Heights in the Great Lakes Region Developed from GNSS and a Gravity Field Model (Paper 8407)

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ABSTRACT

This paper focuses on the determining dynamic heights from reference field geopotential models and geodetic positions determined using GNSS technology. Only GPS data were used and all coordinates are in the IGS08 reference frame. GPS collection campaigns have been conducted on a periodic basis on the majority of the 53 Water Level Stations (WLS) maintained by NOAA on the U.S. side with similar efforts also made on the Canadian side by the Canadian Geodetic Survey (CGS) and NRCan. Twelve of the U.S. WLS are collocated with CORS stations. Three on Lake Superior and three on Lake Erie were selected for this study. Offsets from the GPS phase center to the Electric tape Gauge (ETG), and from the ETG to the water surface were determined. The geometric coordinates were transferred to the water surface and these values were used to estimate the geopotential value from the EGM2008, EIGEN6C4, and the xGEOID15B_Ref. The last model was developed using satellite, airborne and terrestrial gravity and serves as the reference field for development of the latest experimental gravimetric geoid model (xGEOID) that will eventually lead to the underlying physical height model in GRD 22. In particular, the aerogravity data derive from the Gravity for the Redefinition of the American vertical Datum (GRAVD) project, which is intended to refine the geopotential model between 4—200 km wavelengths. Comparison of orthometric heights (i.e., using geoid undulations) revealed trends from West to East across Lakes Superior and Erie of -0.06 m and +0.04 m, respectively. For Erie, that would indicate that Buffalo had a higher water level than Sandusky. Comparing dynamic heights in the same manner resulted in -0.03 m for Lake Erie and +0.01 m for Lake Superior. Both will be investigated further to refine these dynamic heights for a future Datum.

INTRODUCTION

Dynamic heights on the Great Lakes are given by the International Great Lakes Datum of 1985 (IGLD 85). These are realized using the geopotential numbers derived from the North American vertical Datum of 1988 (NAVD 88) adjustment in 1991 (Zilkoski et al. 1992). Recent analysis has demonstrated that a meter level trend exists across the continent when compared against satellite derived geoid models (Figure 1). This played a large part of the reason that NAVD 88 was never adopted in Canada. Further evidence of this trend can be seen in the hydraulic correctors (HC) that must be applied to dynamic heights in each Lake (right image in Figure 1). These values represent the necessary corrections applied to the dynamic heights determined from NAVD 88 geopotential values to obtain water levels that are the same across each Lake. In point of fact, these HC are directly related to the datum defect in NAVD 88. Note that the magnitudes and trends for the HC on each Lake are relatively the same as that of the NAVD 88 datum errors. Hence, a replacement for IGLD 85 should be defined using a gepotential model or geoid height model that does not have such a systematic error.

To that end, geometric coordinates of the water ;level surface were be obtained on three sites in Lake Superior and three on Lake Erie. Figure 2 highlights the locations of the varipous Water Level Stations (WLS) where Electronic tape Gauges (ETG) are dropped to determine water height. Figure 3 shows a sample WLS in Marquette, WI. CORS are mounted on these buildings that provide a means of transferring geometric coordinates to the water surface. Using these coordinates then, a geopotential model or geoid height model can be used to estimate the geopotential of the water surface and derive dynamic heights.

The three sites on Lake Erie (from East to West) are Buffalo, Cleveland, and Marblehead. On Superior, three sites were Point Iroquois, Marquette, and Grand Marais. These sites are circled in red on Figure 2. They are also given in the above order in Table 1 and 2. In Table 1, the WLS and CORS ID's are provided as well as the geometric coordinates for the CORS ARP, the offset between the ATRP and water surface for December 2015, and the derived geometric coordinates of the water surface. Table two then shows the calculated geoptential numbers for several different models: EGM2008 (Pavlis et al. 2012), EIGEN6c4 (Förste et al. 2014), xGEOID15A_REF, and xGEOID15B_REF. The latter two models are produced by the National Geodetic Survey. They combine GRACE, GOCE and EGM2008 data. The A model has no aerogravity from the Gravity for the Redefinition of the American Vertical Datum (GRAV-D) Project, while the B model does. These models are also five arcminute (degree 2160). The B model was used to produce a geoid height model using the remove-compute-restore method, which is termed the xGEOID15B (shown in Figure 4 with the extents of GRAV-D aerogravity incorporated.

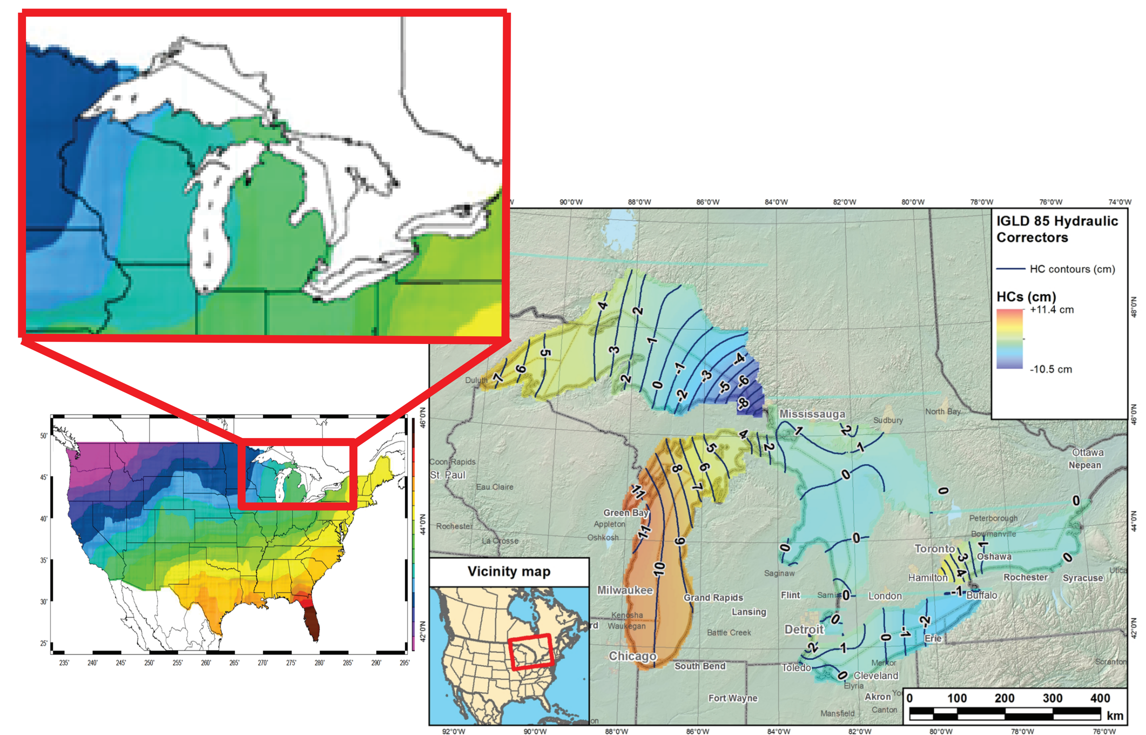

Figure 1. Bottom left image shows long wavelength (600 km+) filtered residual surface between leveling/GPS derived heights and GRACE/GOCE derivved geoid heights. Trend surface indicates datum error in NAVD 88. Upper left image is inset of this for Great Lakes region. Figure to right is plot of hydraulic correctors applied to NAVD 88 derived dynamic heights to correct to the "true" water surface. The same datum errors that plague NAVD 88 create the need for the correctors.

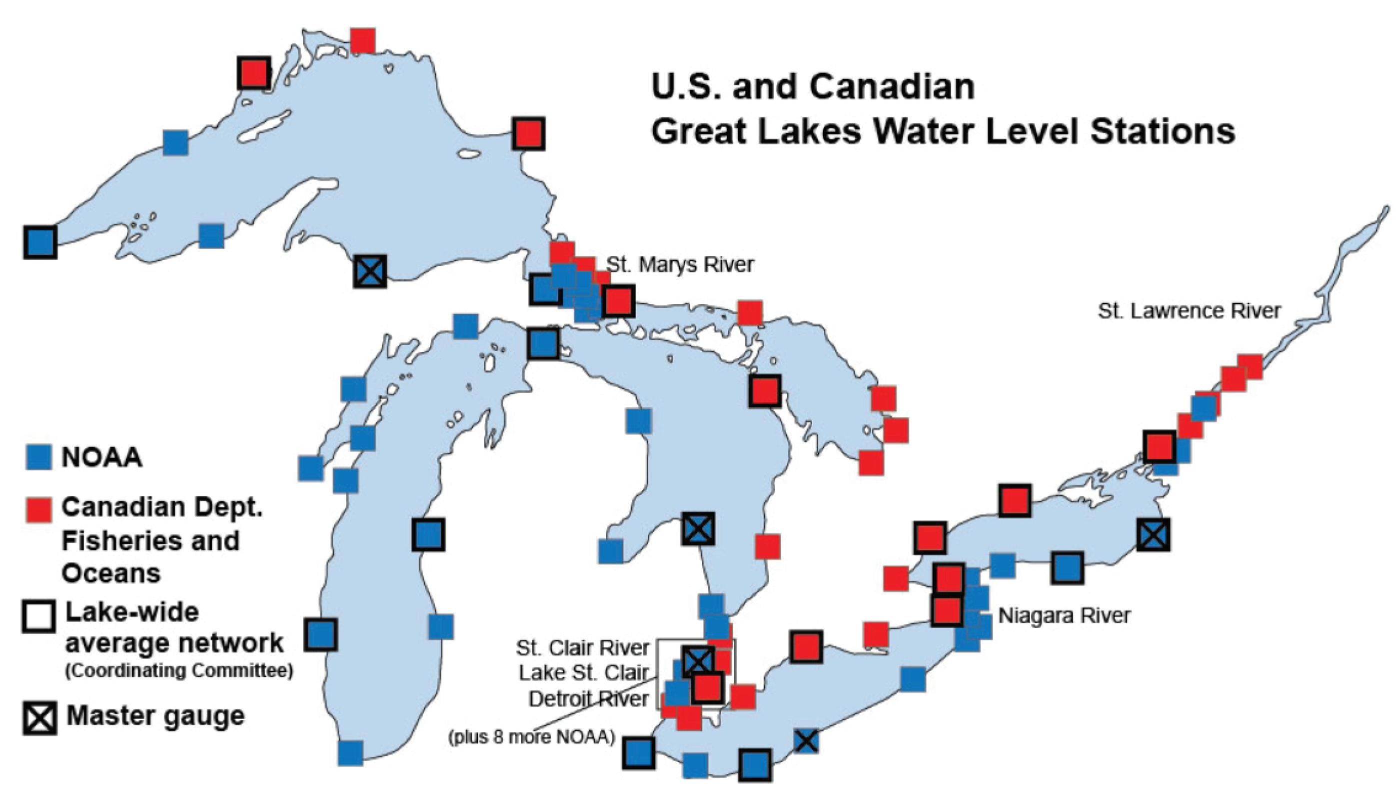

Figure 2. Locations of U.S. and Canadian Water Level Stations (WLS) in the Great Lakes. Table to left provides relative importance of stations.

Figure 3. WLS and collocated CORS i(MIMQ) n Marquette, Wisconsin. Distance was measured from CORS ARP to the Eletronic Tape Gauge (ETG) on the bench in the structure. Drops are made from the ETG table to a well freely connected to the water surface. When the sensor hits the water and completes an electric circuit, the distance is recorded. This provides a means to transfer the water level surface into geometric coordinates.

DISCUSSION

xGEOID15B shows the closest agreement of the three sites on each Lake, where the expectation is that they be identical. Lake Erie has a signiifcant difference, but this is mostly attributable to the value obtained at Buffalo. Neglecting it, agreement is in the 2 cm range. Adding in the local effect from the 1-5 arcminute signal from xGEOID15 improved things slightly but Buffalo's value remained anomalously large. Discussion with other NOAA tides and currents personnel suggest a systemtic difference there due in part to the prevailing winds and the water tension occurring when water descends at a river mouth from a lake. Hence this approach shows some merit for use in defining physical heights for the region - be they dynamic or orthometric.

Site	WLS ID	CORS ID	CORS ARP (IGS08) Latitude (degrees N)	Longitude (degrees E)	HAE (m)	ARP toWL (m)	WL HAE (m)
Buffalo	9063020	BFNY	42.87755697	281.10955496	145.462	-7.610	137.852
Cleveland	9063063	OHCD	41.54074488	278.36485371	144.582	-5.932	138.650
Marblehead	9063079	OHMH	41.54368360	277.26854509	142.866	-5.357	137.509
Pt. Iroquois	9099004	PTIR	46.48458324	275.36915966	151.362	-5.399	145.963
Marquette	9099018	MIMQ	46.54554809	272.62130392	155.102	-7.337	147.765
Grand Marais	9099090	GDMA	47.74855226	269.65874853	157.364	-5.498	151.867

Site	IGLD 85 ht	Dynamic Heights (m) from Geopotential Numbers (W_i) EGM2008	EIGEN6c4	xGEOID15A_REF	xGEOID15B_REF
Buffalo	174.197	173.653	173.635	173.652	173.648
Cleveland	174.158	173.582	173.570	173.564	173.586
Marblehead	174.144	173.541	173.544	173.571	173.566
Pt. Iroquois	183.580	182.901	182.897	182.911	182.906
Marquette	183.614	182.916	182.932	182.941	182.931
Grand Marais	183.613	182.890	182.891	182.908	182.919

Tables 1 and 2. Three sites where WLS and CORS are collocated were selected on Lake Erie (top three) and Lake Superior (bottom three). Geometric coordinates of the water surface are in Table 1 and estimate geoptential values are in Table 2 from various models.

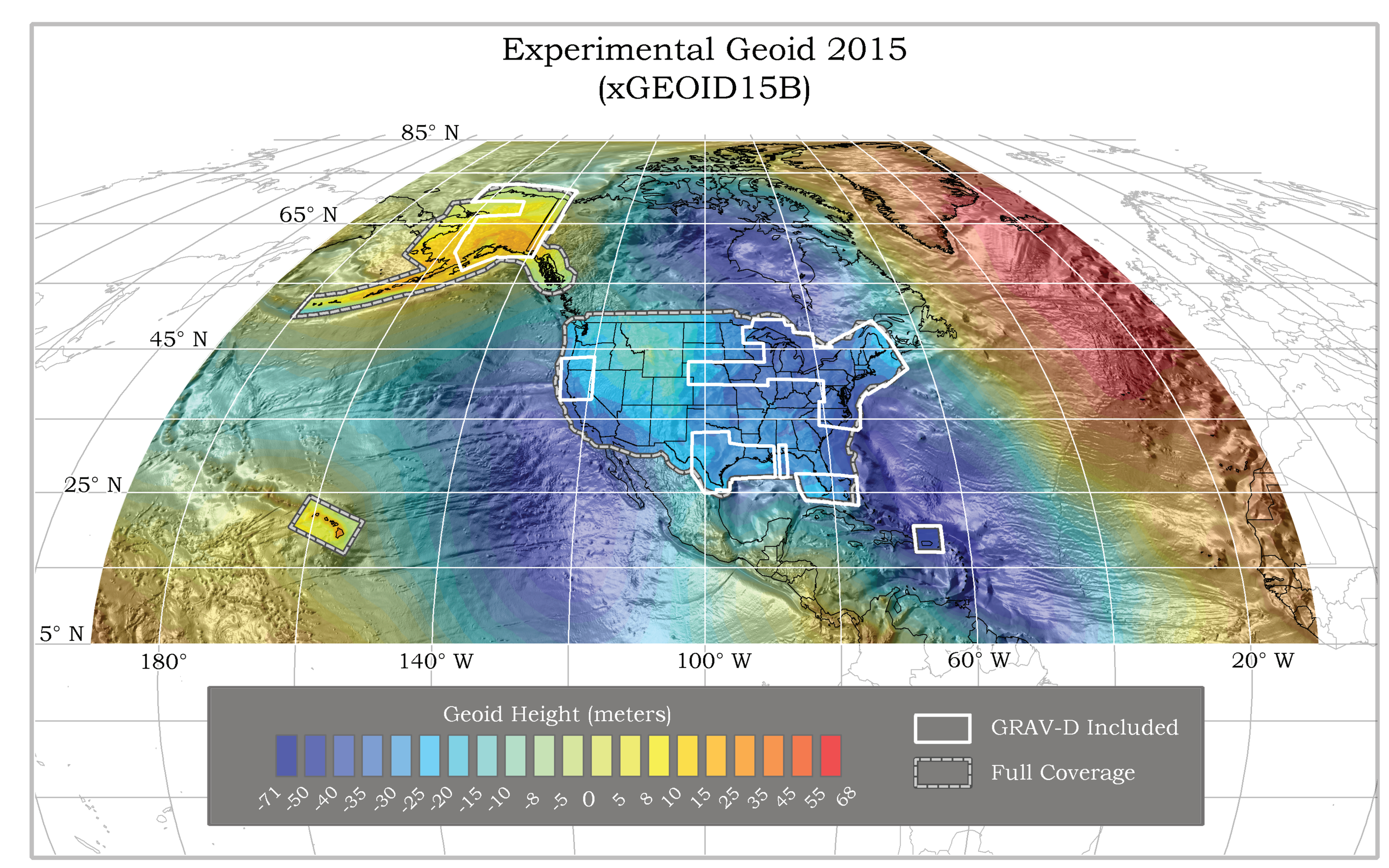

Figure 4. Plot of the current experimental geoid height model fr 2015 using available airborne gravity data (xGEOID15B). Using geometric coordinates, this model may be interpolated to locations to derive orthometric heights.

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