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OAML Feathering Algorithm Overview

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14. ABSTRACT The Naval Oceanographic Office (NAVOCEANO) is developing a new version of its Digital Bathymetric Data Base - Variable Resolution (DBDB-V) data product that will include the Oceanographic and Atmospheric Master Library (OAML) Feathering Algorithm. As a crucial source of historical bathymetry for models and tactical decision aids, DBDB-V is a collection of individual grids with varying resolutions that together provide global ocean floor depth values in a tiled database format. Since DBDB-V consists of grids that have been developed independently over a long period of time, it may be based on input data of significantly varying quantity and quality. When data are extracted across grids of different resolutions, artifacts often occur at the grid boundaries that have a negative visual impact and varying degrees of impact on environmental models. The OAML Feathering Algorithm has been developed to alleviate these artificial bathymetric discontinuities while new variable resolution grid structures are considered as replacements to DBDB-V's rectangular grid structure. In this report, the details of the algorithm's integration into DBDB-V are documented along with specific test cases from DBDB-V version 4.1 level 0 data.					
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OAML FEATHERING ALGORITHM OVERVIEW

INTRODUCTION

The OAML Feathering Algorithm is an enhancement that will be included in the next release of the Naval Oceanographic Office's (NAVOCEANO) Digital Bathymetric Data Base – Variable Resolution (DBDB-V) product [1]. DBDB-V consists of a 5-min-resolution dataset with global coverage and higher resolution datasets with limited coverage at various locations of the Earth's oceans. The OAML Feathering Algorithm is designed to reduce the artifacts that occur at the resolution boundaries in DBDB-V. This report addresses the motivation behind the development of the OAML Feathering Algorithm as well as the implementation and integration of the algorithm in the DBDB-V application programmer's interface (API).

THE PROBLEM

When data are extracted across resolution boundaries in DBDB-V, the data retrieval mixes data from different spatial frequencies, different sources, and different averaging schemes (binning). Because the existing DBDB-V access API does not account for these differences, the resulting data have artificial bathymetric discontinuities that have a negative visual impact (see Fig. 1) and a variable degree of impact on models.

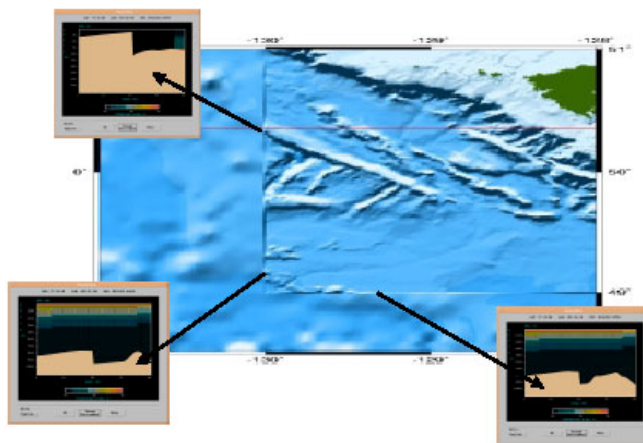


Fig. 1 — Artificial discontinuity between DBDB-V resolutions

The DBDB-V database is a collection of individual grids of differing areal extent and grid resolution. Grids were developed independently over a long period of time and consequently may be based on input data of significantly varying quantity and quality. For the most part, the grid resolutions chosen reflect the maximum resolution obtainable based on the input data available and, hence, reasonably reflect the spatial frequency content of the underlying survey data. More recent grids are generally of higher resolution,

reflecting superior input data coverage and quality. Quality differences arise from improvements in such areas as navigation accuracy, sonar systems, and data processing techniques.

Data extractions from DBDB-V may, therefore, span grids with different grid intervals. When this occurs, there is the potential for a mismatch at the boundary. Differences at the boundaries can result from either or both of the following reasons:

- 1) The finer the grid interval, the higher the spatial frequencies that can be resolved. Hence, if a coarse and a fine grid abut and if the bathymetric field being modeled contains spatial frequencies higher than can be resolved by the coarser grid, discontinuities will occur at the boundary.
- 2) Grids may differ due to differences in the quantity and/or quality of the data that were available when they were created.

Regardless of the origin of these artifacts, it is desirable to mitigate their effect. Ideally, one might choose a global solution such as implementing a true variable-grid storage structure. A more expedient solution would be to include a feathering algorithm within the extraction software.

Long-Term Solution

A long-term solution to the discontinuity in DBDB-V datasets is to change DBDB-V from a regularly spaced, rectangular grid structure to an irregularly spaced grid structure, such as a triangulated irregular network (TIN). The TIN structure would allow processed survey data to be stored in one topological grid structure at its actual location as recorded by the survey vessel. Another benefit is that data from different projections can be stored in the same structure because of the irregular spacing allowed by TINs. The TIN structure would flatten DBDB-V's complex collection of rectangular grids to one global grid that is both extendable and precise. Since the TIN structure would not require processing to fit the structure of a regularly spaced grid, distortion errors due to interpolation and averaging are eliminated from the data product. Other adaptive grid structures, such as curvilinear grids, should also be considered as an alternative to DBDB-V's current grid system.

Short-Term Solution

As a short-term solution, a feathering algorithm can be included in the DBDB-V access API that will merge the data across resolution boundaries to reduce the grid discontinuities. The OAML Feathering Algorithm working group has proposed a two-dimensional, minimum-curvature interpolator that will be included in the next release of the DBDB-V software to diminish the artifacts in data extracted across resolution boundaries.

THE OAML FEATHERING ALGORITHM

The OAML Feathering Algorithm is a two-dimensional interpolation routine that will provide both a feathering capability and a new interpolation option for DBDB-V. This interpolation option will replace the bicubic spline interpolation routine used in previous releases of the DBDB-V APIs.

Minimum Curvature Spline Interpolator

The OAML Feathering Algorithm is implemented by a C function called "zgrid" that is from the MBSYSTEM source code. MBSYSTEM is an open-source software package for the processing and display of bathymetry and backscatter imagery data [2] and is freely available from <http://www.mbari.org/data/mbsystem/default.html>. MBSYSTEM is developed by the Monterey Bay Aquarium Research Institute and the Lamont-Doherty Earth Observatory of Columbia University. The capabilities of the "zgrid" function are best summarized by the header comments in the source code file:

This is a function to generate thin plate spline interpolation of a data field. This code originated as Fortran in the 1960's and was used routinely at the Institute of Geophysics and Planetary Physics at the Scripps Institution of Oceanography through the 1970's and 1980's. The Fortran code was obtained from Professor Robert L. Parker at IGPP in 1989. It was converted to C in 1995 for use with the MB-System software package.

The nature of the interpolation is controlled by a tension parameter and a range parameter. The tension parameter is such that when it is set to 0.0 a pure Laplace (minimum curvature) solution is produced. When the tension parameter is set to infinity, a pure thin-plate spline solution is produced. A value of $1e10$ has commonly been used to yield the spline solutions. The range parameter sets the number of grid spaces from data that will be interpolated such that if the range exceeds the maximum dimension of the grid, then the entire grid will be interpolated.

Feathering Algorithm Integration into the DBDB-V API

The OAML Feathering Algorithm will be implemented in the DBDB-V access API in a modular manner so other algorithms can be plugged into the API in the future. To accommodate the area-based, two-dimensional interpolator, the feathering option is implemented as a two-step process.

First, the API user calls the OAML feathering function (Fig. 2) that accepts the left, right, bottom, and top extents of the feathered grid and the grid spacing. Internally, the feathering function will extract all the "best" (meaning highest resolution) available data for the area specified using the current extraction settings and no interpolation. After the stored data in the area of interest are extracted, the data are sorted, checked for duplicates, and passed to the "zgrid" function to produce a minimum-curvature spline grid solution for the requested area. The API then saves the feathered grid in an internal cache structure so that multiple areas may be feathered without erasing previously feathered grids.

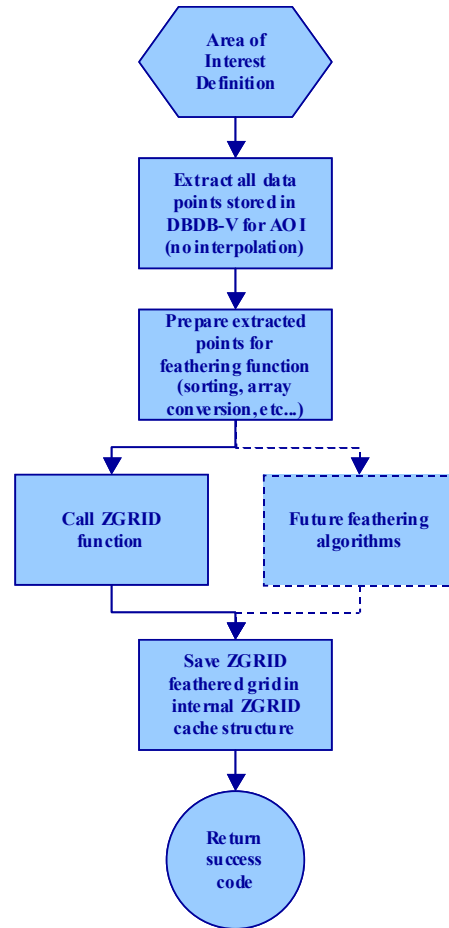


Fig. 2 — High level flow of DBDB-V feather area function

Since all extraction functions in the DBDB-V software are based on the point extraction algorithm, this DBDB-V function has been reconstructed to accommodate the feathering option (Fig. 3). The point extraction function will include a Boolean parameter such that when it is true, the point extraction function will first check the zgrid cache for the feathered grid that contains the requested point and, if the option is false, the algorithm performs a nonfeathered, DBDB-V point extraction. If a requested point does not lie exactly on a node of the feathered grid, data near the requested point are interpolated using a bilinear or nearest-neighbor algorithm depending on the user's current extraction properties.

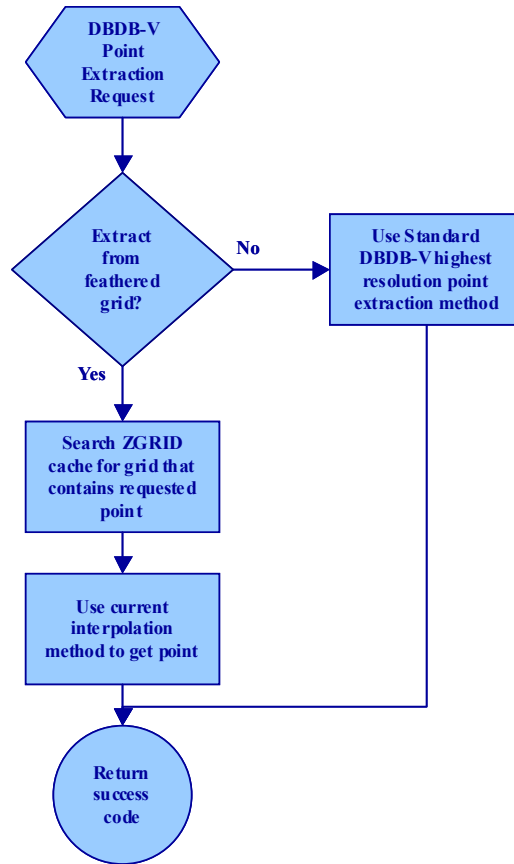


Fig. 3 — Proposed DBDB-V point extraction flow

TEST CASES

In the following four test cases, the DBDB-V 4.1 output is extracted from DBDB-V Level 0 with bicubic spline interpolation enabled (sub-image a). The same region is extracted from the prototype DBDB-V code with feathering capabilities (sub-image b). In each case, a track that crosses the resolution transition is shown as a black line on the surface plots (sub-images a and b) and a depth profile plot in a separate graphic (sub-image c). An addition plot of the DBDB-V resolution coverage for the area of the test case is shown in sub-image d in each case. Each test region represents a known location in the DBDB-V database where there are significant discontinuities between adjacent datasets with different resolution.

Figures 4 through 7 show the test results in sub-images a and b as Sun-illuminated plots for both the DBDB-V 4.1 and feathered output, respectively. These images have been created with the Generic Mapping Tools (GMT) software available from <http://gmt.soest.hawaii.edu/>.

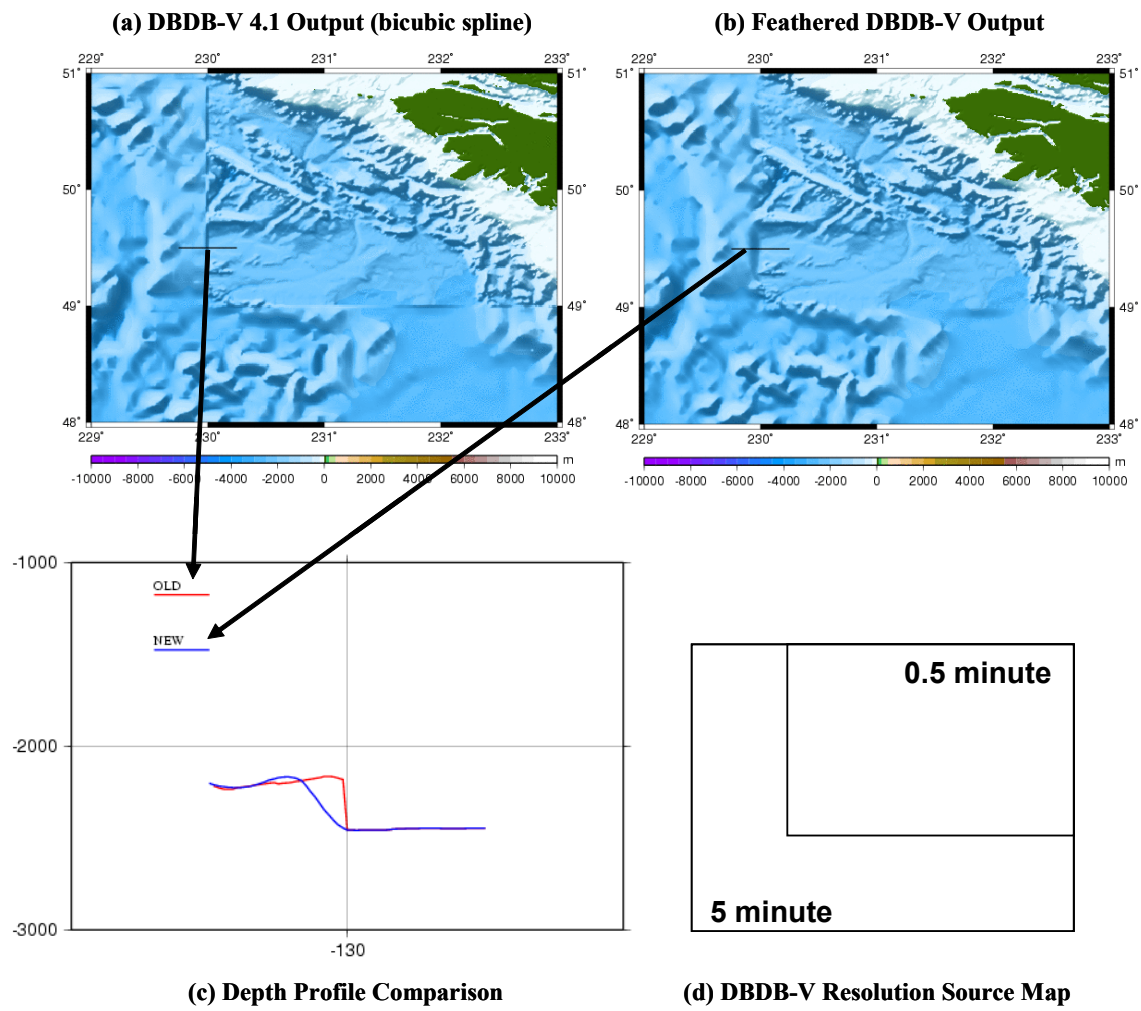


Fig. 4 — Test Case 1

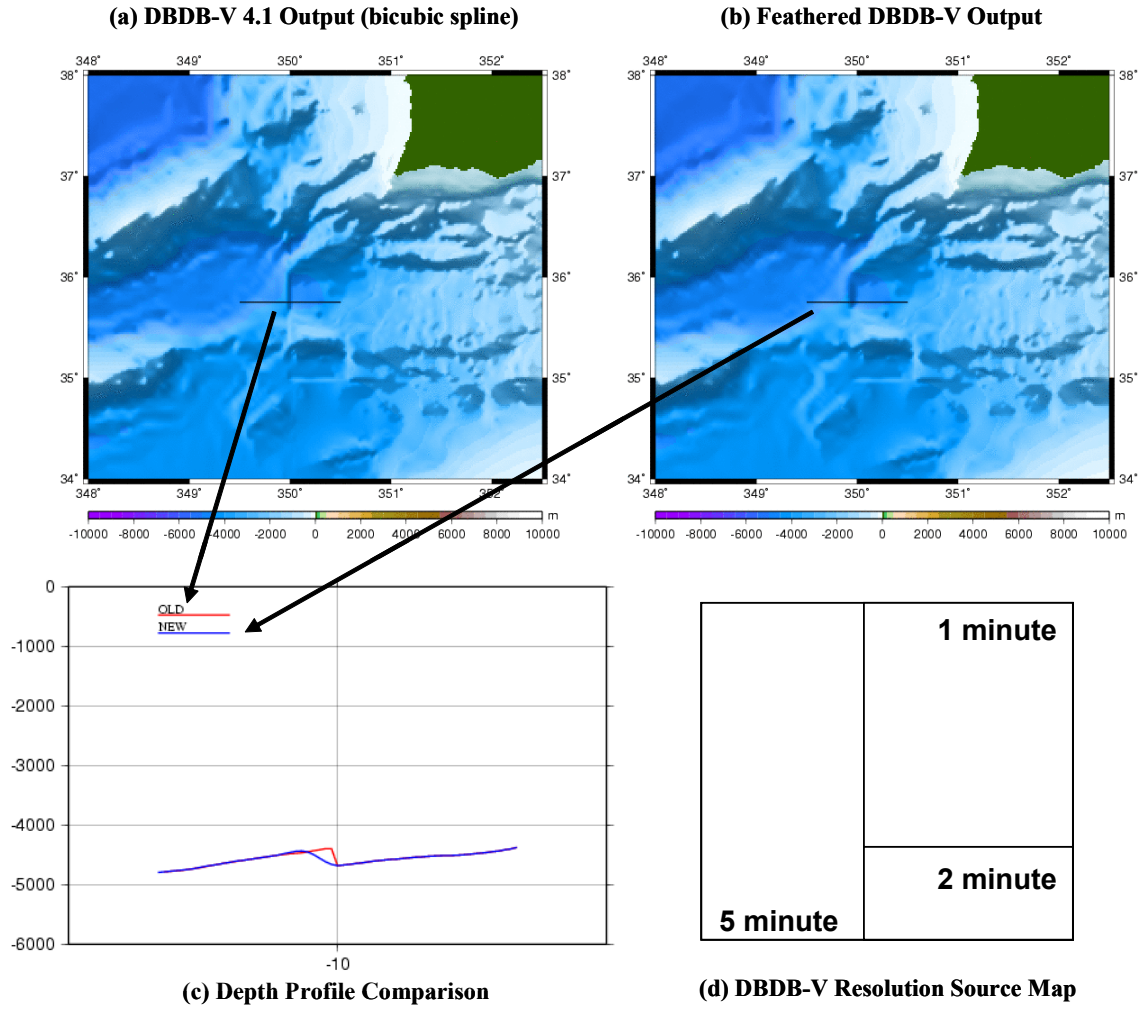


Fig. 5 — Test Case 2

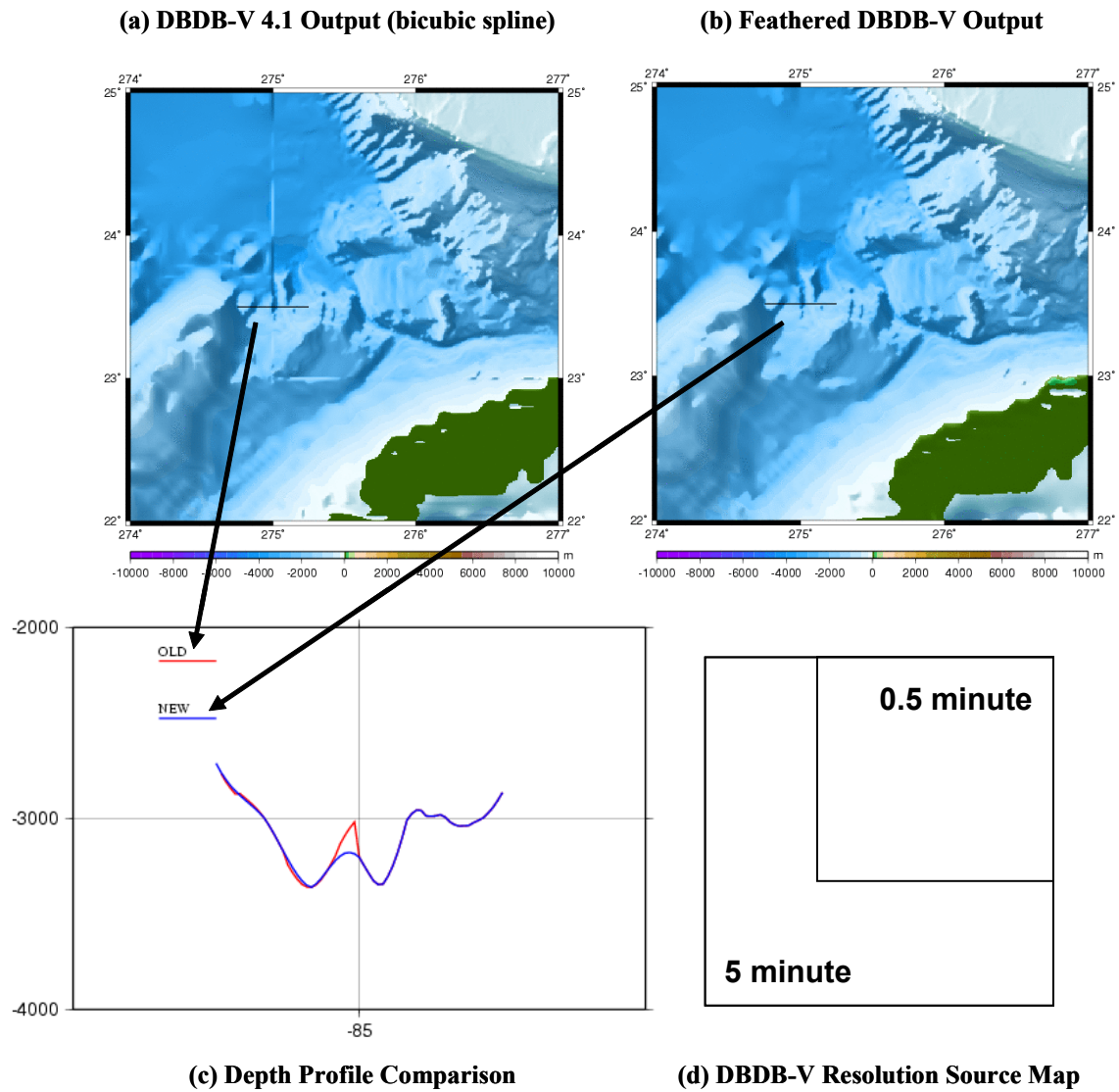


Fig. 6 — Test Case 3

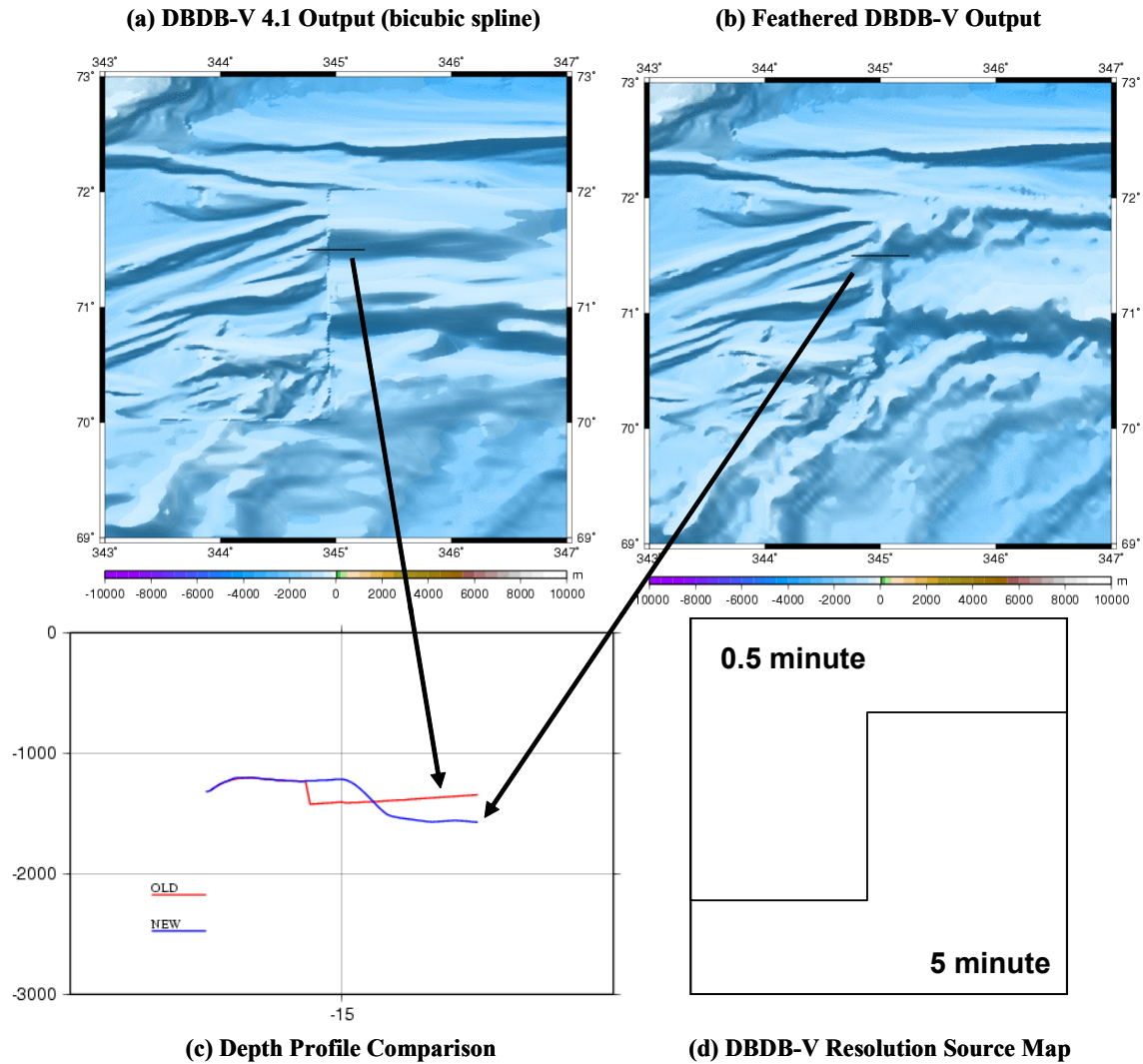


Fig. 7 — Test Case 4

CONCLUSIONS

The OAML Feathering Algorithm is designed to alleviate the inconsistencies between the various grid systems in DBDB-V. Modifying DBDB-V to an irregular grid structure, if executed intelligently, can eliminate the source of the problem by blending all data into one adaptive mesh. However, this major structural change to DBDB-V should be considered a long-term goal.

Until such a long-term solution is achieved, the OAML Feathering Algorithm will provide a tremendous improvement for systems that rely on DBDB-V. To accommodate future developments, the proposed implementation is modular and independent of the structure of the DBDB-V file format. Therefore, the OAML Feathering Algorithm offers new consistency in DBDB-V output that spans multiple resolutions or coordinate systems in both a flexible and efficient manner.

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