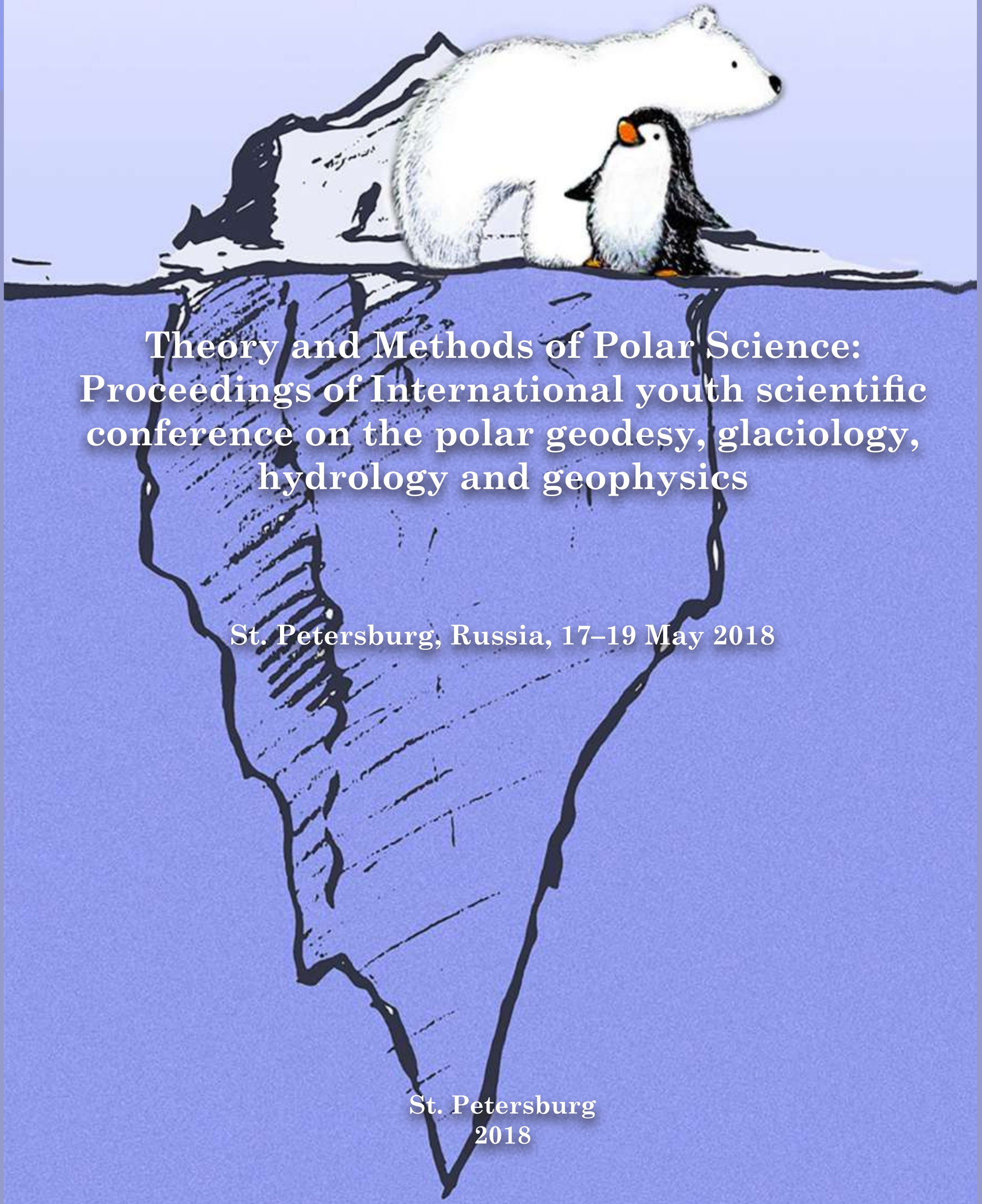

Theory and Methods of Polar Science: Proceedings of International youth scientific conference on the polar geodesy, glaciology, hydrology and geophysics

St. Petersburg, Russia, 17–19 May 2018

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This digest contains the papers presented at the International Youth Scientific Conference on the polar geodesy, glaciology, hydrology and geophysics. The common aspects of the scientific investigations in Arctic, Antarctic and mountain glaciers were discussed. The papers are recommended for a wide range of scientists and students interested in the Earth Sciences. The digest was published with the financial support of the RFBR within the framework of the project No. 18-35-10006.

ARTIFACTS IN THE ARCTIC DIGITAL BATHYMETRY MODELS

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ABSTRACT

Several types of artifacts have been identified in digital bathymetry models which represent shape of the Arctic seafloor. This work presents the classification of the types of artifacts encountered in several versions of bathymetry grids such as IBCAO, GEBCO grid, SRTM30_Plus and Global Topography. All of the above-listed products are publicly available through the internet. The artifacts observed could mislead geological interpretations; therefore it is necessary to emphasize the limitations of the portrayal of the seabed by digital bathymetry models. Any digital bathymetry model is a compilation of various data sources with different accuracies, resolution and distribution. Artifacts in the bathymetry grids are characterized by presence and distribution of the source data. They can be caused by systematic errors in the source data, differences in source data horizontal resolution, by the lack of source data, by gridding algorithm and interpolation method (e.g. filling data gaps with gravity, spline interpolation). The encountered artifacts were classified according to the sounding source data types which characterize them. These include: multibeam surveys, singlebeam surveys, single spot sounding, depth contours digitized from contour maps, “patching” different data sources, coastline dataset used for gridding, as well as the lack of any data. The observed artificial “morphology” in bathymetry grids include small and large scale artificial features: ridges and troughs, peak-like or pit-like features, flat areas, deeps and rises, artificial steps, terracing on slopes and negative depth values on land.

Keywords: artifact, digital bathymetry model, IBCAO, GEBCO, Arctic

INTRODUCTION

The release of global (e.g. GEBCO [13], SRTM30_Plus [2], Global Topography and regional compilations (e.g. IBCAO [6]) improved our understanding in the most of earth processes, since bathymetry serves as the base map for any geological, geophysical, environmental or oceanographic investigation. Beyond fundamental research bathymetric applications vary from navigation purposes to studies of coastal erosion and environmental issues. The off-shore continental shelf bathymetry is of particular interest to coastal states’ resource sovereignty, exploration for natural resources, submarine cable planning, habitat mapping, fisheries management, predicting landslides and modeling tsunami impact [1]. Nowadays there is a drastic increase in the number of applications of digital bathymetry and not only for the scientific purposes. Ever since the release of such exploratory tool as Ocean layer in Google Earth, basically anyone can explore and interpret marine environments and the shape of the ocean floor.

Meanwhile even in the current bathymetric era of high resolution and accuracy multibeam echo sounding and global remote sensing technologies (satellite radar missions), global and regional DBMs of the ocean floor provide limited representation of the shape of the seafloor. Especially such remote and ice-covered areas as the Arctic lack detailed accurate data coverage. Only ~11% of the IBCAO bathymetry model, the most authoritative representation of the Arctic seafloor, is based on multibeam surveys while the remaining ~90% of the Arctic seabed are characterized by single beam soundings from national hydrographic archives, historic point soundings from ice camps and hydrographic charts and in many areas on digitized contours from paper charts [6]. The resolution of digital bathymetry models is defined by the resolution of underlying bathymetric data, which has very sparse density and irregular distribution of source data of various resolutions, which is too inadequate for many marine applications [7]. These data limitations leave the question of accuracy and quality of the DBMs [1].

Artifacts are widely known and common in DBMs. Practically any publication on marine application of DBM mentions artifacts in the models. For many applications the absolute accuracy of the model is not as important as the consistency in the relative change of values. Any operation on the neighborhood values such as aspect, slope and other local derivatives will be affected by the inconsistencies (or artifacts) in the surface [3, 7]. The DBMs are very prone to errors for the reasons of large data gaps that has to be filled by interpolation and wide range of data accuracies [4, 8]. Construction approach of DBMs can be opposed to terrain modeling methods which are often locally adaptive to important landscape features such as ridges and stream lines [14]. One of the main applications of terrain modeling includes hydrological analyses; therefore modeling of land topography is produced on the elements that are hydrologically important. The fact that the surface drains water down the slope provides information to adopt gridding to the directions of the flow, and at the same time serves as a powerful tool for detecting artificial features, such as sinks (pits or depressions) [15]. In the bathymetry world (at least for global products), there has been no attempt yet to constrain gridding by geomorphologic information, which is one of the reasons for distinct artifacts in the bathymetry surface.

All the working groups involved in digital bathymetric modelling examine optimal gridding methods which minimize artifacts caused by interpolation on large data gaps [11, 12, 4, 6]. There is a great number of studies on elimination of artifacts specific to particular data acquisition sensors, e.g. multibeam sonars [5, 8]. Smith addressed the main problems of gridding bathymetry from contour data and errors in DBMs created by systematic errors in singlebeam data. Marks and Smith addressed errors in six publicly available global bathymetry compilations, such as some interpolation artifacts (terracing effect, visible tracklines in the bathymetry, edge matching) and misregistration errors. Meanwhile there is no recent systematic overview of the types of artifacts that can be encountered in the global and regional digital bathymetry compilations.

This work presents classification of the artifacts encountered in current and previous versions of regional and global digital bathymetric models, which provide the Arctic coverage. The analyzed grids include: regional grid IBCAO and global DBMs SRTM30_Plus, Global Topography and GEBCO_08. Illustrated artifacts originate from different versions of these models. We present typical artifacts caused by the data of particular type (singlebeam, multibeam, single soundings, contours), the interpolation method (e.g. filling data gaps with predicted bathymetry), or gridding algorithm used. In the DBMs which use predicted bathymetry (such as Global Topography, GEBCO and SRTM30_Plus) the artifacts are more emphasized due to the gridding algorithm used: the original measured depths are restored into predicted bathymetry surface with smooth transition using spline in tension algorithm [2, 12]. At the same time IBCAO shows more smooth appearance due to improved gridding algorithm, so-called stacked spline method, which yields preserving bathymetric detains of high-resolution data and suppressing the single trackline artifacts [4].

Three regions were chosen for visual inspection for the presence of artifacts in order to cover all types of source data. The types of source data correlate mostly with different morphologic provinces. The following regions were chosen:

Region 1: Shelf area — mainly singlebeam soundings and historic single soundings; correlation of gravity with bathymetry is poor because of assumed crustal density and sediment thickness;

Region 2: Abyssal plain — singlebeam soundings and multibeam coverage; correlation of gravity with bathymetry is poor because of the great sediment thickness;

Region 3: Mid-oceanic ridge — multibeam combined with singlebeam and hydrographic soundings; correlation of gravity with bathymetry is good because sediment thickness is low (depending on the local geologic conditions).

The types of artifacts encountered are classified according to the nature of the source data types which characterize them. The classification table and description of the artifacts' "morphology" is given in Table 1.

Table 1. Classification table of types of artifacts encountered in the DBMs, classification is given according to the source data types which characterize them.

Source data type	"Morphology" of an artifact
multibeam and other swath data (Fig. 2, Prof.1)	artificial high frequency peak-like features in the bathymetry
singlebeam (Fig. 2, Prof. 2,3,4)	linear artifacts such as artificial «ridges» and «troughs» or point features like those caused by single soundings
single soundings (Fig. 4)	artificial peak-like («bumps») or pit-like («holes») features
contours (Fig. 3)	terracing on slopes, or artificial features where contours don't agree with surrounding soundings
interpolation artifacts in the areas with large data gaps (Fig. 5)	flat areas, artificial deeps
no sounding data in predicted bathymetry (Fig. 1)	artificial deeps and rises in the areas where there is no correlation between bathymetry and gravity
edge artifacts — patching several data sources (Fig. 2, Prof. 1)	artificial steps
coastline dataset	negative depth values on land, artificial islands

CONCLUSION

This work presents classification of the artifacts encountered in current and previous versions of regional and global digital bathymetric

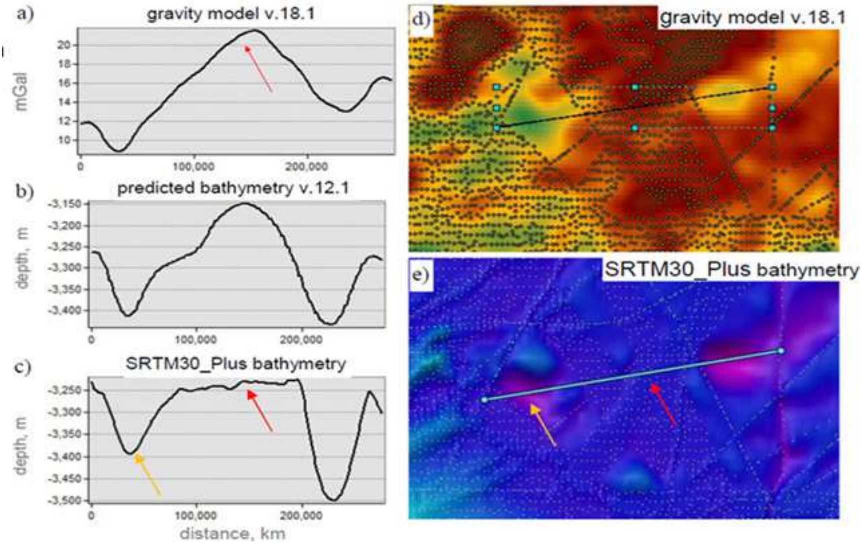

Figure 1. Explains artificial deeps in the SRTM30_Plus (ver. 6.0) bathymetry, in the areas where no correlation between bathymetry and gravity is observed (abyssal plain with high sediment thickness). The dots on the maps (d, e) show the sounding source trackline coverage used for construction of SRTM30_Plus. As discussed in [12], the gravity (a) is scaled by correlation coefficient to the predicted depths (b), and then the measured depths are "polished" to the predicted bathymetry grid to create the final bathymetry grid (c). As can be seen from the profiles, the bathymetry is taken from scaled gravity in the area with no sounding coverage (yellow arrow). Although when gravity and bathymetry profiles are compared in the area where the source sounding data is present (red arrow), there is no observed correlation between them.

models, which provide Arctic coverage. The DBMs include: IBCAO, SRTM30_Plus, Global Topography and GEBCO_08 grids. We present typical artifacts caused by the data of particular type (singlebeam, multibeam, single soundings, contours), the interpolation method (e.g. filling data gaps with predicted bathymetry), or gridding algorithm used. Since the artifacts coincide with the source data coverage used for construction of the grids one of the methods to identify an artifact is to look at source trackline information (e.g. SID). The types of source data correlate mostly with different morphologic provinces, therefore somewhat artifacts also have this correlation. Any DBM is prone to have artifacts, but depending on gridding algorithm they will stand out more or less — e.g. IBCAO bathymetry shows more smooth appearance due to improved gridding algorithm, while datasets which include

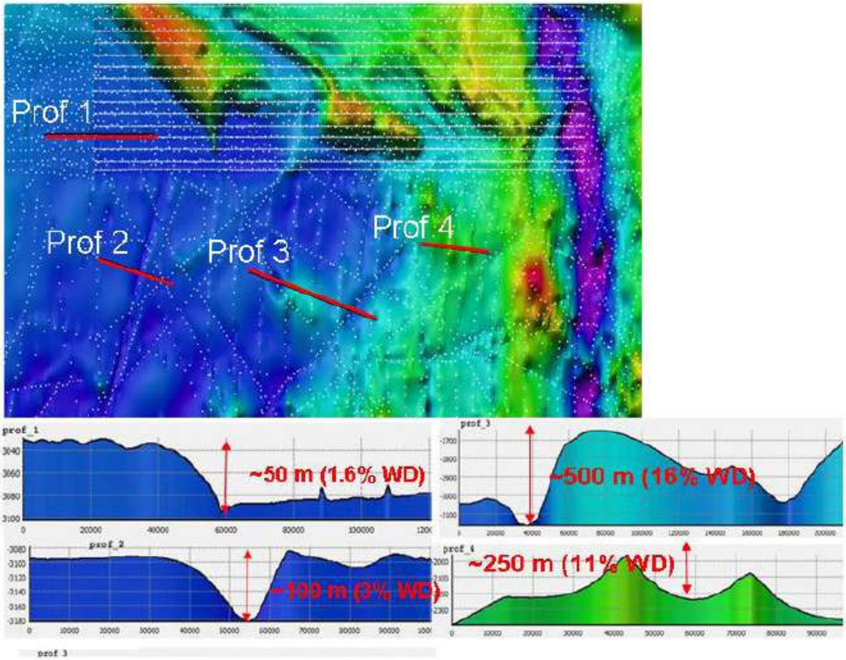

Figure 2. Global Topography bathymetry (ver.13.1) in the mid-oceanic ridge area overlain by source tracklines (white dots) from the Source Identifier file (SID). Artifacts observed: Profile 1: artificial step in bathymetry (patching different data sources), high freq. peak-like features (multibeam); Profile 2,3,4: artificial ridges and troughs (singlebeam). Rainbow depth color scale: from 1200 m (red) — 3600 m (purple). Vertical exaggeration is used.

predicted bathymetry will have more emphasized artifacts. The scale of artifacts varies: from artifacts that can be neglected in deep water areas — to the most pronounced artifacts with the amplitude up to 50% of water depth observed on shelf in DBMs which utilize predicted bathymetry.

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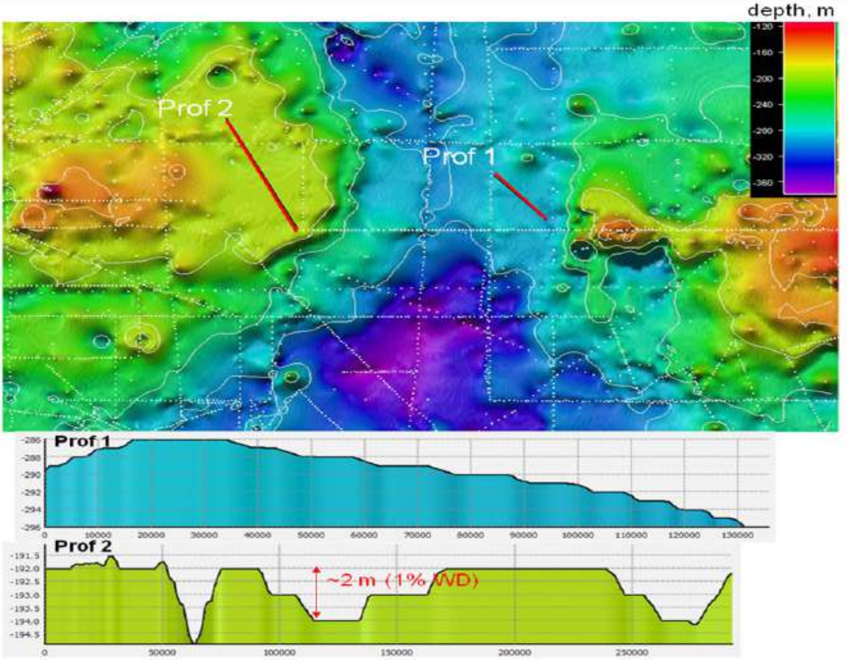

Figure 3: GEBCO_08 bathymetry (ver. 20091120) in shelf area overlain by source tracklines and contours. Artifacts observed: terracing on slopes due to using contours for interpolation. Rainbow depth color scale: from 120 m (red) — 360 m (purple). Vertical exaggeration is used.

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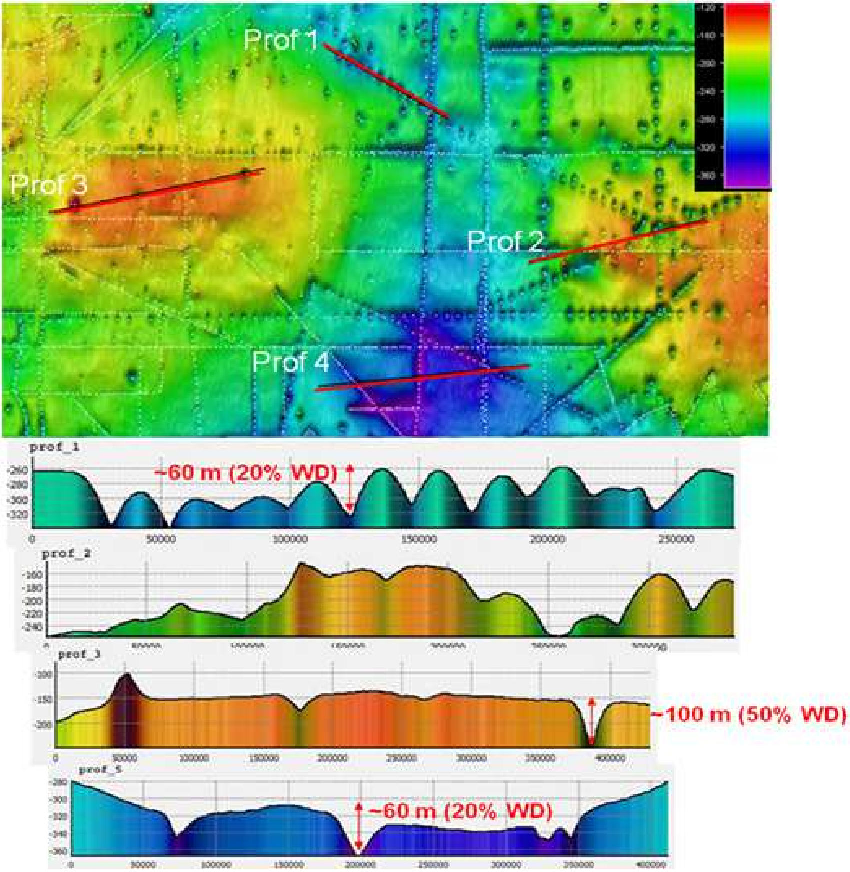

Figure 4: Global Topography bathymetry (ver.13.1) in shelf area overlain by source tracklines. Artifacts observed: artificial “bumps”, “holes” and “troughs” caused by singlebeam, historical single soundings and interpolation with predicted from gravity bathymetry. Rainbow depth color scale: from 120 m (red) — 360 m (purple). Vertical exaggeration is used.

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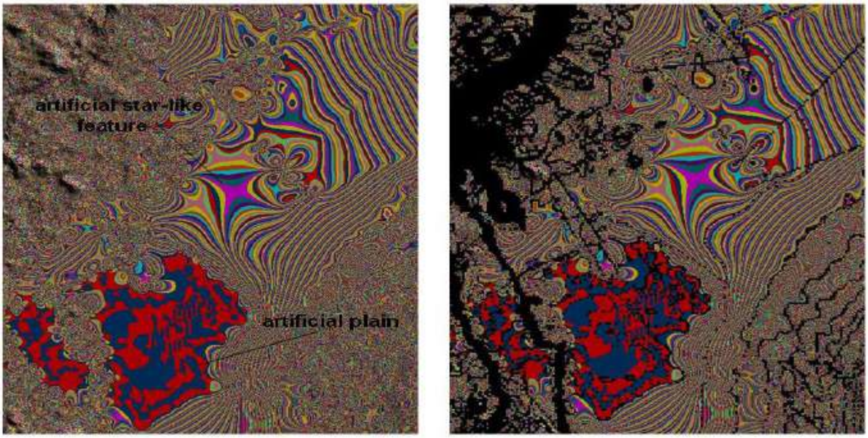

Figure 5: (left) IBCAO (ver. 3.0) bathymetry in the region of Gakkel ridge, unique values color scheme is used (individual color is assigned to each depth value) in order to highlight artifacts. Artifacts observed: artificial plain (red-blue feature), artificial star-like feature caused by lack of data in the area, as well as other artificial funny-shaped features; (right) same as (left) with ship trackline coverage and contours shown in black.

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