



Fredericton

# Surveying on the Ellipsoid: A Canadian Hydrographic Perspective

### Ian Church





### Vertical Referencing of Hydrographic Sonar Data





### **Processing Multibeam Survey Data**

- System Integration
- Raytracing
- Positioning (3D vs 2D)



### Positioning of a Depth Sounding



### **Traditional Depth Sounding Position**

Latitude

Longitude

Vertical: Tides, Draft & Squat

Why are these positions from different sources?

Horizontal: Positioning (GNSS)

# Vertical Positioning

84 D7\_

h

- What is the vertical reference for the numbers on a chart?
- They must be meaningful to a mariner





3g

3g

# Ellipsoid Reference Survey (ERS)

- Find a way to transform data from the Ellipsoid to Chart Datum
- FIG #62 (Mills & Dodd, 2014)
- Know how to do it Lots of potential ways to get the separation







### **Challenge for Canada**



- Canada has a special challenge
  - We need to have agreement across the country long coastline, lots of water and limited resources
  - Few tide gauges and lots of open water
    - Makes interpolation of CD between gauges impossible.



# Interpolation works well in a Narrow Channel, but what about in an Open Bay?



Hudson Bay M2 and K1 Amphidromes (Co-Tidal Charts) 2005 Version (WebTide)

#### Continuously Varying Chart Datum (CVD) for Canada



Figure 1. Tide stations and the four working grid domains, each portrayed in a separate color.

Robin, C., Nudds, S., MacAulay, P., Godin, A., De Lange Boom, B., & Bartlett, J. (2016).
Hydrographic Vertical Separation Surfaces (HyVSEPs) for the Tidal Waters of Canada. *Marine Geodesy*, 39(2), 195–222.



CD Depth = Sonar Depth + Offsets + Ellipsoid - SEPSEP = N + SST + HModel



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### **Geoid-Ellipsoid Separation Models**

- Canada: CGVD2013 (CGG2013)
- USA: Geoid12A: NAD83  $\rightarrow$  NAVD88 (hybrid Geoid)
- USA: USGG2012: WGS84  $\rightarrow$  Geoid
- International: EGM08



#### CGVD2013 Error Map



#### NRCAN, 2014

# CGG2013 Minus GGeoid14

3

Research Analysis by UNB GGE MScE Student **Weston Renoud** 

0.40

0.30

0.20

0.10

-0.00

-0.10

-0.20

-0.30

-0.40

### **Resolution and Akpatok Islands**



### CGG2013

GGeoid14

Differences of +/- 40 cm



CD Depth = Sonar Depth + Offsets + Ellipsoid - SEPSEP = N + SST + HModel

#### Dynamic Ocean Topography

OCEAN DYNAMIC TOPOGRAPHY, 1993-2006



#### DOT: Associated Epoch and a **Reference Geoid**

- Sea Surface Variations Ö
  - Ocean Currents: 1 m
  - Waves
  - Sun Heating: 0.3 1 m
  - Storms, Pressure, Winds. etc

SATELLITE

SEA SURFACE

GEOID





CD Depth = Sonar Depth + Offsets + Ellipsoid - SEPSEP = N + SST + HModel

### Hydrodynamic Model

55

21

#### WebTide

(Hannah, Greenberg, Dupont et al.) Scotian Shelf Model

### M2 Amplitude



#### ➤ Tides:

- Limited Tide Gauge Network
- Hydrodynamic Models

### Canadian Tidal Model Coverage

Match the 2-Dimensionally Varying Chart Datum from Hydrodynamic Model to Established Chart Datum



### **Continuous Vertical Datum**



Accuracy estimates:

CANEAST7.5cmCANWEST6.9cmCANNORTH6.6cmCANHUD17.7cm

For CGG2013 single average error of 2.5 cm used

Tide stations and the four working grid domains, each portrayed in a separate colour, duplicated from Robin et al (2016)



CCGS Amundsen icebreaker – Wert (2004)

#### Water Levels from GNSS



MV AIDAblu Duplicated from Reinking et al (**2012**)



Photo of the GPS-Catamaran at M2 tide gauge location, duplicated from Bonnefond et al (**2003**)



Princess of Acadia – Wardwell (2008)

# RV Nuliajuk



Part of OMG Arctic Mapping Program 2012-2014



Water Height Reduction  $H_{wl} = h_{ellip} - N - heave_{vessel}$   $- heave_{lever} - squat - h_{ant}$ - wlz

#### Where:

- *hellip* the PPP solution height above NAD83(CSRS), *N* the geoid undulation from CGG2013 for the position of the vessel,
- *heavevessel* the vessel heave as reported at the ship's reference point,
- *heave*<sub>lever</sub> induced heave due to offsets of the antenna from the ship's reference point,
- *squat* vessel squat as a function of the speed over ground,
- *h*ant height of the GNSS antenna above the ship's reference point, and
- *wlz* height of the ship's reference point above the water.



### **GNSS** Water Height and Tide Observations



Comparison of GNSS Water Heights to Observations at active Tidal Station: Frobisher's Farthest – Frobisher Bay



#### **Initial Results and Validation**

- NRCAN PPP solutions for the forward mounted CNAV3050 were used as observations
- Estimates of Mean Sea Level wrt Ellipsoid
- Grids were binned at 3 km

2500

2000

1500 tino 1000

500

0

-0.4

-0.2



- The hydrographic community has unique challenges for vertical referencing vs. land surveying
- Ellipsoid Referenced Surveys (ERS) are now possible for all Canadian Waters
- The CVD solution must be continually refined and improved as better Geoid Approximations, DOT estimates and Tidal Estimates become available
- There needs to be additional validations throughout the CVD domain to verify stated uncertainties and to confirm that vertical accuracy requirements are being met



### **Questions?**

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