

A tool for a fast, semi-automatic cleaning of multibeam swath bathymetric records from spikes

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Abstract – Here we show a tool for the auto-cleaning of Digital Terrain Models (DTM) from spikes. This tool basically fits the contiguity of well developed depth measurements in a regularly spaced DTM, that helps to individuate and remove spikes from survey records. The method consist in a recursive approach in which a bathymetric grid is generated starting from very large cell size values (e.g., about ten times the grid cell size of the final product) and then compared with the vertical distance between each measurement and the filtered DTM (residuals). Finally, a threshold value is opportunely chosen and beams with residuals that are larger than the threshold value are excluded from the cleaned record. The processing flow requires several iterations cycles, made by reducing both the cell size and the threshold value for each iteration step. The method here proposed is a self-excluding process that helps to choose between data by killing (or not) each single measurement, thus resulting in a simple removal of wrong measurement from the original bathymetric record.

I. INTRODUCTION

Bathymetric soundings are a powerful tool for seafloor studies of the seafloor morphology. Since the information available in a survey dataset are resolution-dependent, multibeam data are usually processed by taking into account the final aim of the survey. Thus, while large-scale geological structures can be properly imaged by using Digital Terrain Models (DTMs) with grid cell sizes of tens of meters (e.g., seamounts or basins), coastal area and even more specific targets on the seafloor (e.g., archaeological manufacts) need metric or sub-metric grid cell sizes. In recent years, a rapid improvement in the development of sonar systems was recorded, particularly in regards to on-shore and coastal areas purposes. Multibeam sonar systems, in particular, are continuously evolving, often by increasing the number of beams in the swath, thus resulting in a dramatic increasing of time needed (and related costs) for data processing, both for public and private companies. Even if characterized by very high precision, accuracy and reliability, standard tools available on the market (e.g.,

Reson PDS2000 or Caris Hips and Sips swath editing tools) require swath editing of multibeam records, thus

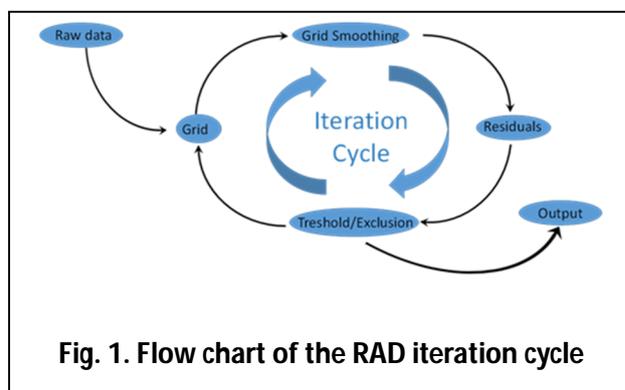


Fig. 1. Flow chart of the RAD iteration cycle

determining a dramatic increasing in cost and time needed for data processing. However, such a kind of approach, basically consisting in a manual removing of spurious measurements, is strongly recommended by the International Hydrographic Organization (IHO) standard, that were created with the purpose of exchanging hydrographic data between national hydrographic offices and users of hydrographic data products [1]. Such a standard protocol implies a manual editing for random noise removal of multibeam swath bathymetry wrong measurements that typically affect data records.

Since the multibeam echo sounding data are huge in large area, efficient processing tool is necessary to deal with such vast amount of data. However, the smaller the cell size, the larger the processing time required to proper image the survey targets. Typically, multibeam bathymetry may suffer of several errors, due to tilted swaths, wrong calibration, wrong positioning due to GPS “jumps”, heave/pitch/roll/yaw-failed correction of the motion sensor, etc [2], [3]. Once processed for navigation “jumps”, tides, etc., multibeam soundings suffers of the presence of “random” wrong measurements called spikes, mainly due to poor acoustic beam detection or to the presence of obstacles along beam pattern.

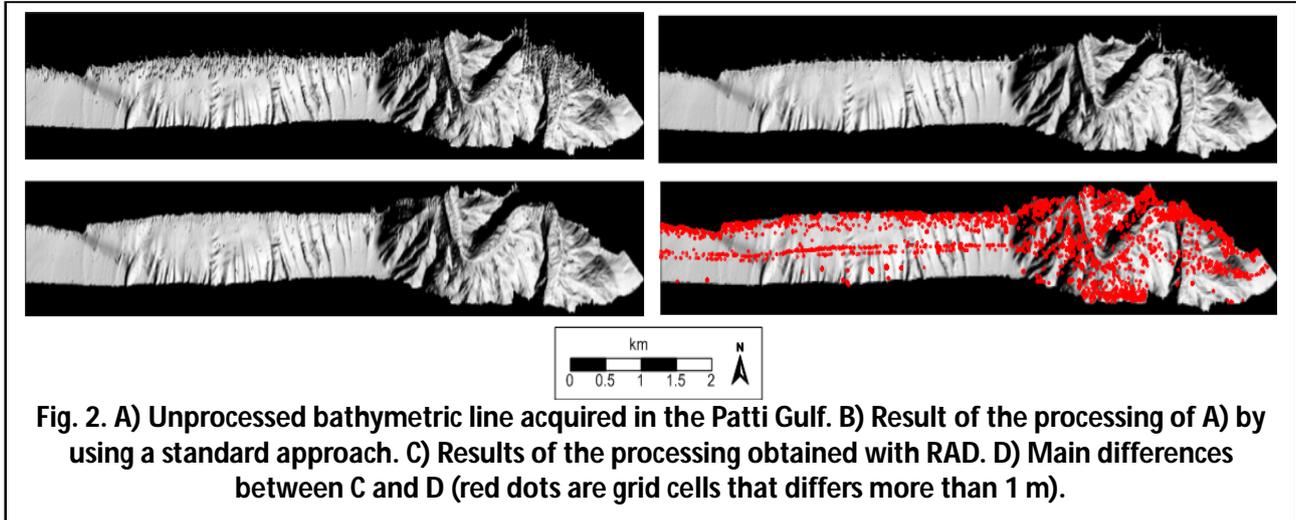
Following the IHO standards, once calibrated and corrected for positioning and tide gauge, bathymetric data should be processed by manually removing wrong measurements from swaths. This step often results in a

time-consuming approach.

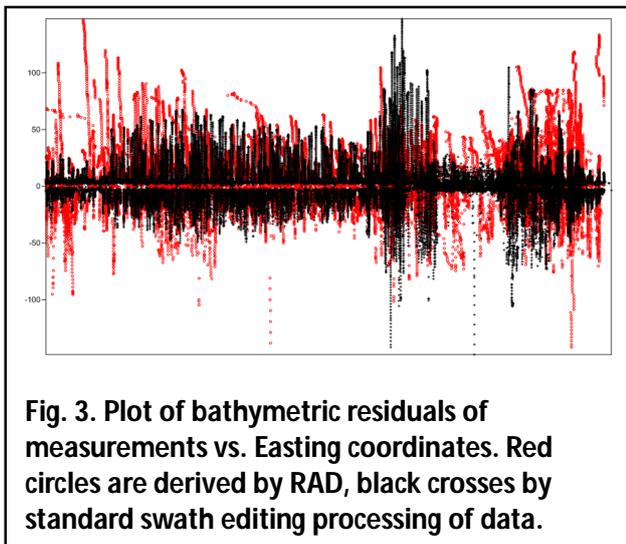
II. THE RAD PROCESSING TOOL

not) each single measurement, with the result that all the final data arise from the original bathymetric records and remain untouched.

III: RESULTS AND DISCUSSION



Here we propose a multi-resolution and recursive method for a fast auto-cleaning of multibeam records that, once started, need only time-machine costs. The method consist in a recursive approach in which a bathymetric grid is generated starting from very large cell size values (e.g., ten times or more with respect to the desiderata) and then compared with the vertical distance between each measurement and the filtered DTM (residuals). Finally, an opportunely chosen threshold is identified and beams with residuals larger than the threshold value are excluded. This processing-flow requires several iterations, made by reducing both the cell size and the threshold value for each cycle. The method here proposed is a self-excluding process that helps to choose between data by killing (or



In order to properly test the efficiency of the RAD approach, we used a double-stepped test. More in detail, 1) We have compared the results of the swath processing approach made in a “classic” way with the elaboration of the same bathymetric line made up by applying the RAD processing tool. 2) We show the results of the RAD approach over two real, large case studies, i.e. Naples Bay and the southern sector of Ischia Island.

The first comparison takes into account a bathymetric line acquired by using an EM710 Simrad (Kongsberg©inc) echo-sounder, an equipment that offers 400 beams in a 140° swath coverage for each ping. This equipment allows to collect soundings until about 2800 m below the seafloor (bsf). Data were acquired during the “Milazzo 2013” Cruise and the crew of R/V Urania of the National Research Council (CNR) on January, 2013. The bathymetric line was acquired with an Eastward navigation, thus the central portion (with respect to the vertical) represents the central sector of the swath, while the northern is its left side. To note that the seafloor slopes northward in this sector. This line seems particularly suitable for our test because it shows both flat and rugged seafloor morphologies.

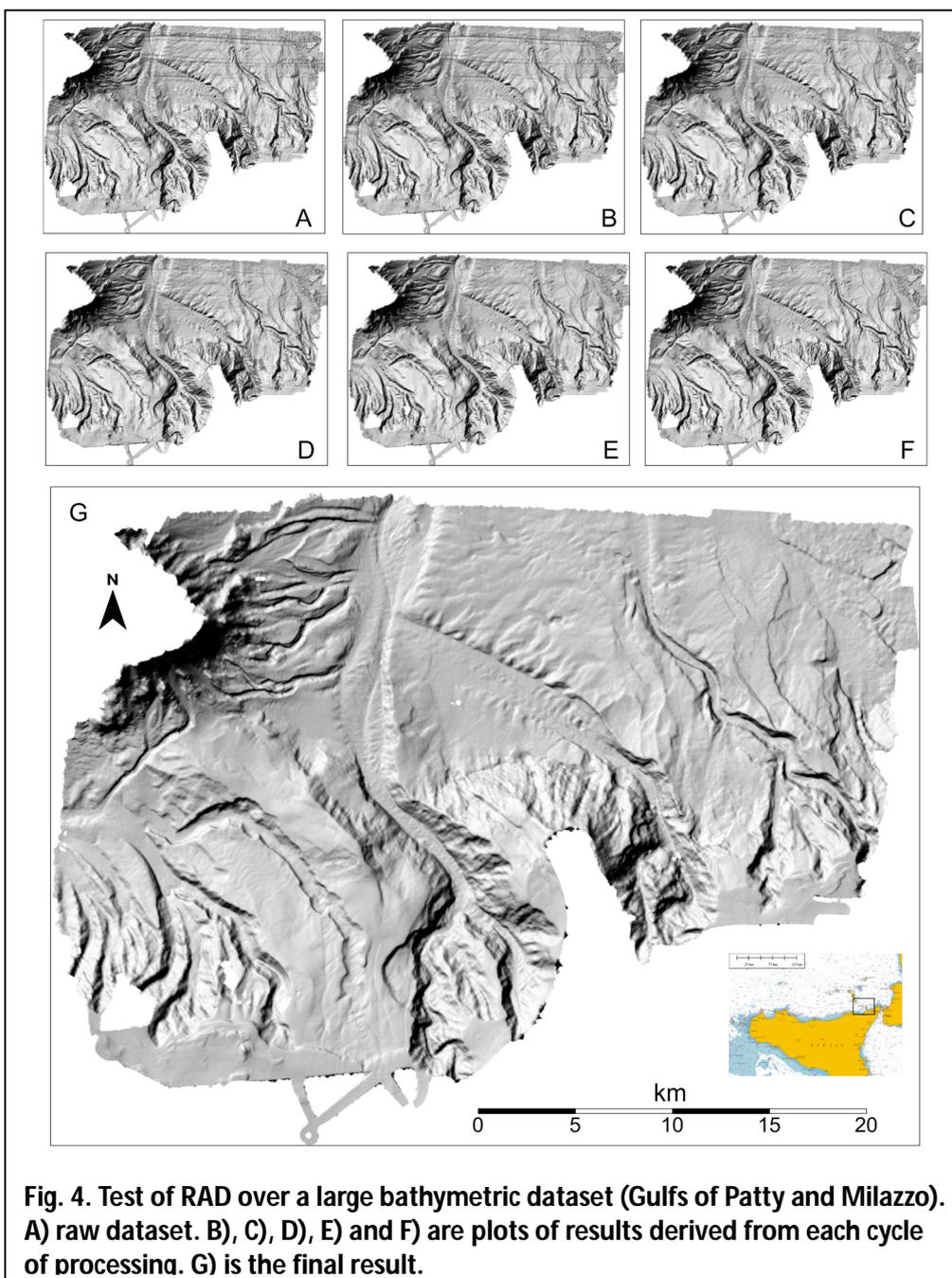
The DTM derived by the raw-data (Fig. 2A), here reported with a 10 m grid cell spacing, is characterized by the presence of a large number of spikes, particularly on its northernmost portion (that constitute the left side of the acquired pings). By applying a classic bathymetric processing (i.e., by using a swath tool under Caris Hips and Sips) we obtained a huge increasing of Signal to Noise (S/N) ratio, as can be easily seen by the disappearing of wrong measurements (Fig. 2B). The bathymetric lines was made up by 1.641.107 beams, and during the swath editing

49.384 measurements were manually deleted.

Results of the RAD tool (eight-cycles) applied to the raw data are showed in Fig. 2C. The final result is obtained by removing 56.497 measurements. To note that the RAD approach seems to obtain better results on the central and the northern sectors of the bathymetric line. Main differences between the two processing approaches are reported by showing bathymetric measurements that differs for more than 1 m in depth between the “classic” and the RAD processed data (red dots in Fig. 2D). To note that the main discrepancies between the two grids are concentrated on the same sectors (northern and central)

that seems to be better processed by using RAD. Finally, we plot the RAD (red dots) and the swath-edited (Black crosses) with respect to the X coordinates (Fig. 3). The two datasets are resulted to be partially coincident but some, local huge differences are also evident.

Finally, we tested the RAD approach over a larger bathymetric sector, made up by several swath lines. Bathymetric data were acquired in the Patti and Milazzo Gulfs, that are characterized by an articulate seafloor morphology due to the presence of structurally controlled canyons (Gamberi et al., Cultrera et al.). The DTM, here reported with a 20 m spacing, shows the presence of



several channels and canyons comprised between the North coasts of Sicily and the southern part of Aeolian Arc. Fig. 4 shows the original dataset (Fig. 4A) and the data processing obtained by applying 6 cycles of RAD (Figs. 4 B-G) respectively. The final DTM (Fig. 4G) well shows the effect of filtering over lateral beams (most of the swaths were acquired E-W, as can be seen by lateral beam noise which is particularly evident in the early stages of data processing (Fig. 4 A-C).

CONCLUSIONS

We presented a method for a fast, semi-automatic cleaning of multibeam records from incoherent spikes. This method is based on a self-exclusion of wrong measurements from the original records, made up by taking into account residual measurements of each beam with respect to the DTM itself. The tested the method both over a single line, with a comparison between results arising from the standard approach and the RAD application, and over a large bathymetric dataset acquired in a sector where the rugged morphology helps to properly view the cleaning results. The method, which is coast-effective, appears to give good results in terms of the final S/N ratio.

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