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An Integrated Bathymetric and Topographic Digital Terrain Model of the Canadian Arctic Archipelago

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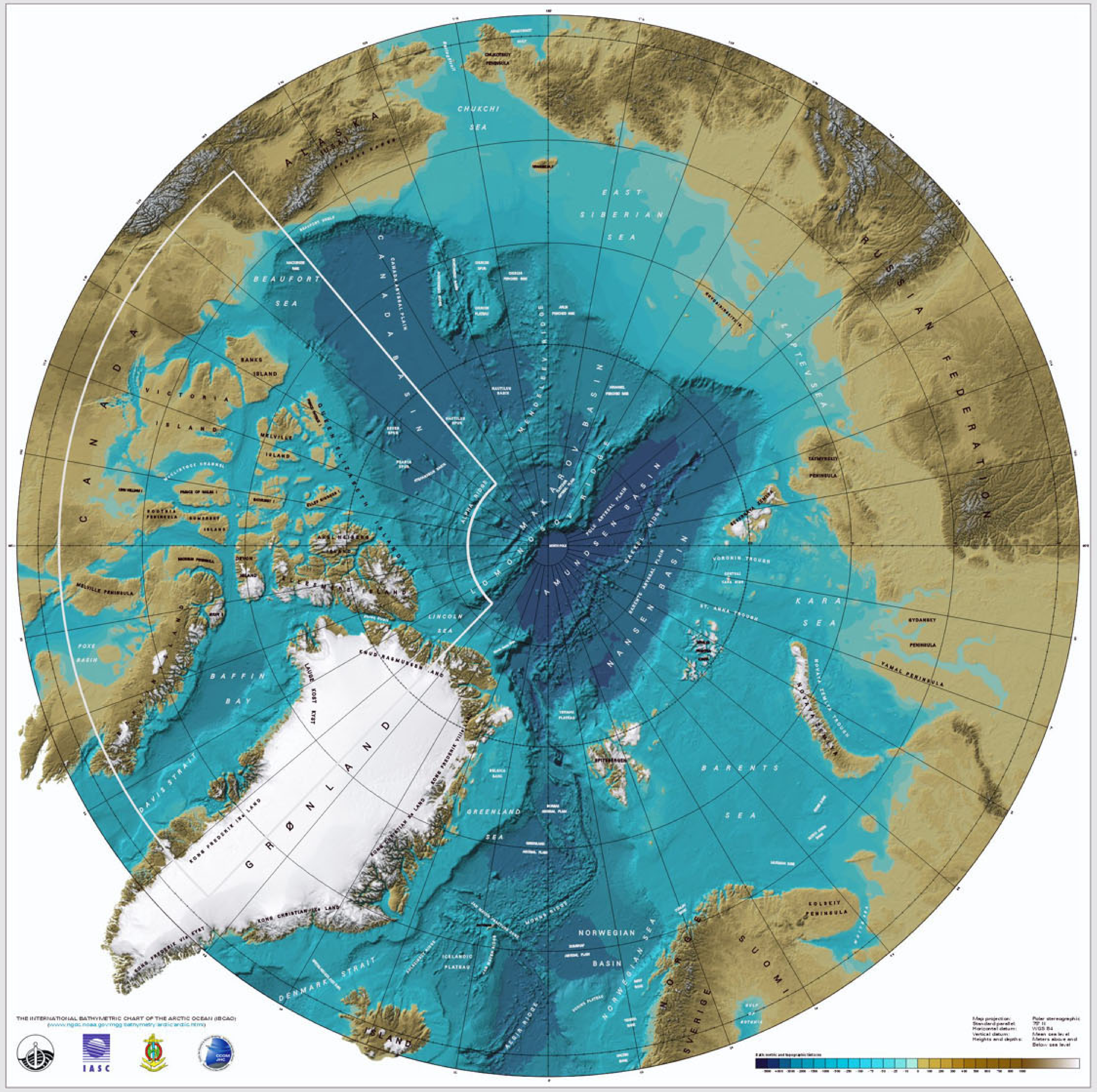

Figure 1. The Arctic Ocean and its shallow marginal seas. The bathymetry is portrayed from the International Bathymetric Chart of the Arctic Ocean (IBCAO) [Jakobsson et al., 2000]. The region shown in Figures 2 and 3 is outlined with a light gray line.

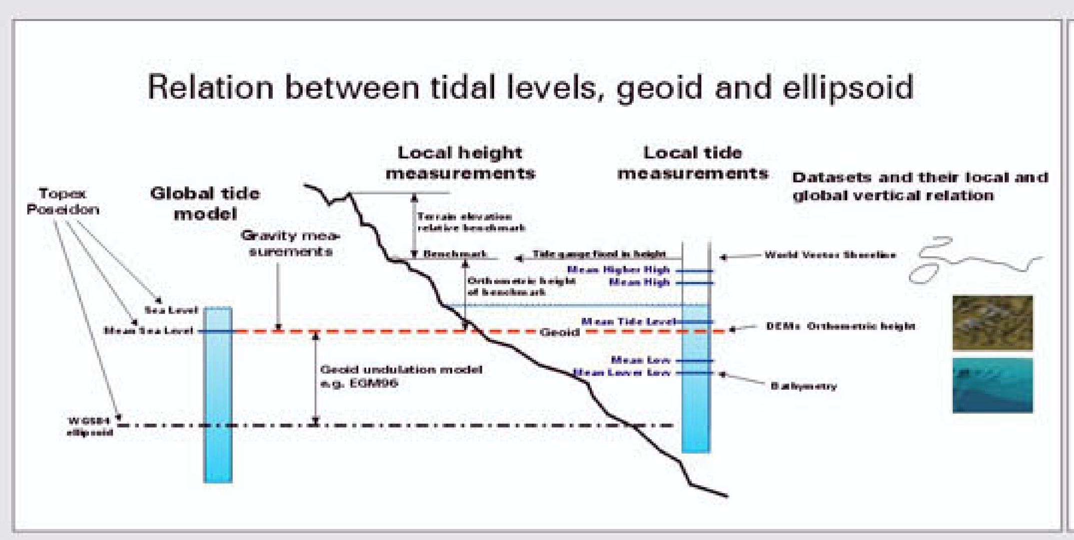

Figure 2. Vertical and tidal datums. Local tide levels and their relation to global Mean Sea Level, the geoid, and the surface of the ellipsoid (WGS84).

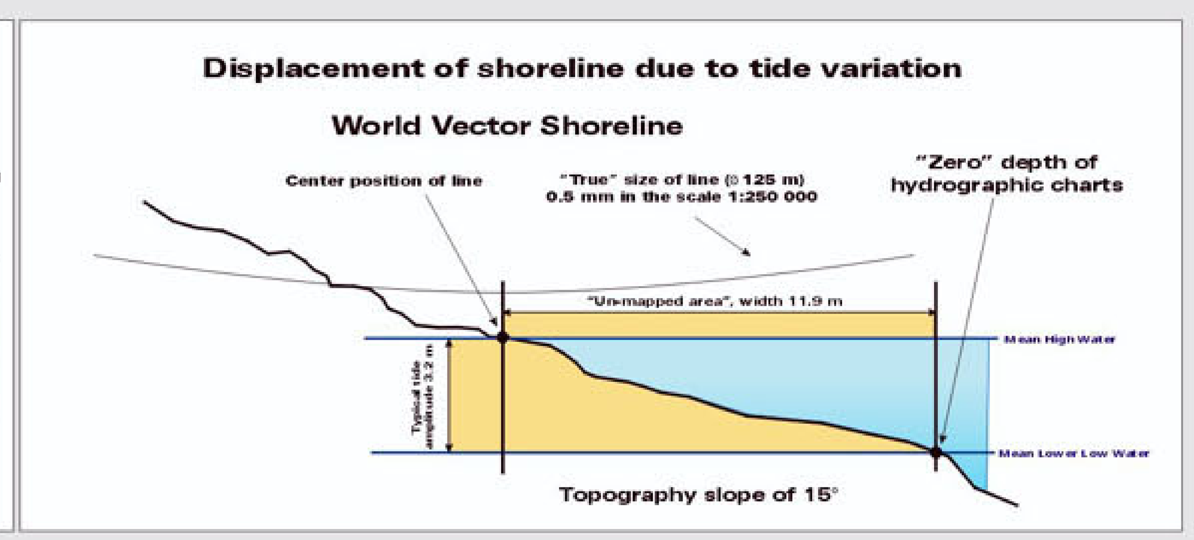

Figure 3. Shore displacement when seen from World Vector Shoreline and hydrographic chart's Mean Lower Low Water.

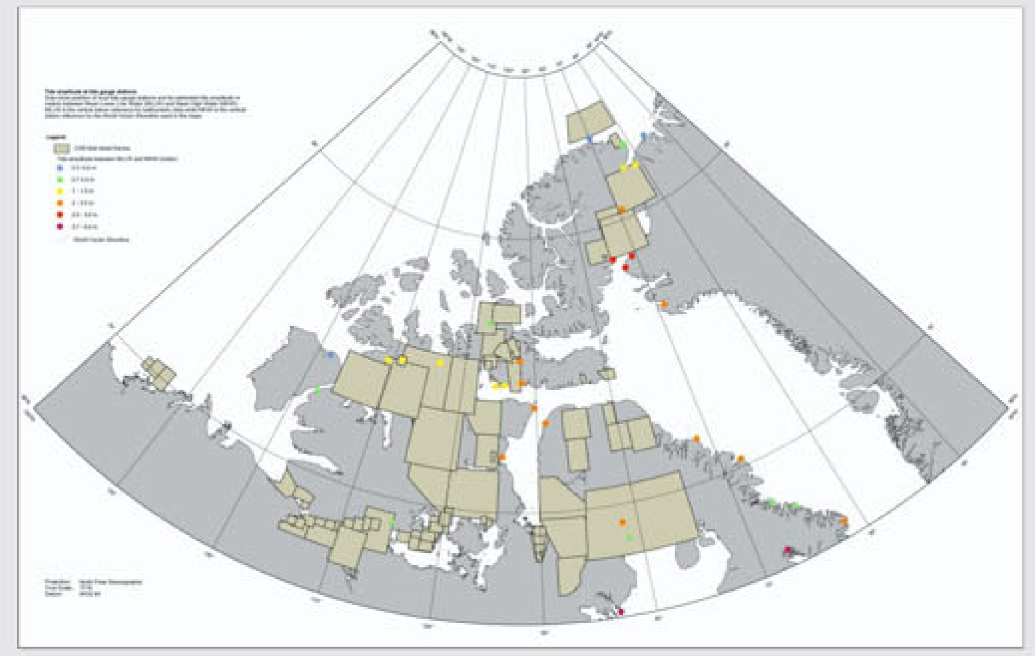

Figure 4. Extent of digitized Canadian Hydrographic Survey's (CHS) field sheets to be used in order to improve the IBCAO model. Data density varies in between the individual field sheets. Colored dots show amplitude of local tide at selected tide stations. The color indicates the amplitude between Mean Lower Low Water (MLLW) and Mean High Water (MHW) in meters.

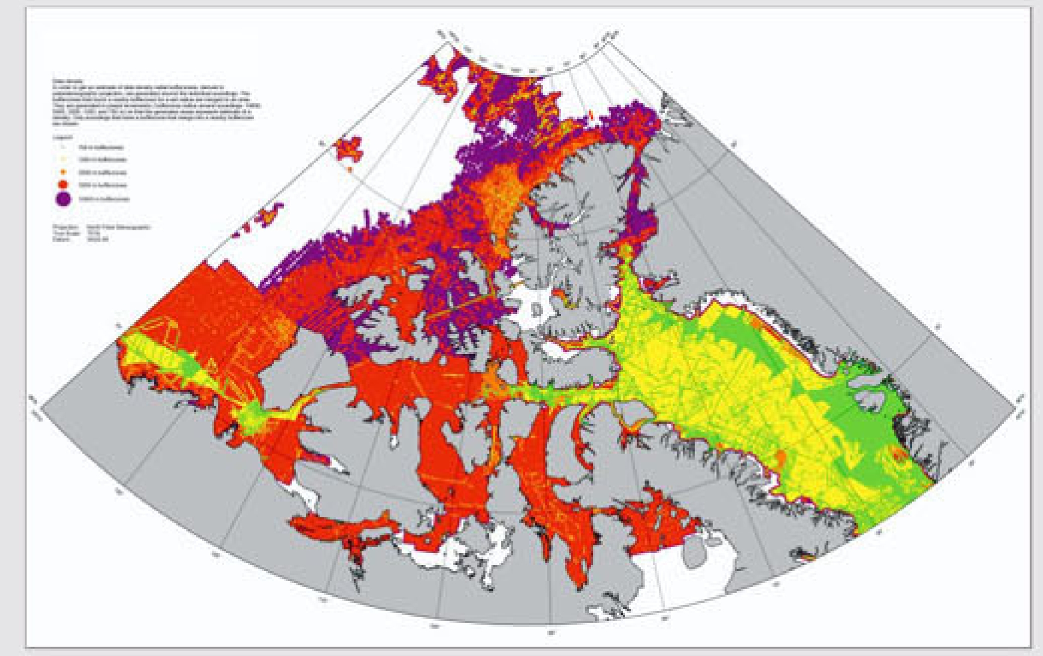

Figure 5. Distribution and density of data (except contours and soundings from nuclear submarines) used for the construction of IBCAO. The applied color scheme represents data density (See map legend for a description).

Introduction

Currently, the International Bathymetric Chart of the Arctic Ocean (IBCAO) [Jakobsson et al., 2000, EOS] contains the most up-to-date digital bathymetric model covering the entire Canadian Arctic Archipelago (Figure 1). IBCAO is a seamless bathymetric/topographic Digital Terrain Model (DTM) that incorporates three primary data sets: (1) all available bathymetric data at the time of compilation; (2) the US Geological Survey GTOPO30 topographic data; and (3) the World Vector Shoreline for coastline representation. The horizontal grid cell size is 2.5 x 2.5 km on a Polar Stereographic projection, which is adequate for regional visualization and analysis, but which may not be sufficient for certain geoscientific and oceanographic applications. However, in some areas the database that was constructed during the IBCAO project holds bathymetric data dense enough to justify a compilation with much higher resolution than 2.5 x 2.5 km. This is the case for some areas of the Canadian Arctic Archipelago, where the Canadian Hydrographic Service (CHS) has carried out hydrographic surveys for many years (Figure 5, IBCAO data density map). In addition, CHS has recently provided data from digitized field sheets with higher density than previously available for the IBCAO compilers (Figure 4). This project aims to improve the IBCAO model in the portions of the Canadian Arctic Archipelago where the available data is dense enough, and to improve the IBCAO database by incorporation of metadata describing the data from the CHS hydrographic surveys.

Requirements for the construction of an integrated bathymetric and topographic DTM

The construction of a seamless high-resolution bathymetry/topography DTM requires a consideration of the vertical datums that the land elevations and ocean depths are referred to. [e.g. Gesh and Wilson, 2002, Marine Techonolgy]. Bathymetry is commonly referred to a local tidal datum (e.g. Mean Lower Low Water: MLLW), whereas land elevations are described as orthometric heights (elevations above Mean Sea Level). To reduce these data sets to a common reference frame, a tidal model and information about the geoid are needed, as well as the land benchmarks to which the local tidal datums have been referred (see illustration in Figure 2). To be able to do all corrections an "ideal" list of metadata parameters was set up (Table 1). Some of this information exists in the CHS´s archive, but with legacy data sets, the metadata might not be readily available, or crucial pieces of information might be missing. CHS has recently extracted metadata for some of the bathymetric sounding data sets from their field sheets used in the IBCAO compilation. For a large part of the CHS legacy data, some of the key metadata is difficult to recover, imposing an obstacle to the full process of compiling an integrated bathymetric and topographic DTM. However, the corrections that need to be applied to the individual data sets in terms of vertical adjustments are in some cases very small, and where the spatial data density is sparse, their application might not be justifiable, especially taking an overview presentation scale (e.g. 1:250 000) into account (Figure 3). In addition, there might also be a risk of inserting new uncertainties into the data by applying corrections based on poorly constrained models. For example, this would be the case if an inappropriate tidal model were used in the vertical datum correction process. These issues have raised the following questions in our project:

What are the magnitudes of the parameters for bringing bathymetric and topographic data to a common vertical datum in the Canadian Arctic Archipelago?

Is it possible to determine a threshold value for the horizontal grid resolution where vertical datum corrections become an issue?

To answer these questions, we have assembled information about tidal amplitudes in the Canadian Arctic Archipelago (Figure 4). In addition, we have looked into the IBCAO contributing data sets, their assumed vertical datums, uncertainties, and resolutions (e.g. see the case for World Vector Shoreline in Figure 3). In summary, we conclude that it is not possible to pursue the vertical datum correction to its full extent in this region, on account of the absence of a suitable tidal model, the uncertainties and relatively poor resolutions of the data, and missing metadata. However, the newly available data from CHS make it possible to vastly improve some areas of IBCAO (see example: Figure 7, 8A, 8B ,and 8C). We are currently awaiting the release of topographic data over Canada in the scale 1:250,000, which we will use for improving the topography portrayal in IBCAO. Furthermore, we have improved the IBCAO database with metadata for the newly included CHS data. For example, this will be used in order to get information about the horizontal datum for the individual field sheets, information that during the compilation of IBCAO not was available. The amount of applied horizontal shift from NAD27 to NAD83 is illustrated for different parts of the Canadian Arctic Archipelago (Figure 6).

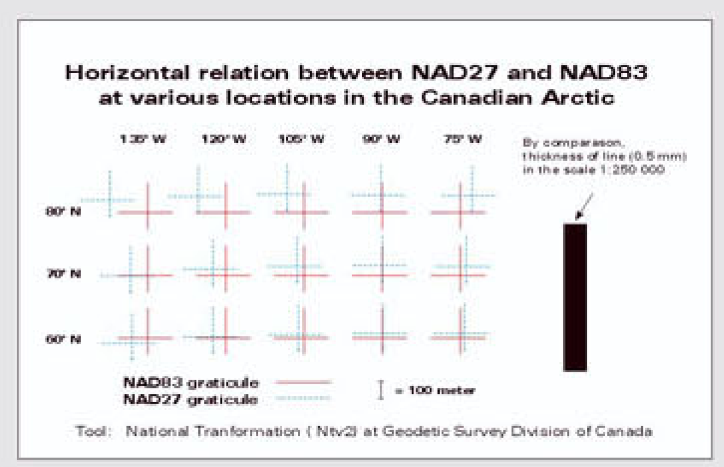

Figure 6. The horizontal shift applied to the legacy datasets that according to metadata were referenced to the NAD27 horizontal datum. WGS84 is to be used as the common reference but the difference between NAD83 and WGS84(G873) is in this context negligible.

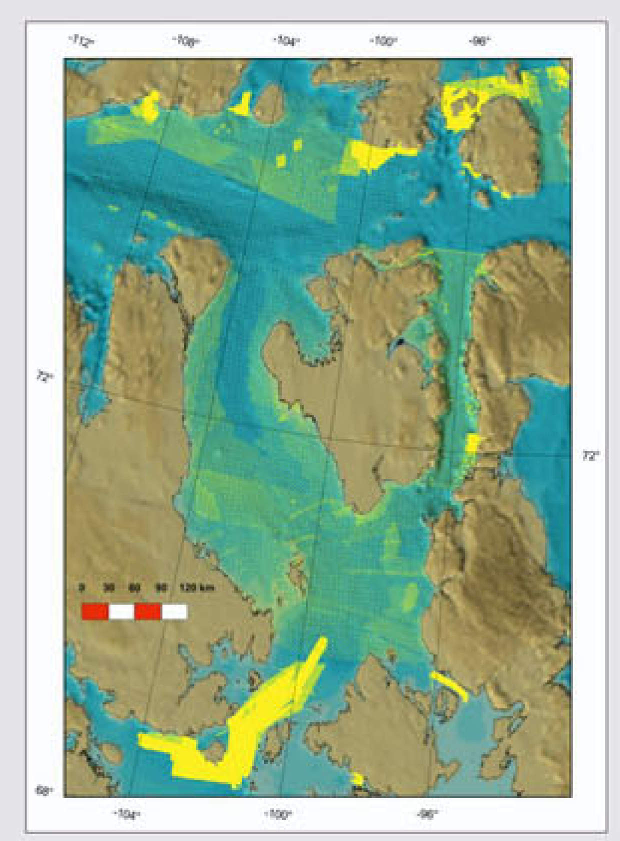

Figure 7. Example of an area from the Canadian Arctic Archipelago where the newly included CHS data contributes with higher density than previously available for IBCAO. The bathymetry of this area has been gridded and the result is rendered in Figure 8A, 8B and 8C.

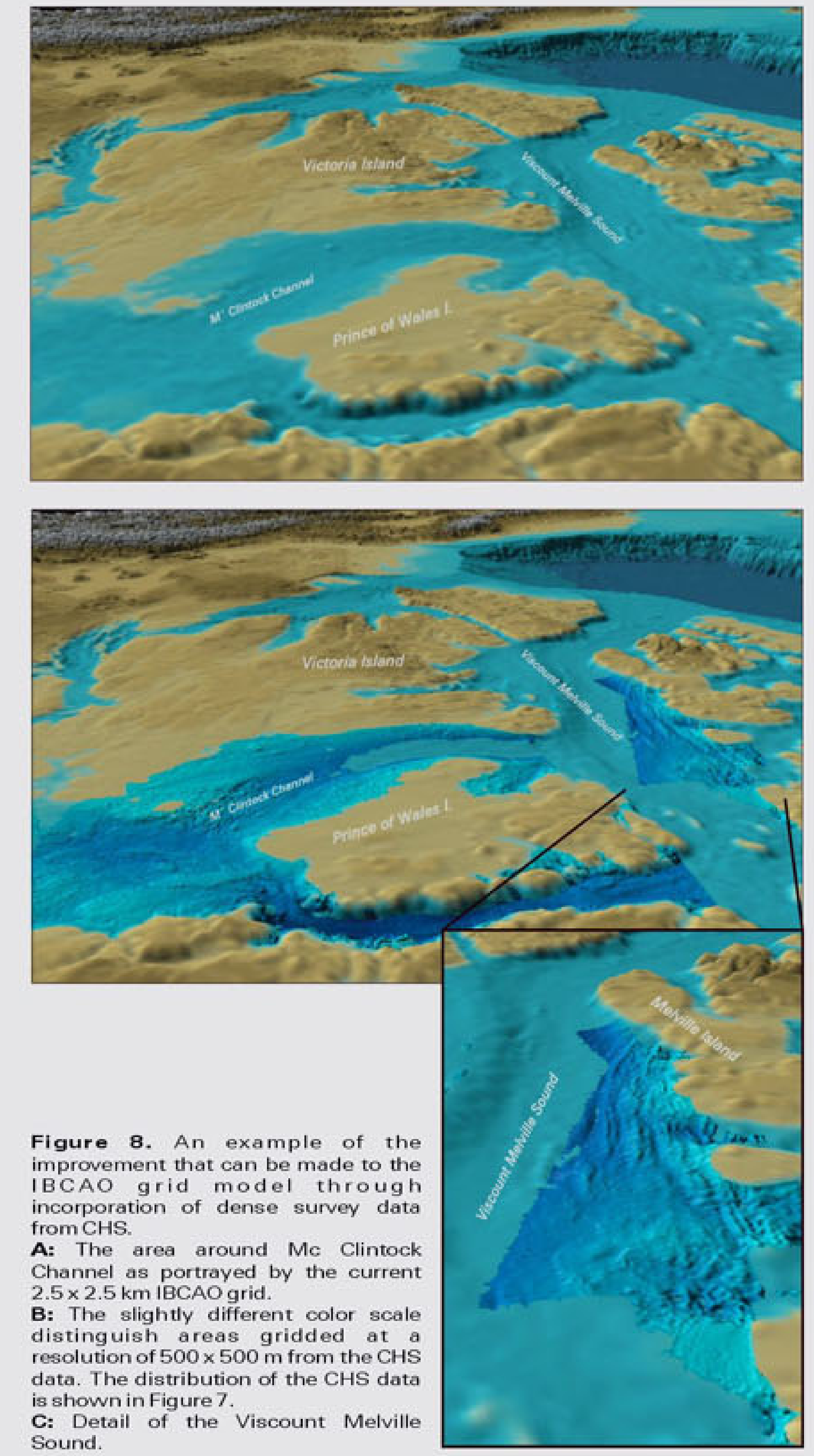

Figure 8. An example of the improvement that can be made to the IBCAO grid model through incorporation of dense survey data from CHS.
A: The area around Mc Clintock Channel as portrayed by the current 2.5 x 2.5 km IBCAO grid.
B: The slightly different color scale distinguish areas gridded at a resolution of 500 x 500 m from the CHS data. The distribution of the CHS data is shown in Figure 7.
C: Detail of the Viscount Melville Sound.

Sea mission		Land mission	
	Survey ID (Fair sheet) Location and time frame Ship Chief hydrographer		Mission ID Location and time frame Method, instrument ...
Local tide measurements	Tide gauge location (X,Y) Time, duration, resolution Benchmark ID Benchmark location (X,Y)	Gravity measurements	Time frame Instrument/Method Units Accuracy
Regional tide measurements	Tide gauge location (X,Y) Time, duration, resolution Benchmark ID Benchmark location (X,Y)	Geoid measurements	Time frame Model Units Accuracy
Soundings	Bathymetric system Through sea ice (yes/No) Vertical datum (MWL, MLLW, ...) Units (feet, fathoms, meters) Accuracy Rounding, truncation	Navigational system	Navigational equipment Horizontal datum Units Accuracy
Navigational system	Navigational equipment Horizontal datum Units Accuracy	Elevation data	Coverage Time Vertical datum Units Accuracy
Map sheet info	Digital/Analog Digitizing method (tablet, OCR ...)	Isostatic considerations	Model type Rate of uplift, tilting
Isostatic considerations	Model type Rate of uplift, tilting		

Table 1. The "ideal metadata list". Ideally, these parameters should build up the metadata to enable all possible conversions and quality estimations.