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USING TREE RINGS FROM SOUTHEAST ALASKA TO RECONSTRUCT JANUARY – JUNE MICHIGAN-HURON LAKE LEVELS

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INTRODUCTION

The Great Lakes (GL) are the largest freshwater system on Earth, holding 84% of North America's water supply (EPA, 2025). People rely on the GL for drinking water, jobs in tourism, recreation, and marine transportation (NOAA, 2026), and they are home to more than 3,500 plant and animal species, some of which are found nowhere else on Earth (GLC, 2026). With over 7,250 kilometers of coastline in the U.S. (NOAA, 2026), flooding and coastal storm damage due to rising and falling lake levels is of primary concern (Meadows et al., 1997).

The objective of this study is to reconstruct historical lake levels in Lake Michigan-Huron (MH) leveraging the strong correlations between Alaskan tree ring series and monthly lake levels. Tree rings represent one year of a tree's life, making them a good indicator of annual climate variations. The main tree ring proxy used for climate reconstruction is tree ring width (TRW), which is influenced by changes in climate conditions (Popa et al., 2022). Favorable climate conditions result in strong tree growth, while extreme temperatures, precipitation, or other stress- inducing events may limit tree growth (Popa et al., 2022).

Teleconnections such as the Pacific North American teleconnection (PNA) provide the basis for the correlations and a context for the climatic similarities between these two geographically distinct regions. The PNA is a pattern of air pressure anomalies over the Pacific Ocean and North America that correlate with temperature and precipitation anomalies across North America (Dahlman, 2009). Rodionov (1994), Ghanbari and Bravo (2008), and Rogers and Coleman (2009) found that a negative PNA is linked to increased winter precipitation over the GL region (Fig. 1), possibly leading to higher lake levels. Furthermore, the PNA is correlated with atmospheric pressure all over the globe, and the GL region and Southeast Alaska have similar correlations (Fig. 2), indicating a teleconnection between the two areas.

This tree ring reconstruction will bridge the gap between geologic and observational records, linking historical and geologic lake level variability with tree rings and other observed climate conditions. Quinn and Sellinger (2006), and Wiles et al. (2023) have successfully used tree rings to reconstruct historical GL levels, whereas Brinkmann (1992) used tree rings

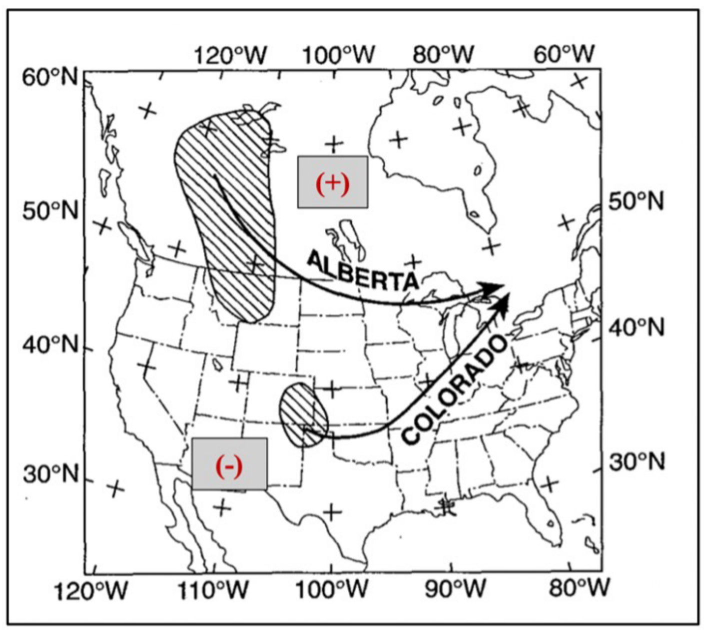

Figure 1. Cyclone activity and storm tracks during positive and negative PNA phases. Precipitation comes from Alberta during the positive phase, and Colorado during the negative phase, carrying significantly more precipitation during the negative because of proximity to the Gulf of Mexico and cyclogenesis east of the Rocky Mountains (Rodionov, 1994).

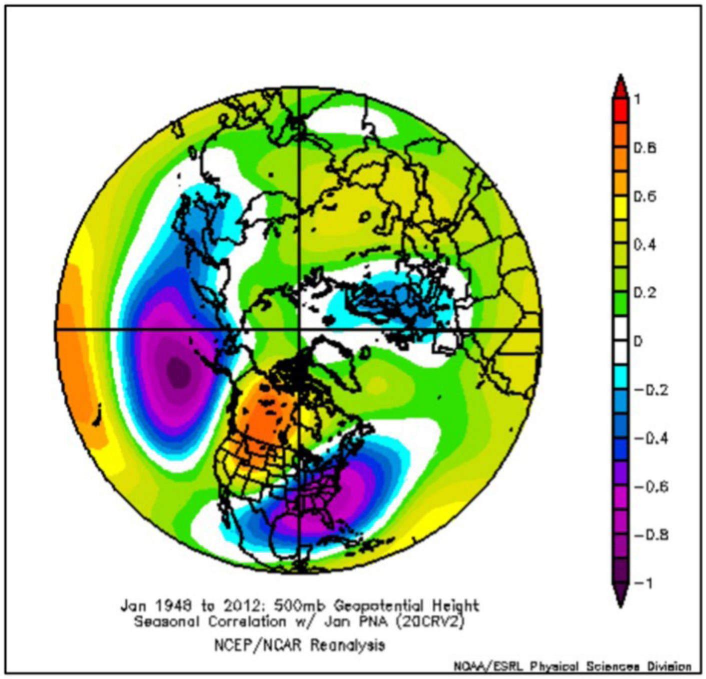

Figure 2. PNA correlated with atmospheric pressure. Monthly data from January 1948-2012 500mb heights, or the elevation above sea level where the atmospheric pressure is 500 millibars, correlated with the PNA index. Note the similar correlation between Southeast Alaska and the GL Region (NOAA, 2012).

to model GL net basin supply (NBS). Understanding historical peaks and lows in the lake level record will provide a basis for better anticipating lake level behavior in the present and into the future.

MATERIALS AND METHODS

Two hundred and two ring width chronologies were screened as potential predictors for lake level reconstruction (NOAA, 2026). These tree ring chronologies were standardized using the signal-free, age-dependent spline approach (Melvin & Briffa, 2008, 2014). This study uses the TRW of 10 chronologies from Southeast Alaska, significantly correlated at the 0.01 confidence level, the oldest tree reaching back to 1247 CE. The chronologies were then used to build a reconstruction of MH (Fig. 3) using a 2-PC model of PCReg (principal component regression analysis; Cook, E.R., 1985).

The reconstruction of Lake MH spans from 1650 to 1990 and has a calibration period of 131 years (1860 – 1990). Analysis of the tree ring chronologies and lake levels yielded a viable long season for reconstruction (January – June) as these months exhibited the strongest correlations between tree rings and lake

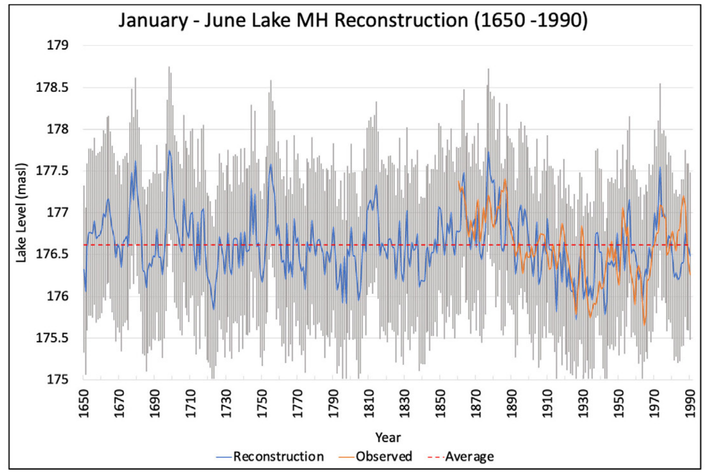

Figure 3. Reconstruction of January – June MH lake levels (1650 – 1990). Many of the early highs (1677, 1698, 1755, and 1810) are linked to volcanic eruptions and later highs and lows are linked to regional or global climate events. Blue line represents the reconstruction, orange line represents observed lake levels from 1860 to 1990, and gray bars represent the 95% confidence interval derived from the root squared mean error (RSME).

levels. Ten chronologies from Southeast Alaska were retained that were significantly correlated at the 0.01 confidence level for the full calibration period (Table 1). Each tree-ring series was also screened for time stability for the early (1866 – 1925) and late (1926–1990) calibration periods individually at the 0.01 level of significance.

RESULTS

The ten series used for full modeling in PCReg

Table 1. Correlation of S. Alaskan chronologies and lake levels (1860 – 1990).

SAMPLE	LAT.	LONG.	FIRST YEAR	LAST YEAR	SPECIES	CORREL.
COREYA	60.36	-145.40	1365	1992	TSME	r = 0.44
FULLTM	60.05	-150.01	1525	2004	TSME	r = 0.46
GNUNAT	61.05	-146.59	1410	2000	TSME	r = 0.29
MASSRK	60.38	-145.25	1508	1992	TSME	r = 0.52
MCGINN	58.26	-135.36	1380	1999	TSME	r = 0.51
RCKTOR	61.03	-147.06	1406	2002	TSME	r = 0.37
WITTIE	60.50	-148.35	1412	1991	TSME	r = 0.29
WOLVER	60.22	-148.54	1247	1991	TSME	r = 0.50
WRIGHT	58.45	-135.59	1552	2010	TSME	r = 0.52
YAKALS	59.33	-139.21	1576	1995	PCSI	r = 0.41

Notes: Southern Alaskan chronologies and their correlation with January – June MH lake levels (1860 – 1990). The ten ring-width chronologies used for modeling with first and last years are noted, along with latitudes and longitudes. TSME is Tsuga mertensiana (mountain hemlock) and PCSI is Picea sitchensis (Sitka spruce). R values are based on the correlation between January – June TRWs and MH lake levels from 1860 - 1990.

(Cook, E.R., 1990) were transformed into principal components, explaining 33.8% of the variance in January through June MH lake levels for the full calibration period. To assess the regression model, we calibrated two models using the first half of the lake level data (1860 – 1925) and the latter half of the data (1926 – 1990), explaining 33.3% and 27.6% of the variance, respectively (Table 2). After isolating the early and late periods of lake level data for modeling, we verified the model by calculating reduction of error (RE) and coefficient of error (CE) values. The positive RE values for both periods indicate that the model performs better than just using the mean of the calibration period as a predictor (Fritts et al., 1990). The CE value is slightly negative, indicating that the reconstruction does not outperform the mean of the verification period. However, positive RE and correlation values suggest the model retains predictive skill.

Table 2. Statistics for the Lake Michigan-Huron Reconstruction.

Calibration	Variance (%)	Reduction of Error (RE)	Coefficient of Efficiency (CE)
1860 - 1990	33.8		
1860 - 1925	33.3	0.343	-0.108
1926 – 1990	27.6	0.393	-0.216

Sign test (residual balance) results were favorable for the full reconstruction, with 68 positive residuals and 63 negative residuals, further verifying the model. The 131-year calibration period is also favorable for the model, as it captures most of the 20th century and nearly half of the 19th. The observed lake levels for January through June were compared with the reconstruction estimates and they exhibited a strong correlation (r = 0.58, N = 130 years).

DISCUSSION

Highs in the MH lake level reconstruction are attributed to volcanic eruptions and altered climate patterns (ENSO), whereas lows are linked to drought. Research in the GL has been done that correlates evaporation with ice cover (Van Cleave et al., 2014; Blanken et al., 2011), concluding that ice can act as a "lid" over lakes, keeping evaporation to a minimum. Due to the slow decay of volcanic aerosols and the reconstruction exhibiting high lake levels following eruptions, cooler temperatures from a lack of solar radiation likely increased ice cover and reduced evaporation on MH, contributing to higher lake levels in 1677, 1698, 1755, and 1810 following eruptions in 1673, the 1690s, 1755, and 1809 (Gao et al., 2008, D'Arrigo et al., 2013).

The reconstruction shows a peak in 1877 at 177.73 meters. From 1876 to 1878, the world experienced a series of droughts and consequent famine particularly in India, China, Egypt, Morocco, Ethiopia, Brazil, Colombia, and Venezuela (Singh et al., 2018). These extreme conditions correspond with the conditions produced by a very strong 2-year El Niño. Over the past 40 years with climate change, moisture contribution to the GL Region from the Mid-Pacific has increased significantly (Yang et al., 2023). During a typical El Niño (lasting 9-12 months; NOAA, 2016), the Pacific Jet Stream extends across the Southern US, bringing increased precipitation. During this very strong El Niño, it is possible that circulation patterns were altered and moisture from the Mid-Pacific was transported to the GL Region, leading to an increase in precipitation and MH lake levels from 1876 – 1878.

There is a low stand of MH lake levels from 1915 through 1963, likely due to temperature changes and dry conditions in the US. A series of droughts occurred in the 1930s through the 1950s due to changes in tropical Pacific SSTs, which affected global circulation, resulting in anomalies over North America (Seager et al., 2005). Also in the 1930s, the Great Plains experienced extreme drought eventually leading to the infamous Dust Bowl, which continued into the 1940s, providing further evidence of dry conditions in the US in the early 1900s (Seager et al., 2005). From about 1900 to 1950, there was a global temperature rise thought to be caused by an increase in greenhouse gases, a reduction in volcanic aerosols, or a small change in solar irradiance (Hegerl et al., 2018). This warming was caused by changes in SSTs, resulting in altered atmospheric patterns, like a decreased southerly inflow of moist air over the US (Hegerl et al., 2018). In 1973, the reconstruction shows another peak at 177.55 meters, attributed to above-normal precipitation in the GL Region from 1971 to 1974 because of wetter and cooler conditions in the GL basin (Stevens, 1973; Changnon, 1987).

CONCLUSIONS

The objective of this research was to build a well-verified reconstruction of historical MH lake levels. In summary, this study yields the following conclusions:

- Tree rings from Southeast Alaska capture climate variability relevant to MH levels.

- Calibration and verification statistics confirm a robust, well-verified 340-year reconstruction with a 131-year calibration period.

- Known climate conditions (volcanic eruptions, ENSO, drought, precipitation) compare well with the reconstruction model.

- Atmospheric climate patterns, volcanic forcing, and the PNA influence MH lake level fluctuations.

- Altered climate conditions influencing historical lake levels may help to inform lake level responses to climate change in the future.

- A strong ENSO event in 2026 may lead to increased lake levels in the coming years due to altered moisture patterns.

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