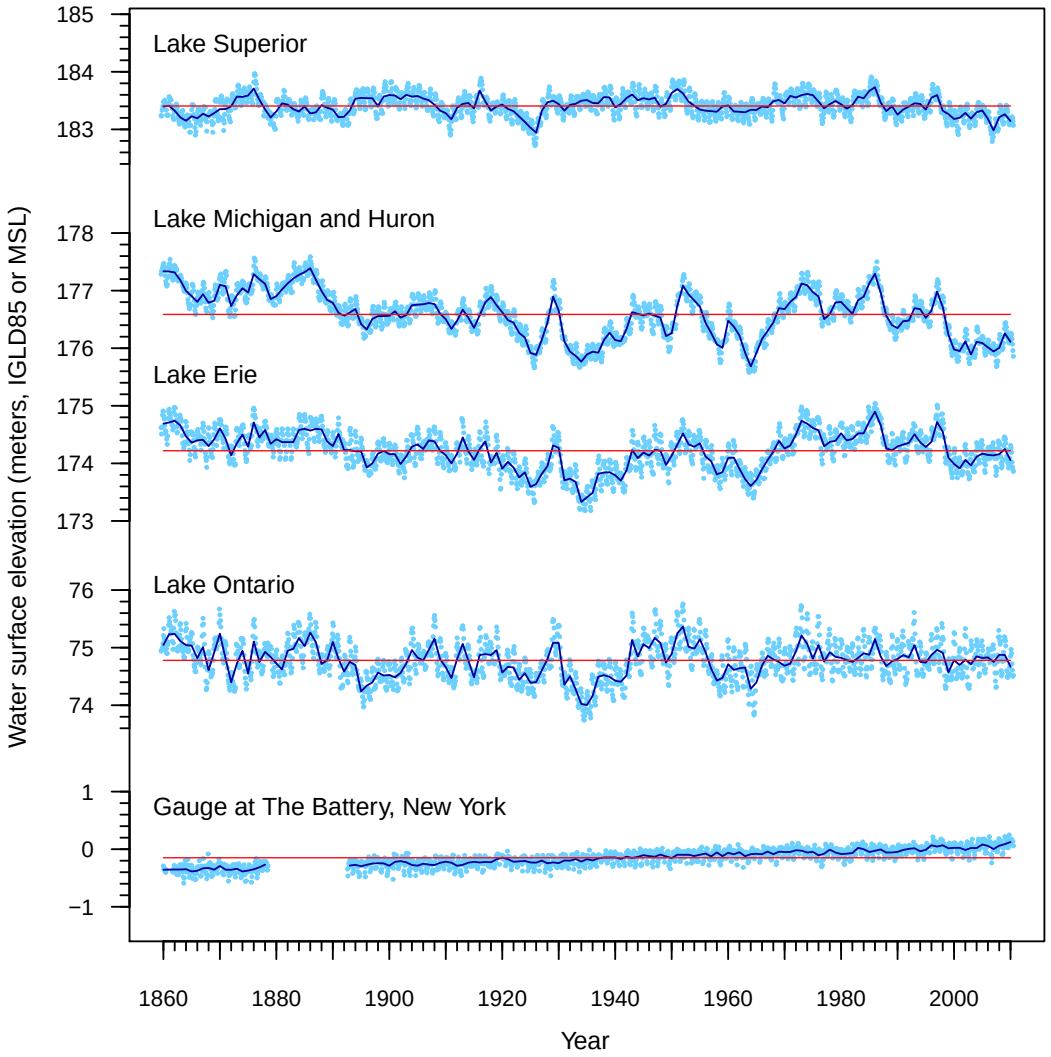
Great Lakes economy and ecosystems: shipping

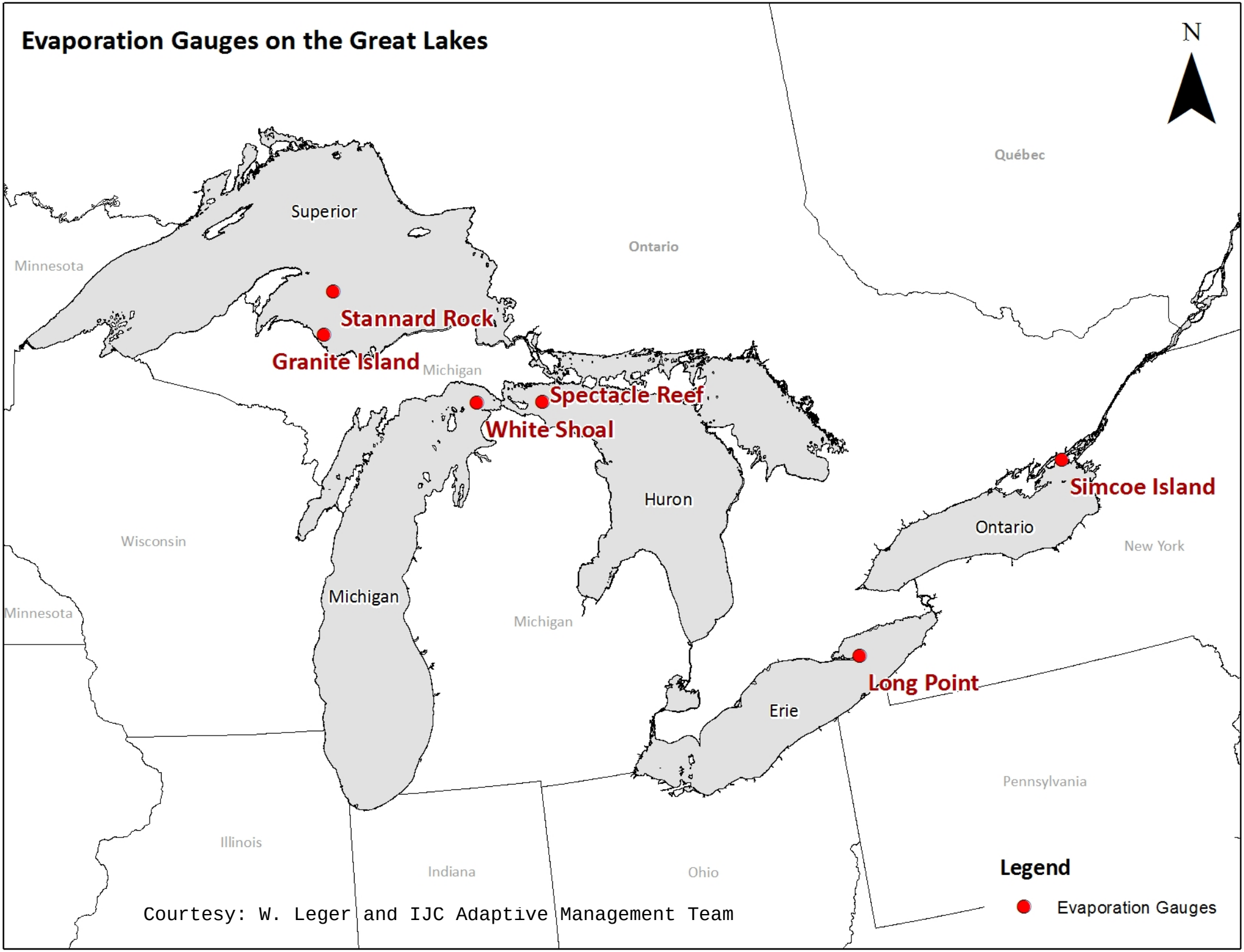
Impact of Dredging Crisis on Per-Trip Carrying Capacity
Major Great Lakes Vessel Classes

Major Great Lakes Vessel Classes	Vessel Length *(feet)*	Per-Trip Carrying Capacity *(net tons)*	Capacity Per Foot Of Draft *(net tons)*
	1,000	69,664	3,204
	806	34,720	1,752
	767	28,336	1,524
	730	27,558	1,380
	635	22,064	1,284
	501	13,776	852

Source: Great Lakes Maritime Task Force 2013

Water levels: data (long-term)




Evaporation Gauges on the Great Lakes
N
Québec
Superior
Ontario
Minnesota
Stannard Rock
Granite Island
Michigan
Spectacle Reef
White Shoal
Huron
Simcoe Island
Ontario
New York
Wisconsin
Michigan
Minnesota
Michigan
Long Point
Erie
Pennsylvania
Illinois
Indiana
Ohio
Legend
Evaporation Gauges
Courtesy: W. Leger and IJC Adaptive Management Team


Huron:
Spectacle Reef
Courtesy: P. Blanken (UC Boulder)
Superior: Stannard Rock

Measurements at Stannard Rock

Courtesy: P. Blanken (UC Boulder)

32.4 m (Superior) 28.3 m (Huron)

Wind speed & direction

Radio communication

Incident short- & long-wave radiation

Latent, sensible, momentum fluxes; atm pressure, [H_2O]

Air temperature and humidity

Water surface temperature

Rain: total & rate

0.5-hr means June 2008 (Superior)
Sept 2009 (Huron) - present

June 7, 2012

Land Warmer than Lakes:

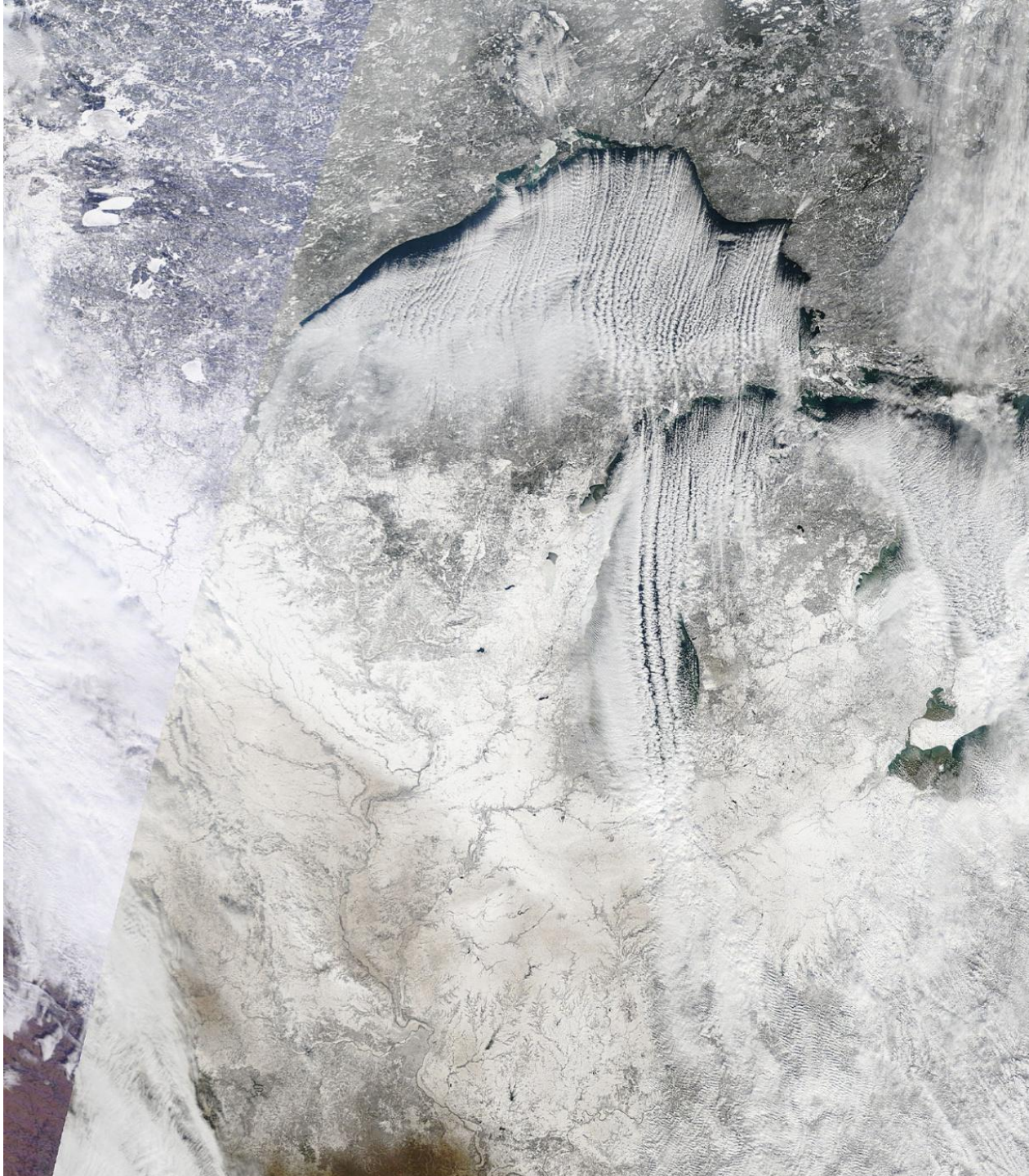
- Clear-skies over lakes (subsidence H pressure)
- cumulous clouds over land (convective surface L)
- Lake-breeze fronts (NW Superior Shore)

Courtesy: P. Blanken (UC Boulder)

December 13, 2010

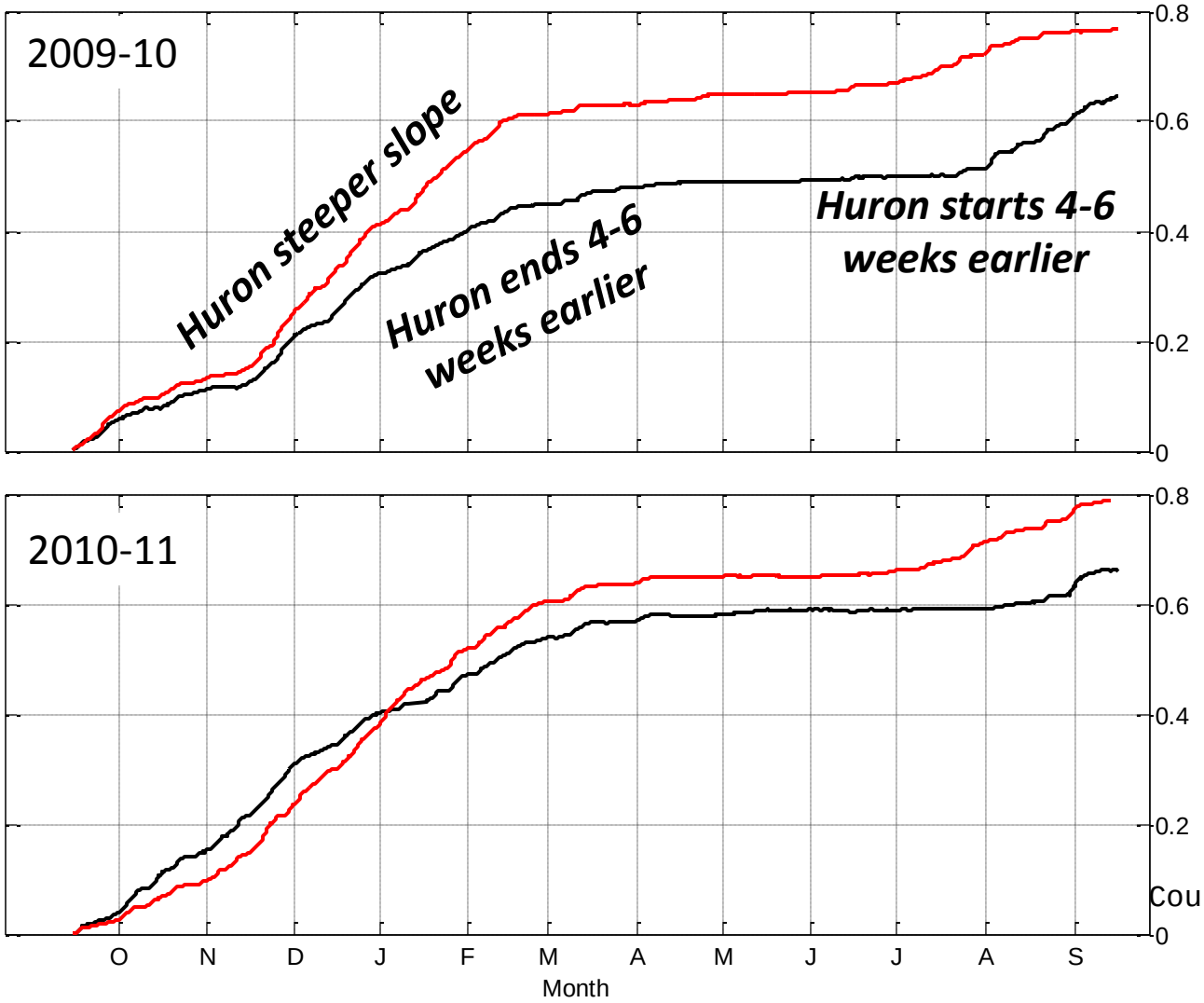
Lakes (ice-free)
Warmer
than Land:

- Cloudy over lakes (cloud streets)
- Downwind Lake-effect snow
- Massive quantity of heat and moisture removed from lakes



Courtesy: P. Blanken (UC Boulder)

Seasonal Evaporative Water Loss



Huron: 767 mm

Superior : 646 mm

Huron 19% > Superior

Huron: 787 mm

Superior : 660 mm

Huron 19% > Superior

Courtesy: P. Blanken (UC Boulder)