# Bi-Nationally Coordinated Water Levels: Charting the way for a new International Great Lakes Datum

Khaleel Arfeen[1], Sierra Davis[2], Michael Craymer[3], Adam Grodsky[2], Terese Herron[1], Michael Michalski[2], Jeff Oyler[2], Laura Rear McLaughlin[2]

[1]*Canadian Hydrographic Service, Department of Fisheries and Oceans Canada*
[2]*Center for Operational Oceanographic Products and Services, NOAA*
[3]*Geodetic Survey Division, Natural Resources Canada*

On Behalf of the Vertical Control – Water Levels Subcommittee
Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data

**Canadian Hydrographic Conference – June 6-9, 2022**

# Speaker Introductions

Khaleel Arfeen - Physical Scientist, TCWLSci Unit, CHS

Sierra Davis - Oceanographer, Datums Team, NOAA CO-OPS

# International Great Lakes Datum (IGLD)

- IGLD is the official vertical datum reference for water level measurements and navigation products through the Great Lakes, their connecting channels and the St. Lawrence River
- Required for the unified, internationally coordinated collection, compilation and use of data for hydraulics, hydrology and water level management:
  - **Marine navigation and transportation**
  - **Regulation of lake & river flow through connecting waterways**
  - Nautical chart updates (CHS, NOAA)
  - Lake level forecasting
  - Coastal Zone Activities

# Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data

- Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data
- Formed in 1953
- Ad hoc group of Federal experts
- Four subcommittees
  - Hydraulics
  - Hydrology
  - Coordinated Regulation and Routing Model
  - Vertical Control - Water Levels
    - Update and revise IGLD
    - Standardize water level data processing

Environment and Climate Change Canada

Environnement et Changement climatique Canada

Fisheries and Oceans Canada

Pêches et Océans Canada

Natural Resources Canada

Ressources naturelles Canada

US Army Corps of Engineers

# Updating IGLD (1985) to IGLD (2020)

- Need to update every 25-30 years to account for movement of Earth's crust (GIA) - Overdue!
- IGLD (2020) will use geoid-based North American - Pacific Geopotential Datum of 2022 (NAPGD2022)

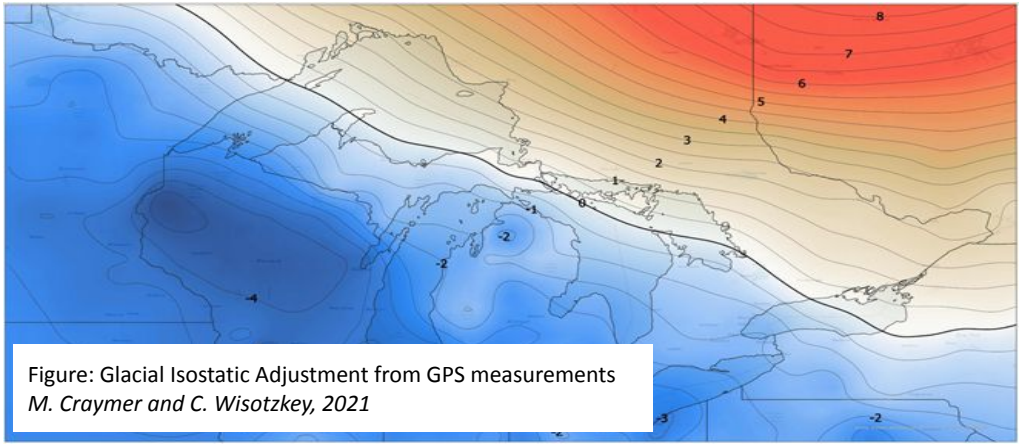
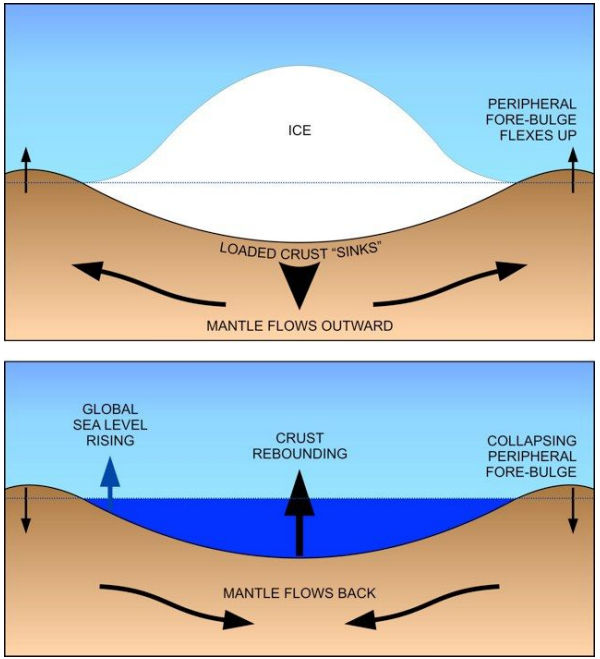



Figure: Glacial Isostatic Adjustment from GPS measurements
*M. Craymer and C. Wisotzkey, 2021*




The general process of GIA. Top: Heavy ice loads Earth's surface. Bottom: Once the ice is removed, some areas rebound, while others collapse.

# New Technologies for IGLD (2020)

- Global Navigation Satellite Systems (GNSS)
  - Field Campaigns - seasonal and permanent WL stations
  - NOAA Continuously Operating Reference Stations (CORS)
  - NRCAN Canadian Active Control Systems (CACS)
- Updated Spatial Reference Systems
  - NATRF2022, NAPGD2022/CGVD2013, GEOID2022
- Data transmission, automated processing, datum determinations and transformations
- Water level station hardware
  - Use of Microwave Radar Water Level Sensors
  - GOES satellite data transmission
  - Station upgrades and new station installations

GNSS Field Occupation

MWWL Sensor

# Importance of Water Level Measurements

## Permanent Gauging:

***Essential for Day-to-Day Operations and Long-Term Monitoring***

Photo: Chamber of Marine Commerce

**Marine Navigation:**
- Safe and efficient marine commerce
- Recreational safety
- Storm warnings and real-time water level data availability

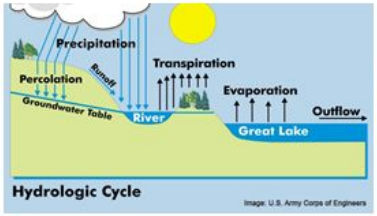
**Water Level Regulation and Policy:**
- Hydro-electric power
- US-Canadian treaty agreements
- Official vertical datum – IGLD


**Coastal Management:**
- Storm surge warnings
- Water level forecasting
- Restoration projects
- Dredging

**Long-Term / Time Series Analysis Studies:**
- Extensive water level time series used to compute Low Water Datum (chart datum)
- Crustal motion (GNSS equipped stations)
- Water level variability (long-term, annual, seasonal, monthly)

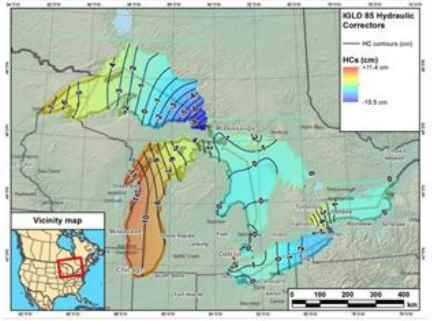
## Seasonal Gauging:

***Supports Permanent Station Network by Filling Data Gaps***



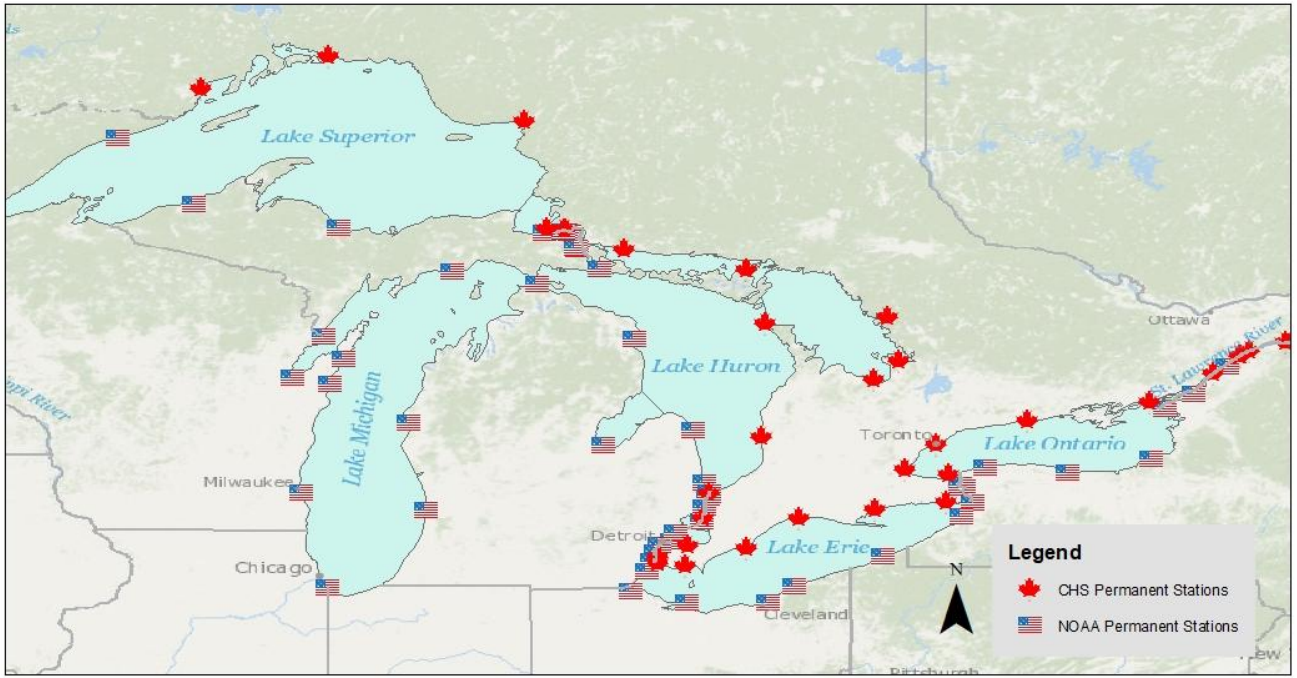

**Lake topography changes: river discharge, prevailing winds, temperature variations**

**Refine and/or Validate Numerical Models**


Data from both station types will be used to compute IGLD (2020)

# Coordinated Water Level Data for IGLD (2020)

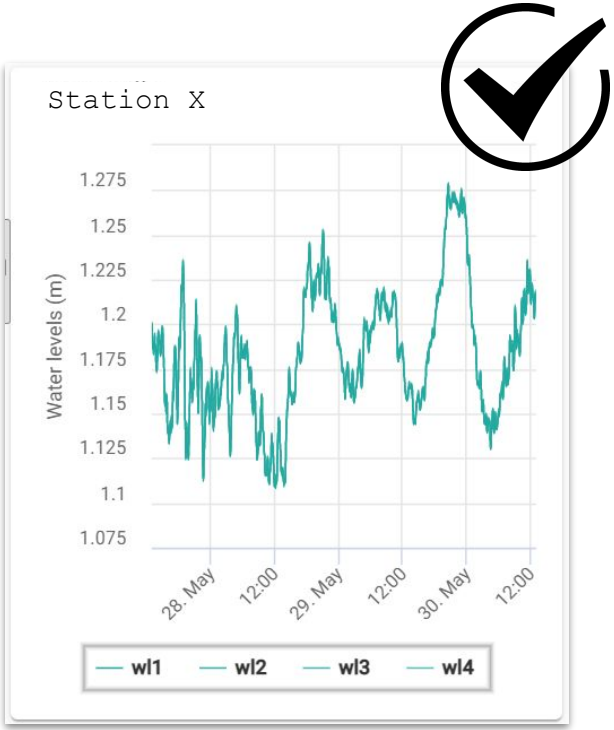



Seasonal and Permanent Gauging
- 111 permanent, 129 seasonal

- Coordinated Water Level Data
- IGLD (2020) epoch: 2017 - 2023

# Water Level Data Quality Control & Product Generation

- Data Quality Control Checks
  - Daily Monitoring of Data
  - Automated Checks & Expert Review
  - Outlier Identification and Removal
  - Flat Data Identification and Mitigation
    - Ex. Well Icing, Sensor Malfunction
  - Datum and Sensor Offset Value Check
  - Primary sensor vs. redundant sensor
    - Offset should remain within tolerance (+/- 0.003m)
- No Predictions or Transfers From Neighboring Stations
  - No mathematical filling of data gaps (observed data only)
- Product Generation
  - Hourly Heights, Daily Means, Monthly and Yearly Averages
  - Hydrographic operations: 3- and 6-minute datasets



# Data Ingestion / Quality Control

- Data from the permanent stations undergo a standard daily QC process for both US and Canadian stations
- Seasonal/temporary stations undergo a slightly different process for ingestion (CHS)
  - During the season: Daily monitoring for incoming data
  - End of the season: Data undergoes QC process
- NOAA/CHS employ a similar method of anomaly/outlier detection:
  - Plotting of data to visually inspect spikes, gaps, flats
  - Flagging of anomalies/outliers via a rate of change and/or statistical methods

# Data Product Coordination and Dissemination

9075080 Mackinaw City, MI

13320 Toronto, ON

CHS & NOAA

**Ingestion & Data QC**

*- Raw data stored*
*-Anomaly/outlier detection*
*- Visual identification of spikes, gaps, and flats*

**3- and 6-minute data**
*Navigation*

**Hourly Heights**
*Used to calculate daily and monthly means*

**Daily Means**
*Regulation of Lake Superior and Ontario, flow determinations*

**Monthly Means**
*Trends and forecasting*

**Annual Means**
*Trends, forecasting, climate impacts*

**Generated products are made publicly available through web-based applications.**
**Products support the computation of IGLD (2020).**

# Product Comparison by Organization

| Product | NOAA | CHS |
|---|---|---|
| **Hourly Heights** | - Calculated from top of the hour value (from averaged 6-minute data)<br>- If top of hour is not available, does not get next available data, instead is not recorded<br>- All data is kept on Local Standard Time (LST) | - Calculated from top of the hour value (instantaneous value, no averaging)<br>- If top of hour is not available, does not get next available data, instead it is not recorded<br>- All data is kept on Local Standard Time (LST) |
| **Daily Means** | - Averaged from hourly heights | - Averaged from hourly heights |
| **Monthly Means** | - Averaged from hourly heights for a month | - Averaged from daily means for a month |
| **Yearly Means** | - Calculated from monthly means for a year | - Calculated from daily means for a year |
| **General** | - Use engineering rounding<br>- Products referenced to LST on IGLD (1985) and Low Water Datum (LWD) | - Use engineering rounding<br>- Products referenced to LST on IGLD (1985) and Low Water Datum (LWD) |
| **Units and resolution** | - Collect data in meters<br>- Disseminate in meters with precision to the millimeter<br>- Data available in both meters and feet (CO-OPS APIs, Tides and Currents website) | - Collect data in meters<br>- Disseminate in meters with precision to the millimeter |

Note: (underlined items) = coordination and standardization underway

# IGLD Seasonal Gauge QC - CHS Case Study

- A system was developed to process the Seasonal Data in Python via Jupyter Notebook
- This system allows for full transparency, repeatability and accessibility
- No programming knowledge necessary for operation
- Guided and interactive process allows staff to focus on the analysis
- Outliers and anomalies are flagged as bad and treated as missing values
- At the end of the process, a cleaned dataset is saved along with a printout of the notebook file (self-documenting)

# IGLD Seasonal Gauge QC- CHS Case Study

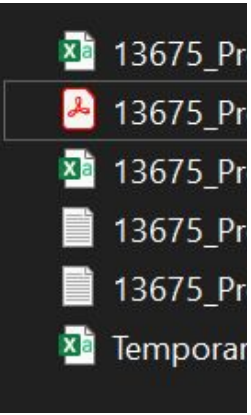
## Step 1: Load Data + Describe

```
# setup
import pandas as
import matplotlib
from matplotlib i
import datetime
%matplotlib inlin
matplotlib.rcPara
```



> USER INPUT RE

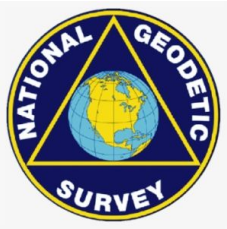
```
# import CSV datafile

# > update file name
file = '13675_PresquilePoint_2018.Raw.csv' # > update file name
df = pd.read_csv(file, skip_blank_lines=True, low_memory=False, parse_dates=[['date', '
df.dropna(how="all", inplace=True)
```




# Lessons Learned

- Challenges: lack of digital documentation from IGLD (1985), field work delays, document access for coordination
- Achievements: bi-national knowledge transfer, documentation and note taking for IGLD (2020), identification of some data discrepancies
- Importance of documentation
  - Increase transparency, mitigates legal risks
  - Timespan between IGLD updates, staff turnover
  - Preparation for next IGLD update

# Further Information





Natural Resources Canada | Ressources naturelles Canada

Canada

## Geodetic Data:

**NRCAN:** https://www.nrcan.gc.ca/maps-tools-and-publications/geodetic-reference-systems/data/10923

**NOAA NGS:** https://geodesy.noaa.gov/INFO/gnss-gps-data.shtml


## Water Level Data:

**CHS:** https://tides.gc.ca/en/tides-and-water-levels-data-archive

**NOAA CO-OPS:** https://tidesandcurrents.noaa.gov/stations.html?type=Water+Levels

# Further Information


www.greatlakescc.org

***Determining Heights in the New IGLD (2020)*** **- Mike Craymer (Session 6B)**

***International Great Lakes Datum: Possible Impacts and What you Need to Know*** **- Terese Herron, Laura Rear McLaughlin (Session 7B)**