A Historical Monthly Hydrometeorological Database for the Great Lakes

T. Hunter, 1 A.H. Clites, 1 R.A. Bolinger, 2 and A.D. Gronewolf 1

NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI
University Corporation for Atmospheric Research, Boulder, CO

Background
Starting in 1983, the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL) has been developing and maintaining a historical time series of North American Great Lakes circumscale monthly hydrometeorological data. This collection of data sets, which we hereafter refer to as the NOAA-GLERL monthly hydrometeorological database (GLM-HMD), is, to our knowledge, the first (and perhaps still the only) to assimilate hydrometeorological measurements into model simulations for each of the major components of the water budget across the entirety (i.e. both United States and Canadian portions) of the Great Lakes basin for a period of record dating back to the early and mid 1900s.

Preliminary Analysis
The GLM-HMD is a multi-scale, multi-method research data product that we built for the purpose of understanding how the variability and long-term trends in historical precipitation and evaporation have influenced Great Lakes water levels, fresh water supplies, and aquatic ecosystems. This database is the product of numerous years of development and increasing data maturity and availability as well as evolving data collection strategies and science needs over the course of its development. The database is intended to serve as a resource to support ongoing research on the Great Lakes region, help validate and assess forecasting models, and provide a historical context for understanding the long-term impacts of climate change on the Great Lakes basin.

Over-lake Evaporation
We estimate total monthly evaporation over each lake by aggregating daily simulations from NOAA-GLERL’s one-dimensional Large Lake Thermodynamics Model (LLTM). While the LLTM has been employed in both research-oriented and operational programs for decades, we recently implemented several important improvements. First, in 2012, we began implementing an alternate formulation of over-lake cloud cover fraction of the inputs to the LLTM relative to the pre-2012 methodology, draws from the relatively broad range of meteorological stations in the NOAA-NCDC Integrated Surface Hourly Databases. Second, we recalibrated (also in 2012) the LLTM using the most recent set of lake water temperature estimates from NOAA’s Coastalwatch Great Lakes basin surface water temperature (GLST) database. Though the period of record for the GLST data begins in 1983, the data is only available in the context of the historical evaporation estimates from 1948 to 1950, setting aside simulations from 1948 and 1949 as a model initialization period.

Figure 2. The North American Laurentian Great Lakes and the boundary of the Great Lakes basin. Great Lakes (GL) stations are black, boundary stations are the gray line, and recommended national (RAN) stations are the white line.

Figure 1. Historical NOAA-GLERL subbasin delineations (black lines) that serve as a basis for spatial precipitation, evaporation, and runoff measurements for the 1948-present period of record.

Figure 3. Spatial distribution of hydrometeorological variables across the Great Lakes basin from 1948 to 2019. Mean monthly subbasin-averaged values are overlaid on a background of historical NOAA-GLERL subbasin delineations. The black line indicates the extent of the Great Lakes basin, and the white line indicates the extent of the United States. Variability and long-term trends in precipitation and over-lake evaporation are consistent among the subbasins, suggesting that the database is capturing the variability and long-term trends in the Great Lakes basin.

Tributary Runoff
We estimate historical monthly runoffs by interpolating daily streamflow measurements from both the United States Geological Survey (USGS) and Water Survey of Canada (WSC) across a large number of stations that meet GLERL-ARM selection criteria. For each subbasin with at least one station, we estimate the cumulative basin supply by subtracting the contributions of tributary inflow and over-lake precipitation from the observed streamflow measurements.

Availability
The database is freely-available from NOAA-GLERL at the following web-site:
www.glerl.noaa.gov/data/arch/hydro/mnth-hydro.html
and through the Great Lakes Dashboard project:
www.glerl.noaa.gov/data/dashboard/portal.html

Figure 5. Time series of historical data from the GLM-HMD-2 including total annual over-lake precipitation and over-lake evaporation (P-E). The dashed line indicates the percent change relative to the 1948–1950 period of record.

Our estimates indicate particular pronounced decreasing trends in December and August NBS over Lake Superior in recent years. Our estimates indicate a persistent shift over the past 60 years from a positive to negative effect in February for all lakes, as well as a critical component of broader scale changes taking place across the entire Great Lakes ecosystem.

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For Further Reading:

Application: Understanding historical trends in the annual water budget and annual average surface air temperature of the Great Lakes basin

Our estimates of historical (1950 to present) Lake Superior monthly NBS (top row Figure 6) provide insight into potential origins of annual and decadal NBS trends. More specifically, our estimates indicate a persistent shift over the past 60 years from a positive to negative effect in February for all lakes, as well as a critical component of broader scale changes taking place across the entire Great Lakes basin.

Application: Changes in the Lake Superior seasonal water budget

Figure 6. Monthly data from the GLM-HMD for Lake Superior including net basin supply (NBS), runoff (R), over-lake precipitation (P), and over-lake evaporation (E). The dashed line indicates the percent change relative to the 1948–1950 period of record.