A stable vertical reference for bathymetric surveying and tidal analysis in the high Arctic

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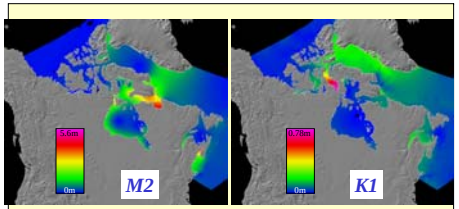
The EM300 multibeam sonar mounted on the Amundsen is one of the prime tools used for marine geomorphologic and hydrographic investigations as part of ArcticNet. Under reconnaissance conditions, the data, as collected, serve as a valuable source of information even if imperfect. Sources of imperfection generally include bottom tracking degradation due to seastate or ice-conditions, imperfect sound speed information and imperfect calibration but perhaps most significantly the lack of a stable vertical datum. .

The measurements, as routinely collected and currently presented, are strictly with respect to the local water surface. If multiple passes of data, acquired on different missions and at different phases of the tide, are to be used to build up an accurate picture, variations in the long term vessel elevation due primarily to tide, but also due to draft changes (due to loading, squat and trim) have to be properly backed out. The traditional method used for this has been through the use of a network of tide gauges combined with draft and squat estimates. Such an approach is not practical however in the high arctic as the existing network of water level monitoring stations is too sparse and the existing hydrodynamic models have not yet proven reliable at robust spatial interpolation.

An alternate approach to a stable vertical datum is to adopt the ellipsoid as the reference. Recent advantages in wide-area differential GPS (WADGPS) now allow vertical referencing to within a few decimeters vertically without the need for coastal base stations. With appropriate filtering and use of inertial sensors, the same data can potentially be relied upon for work at the decimeter level. In doing so it completely bypasses the need for draft, trim and squat measurements. As part of an experiment, almost all data acquired so far with the Amundsen has had synoptic measures of the vessel ellipsoid elevation derived using the CNav WADGPS service. This potentially allows us to co-reference the data using a common vertical datum.

A particularly critical application for this will be repetitive monitoring of the seabed instability features (rotational slump fields) to try and detect fine scale changes. An additional byproduct of this technology is that, as long as appropriate draft and squat models are applied, the same data can be used to examine the variations in the phase and amplitude of the tide at locations remote from the existing tides network. This will allow calibration of existing hydrodynamic models, improved confidence in the extrapolation of the geoid-ellipsoid separation offshore and even perhaps the establishment of viable chart datums interpolations for these remote areas.



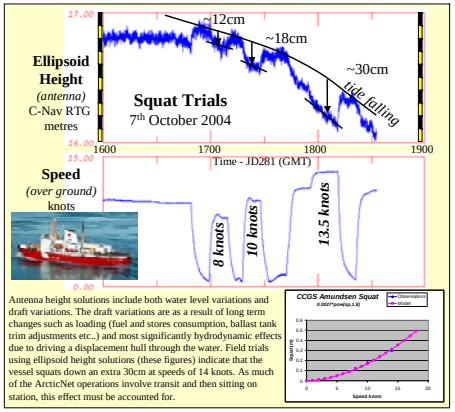
M2 and K1 tidal amplitudes (range = 2x)

WebTide

http://www.mar.dfo-mpo.gc.ca/science/ocean/coastal_hydrodynamics/WebTide/webtide.html

3 models – Arctic Archipelago – Hudson Bay - NW Atlantic.

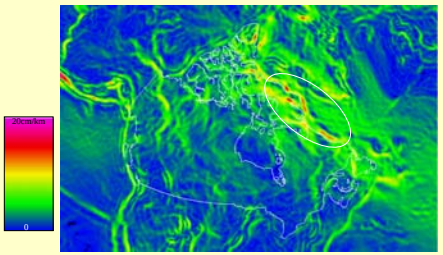
An independent means of predicting sea surface topography. Obviously does not include non-tidal variations (storms, river input, seiches, long term barotropic sea surface slopes etc..). Calibrated against existing observed harmonics (M2,S2,N2,K1O1). Can be used as a check on C-Nav geoid height signal.

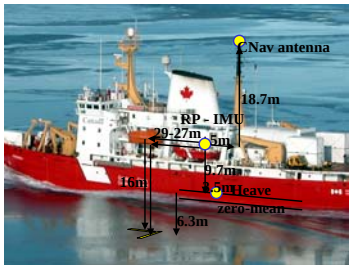


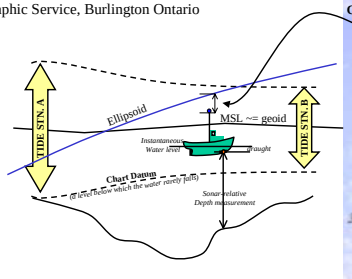
Antenna height solutions include both water level variations and draft variations. The draft variations are as a result of long term changes such as loading (fuel and stores consumption, ballast tank trim adjustments etc..) and most significantly hydrodynamic effects due to driving a displacement hull through the water. Field trials using ellipsoid height solutions (these figures) indicate that the vessel squats down an extra 30cm at speeds of 14 knots. As much of the ArcticNet operations involve transit and then sitting on station, this effect must be accounted for.

EGM96 – Gradient Map

The ellipsoid-geoid separation surface is generally most reliable in areas of low slope. Estimates of sea-surface topography are most likely to be compromised in areas of rapid geoid undulations. The most notable regions in Canada lie along the east side of Baffin Island and along the Labrador margin (where the Makkovik survey (right-most data set) took place).





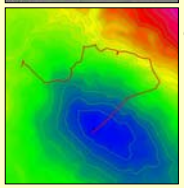


NorthWest Passage Transit : ArcticNet Leg-9

A comparison of geoid height observations against WebTide tidal predictions.

CCGS Amundsen Shiptrack, July/August 2004

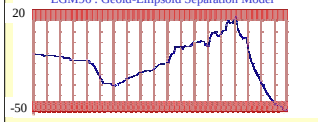
Passing through all three of the WebTide model zones



EGM 96 :
Geoid Ellipsoid Separation

5m contours

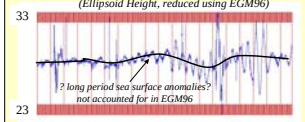
EGM96 : Geoid-Ellipsoid Separation Model



C-Nav WADGPS – Antenna Ellipsoid Height

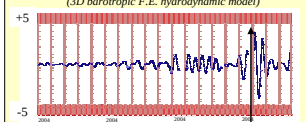
C-Nav AntennaGeoid Height

(Ellipsoid Height, reduced using EGM96)



WebTide Predictions

(3D barotropic F.E. hydrodynamic model)

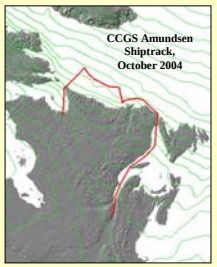


Arctic8 Model
M2-S2-N2-K1-O1

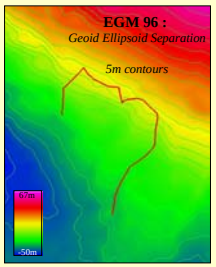
Hudson Bay Model
M2-S2-N2-K1-O1- M4-MS4

Labrador Sea Transit - Ungava Bay to Quebec City

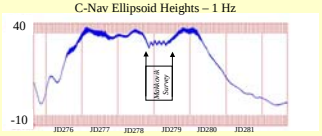
A comparison of geoid height observations against WebTide tidal predictions in an area of particularly steep geoid-ellipsoid slopes..



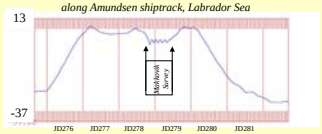
CCGS Amundsen Shiptrack, October 2004



C-Nav Ellipsoid Heights – 1 Hz



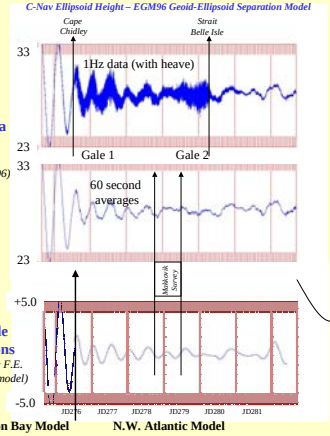
EGM96 – predictive model of Ellipsoid-Geoid Separation
along Amundsen shiptrack, Labrador Sea



C-Nav Ellipsoid Height – EGM96 Geoid-Ellipsoid Separation Model

C-Nav Antenna Geoid Height

(Ellipsoid Height, Reduced using EGM96)



WebTide Predictions

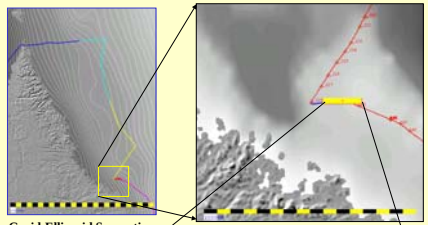
(3D barotropic F.E. hydrodynamic model)

Hudson Bay Model
M2-S2-N2-K1-O1- M4-MS4

N.W. Atlantic Model
M2-S2-N2-K1-O1

Makkovik Bank EM300 Bathymetric Survey

Steaming up and down the geoid-ellipsoid slope on the edge of Labrador margin. A practical application of the use of C-Nav ellipsoid heights as a means of reducing a hydrographic survey. .



Geoid-Ellipsoid Separation
(EGM96, 1m contours)

The survey consisted of 9 E-W parallel lines, each around 25 km long, lasting 60-70 minutes, depending on speed