

Multi-beam backscatter image data processing techniques employed to EM 1002 system

**William Fernandes and Bishwajit Chakraborty
National Institute of Oceanography
Council of Scientific and Industrial Research
Dona Paula, Goa: 403 004**

ABSTRACT:

Application of multi-beam bathymetric data provides interesting features. Apart from obtaining bathymetric data, seabed characterization can also be implemented using multi-beam backscatter data which is acquired simultaneously along with the bathymetric data. However, use of multi-beam backscatter image data for seafloor characterization is limited due to the presence of artifacts in raw data. Because, angular backscatter strength data show higher values towards the normal incidence angles especially for smooth seafloor compared to outer beam angles. Therefore, off-line corrections are essential to compensate outer beam backscatter strength data such a way that the effect of angular backscatter strength is removed. In this work the technique employed to backscatter strengths data of the multi-beam system provides normalized seafloor image which useful for studying seafloor sediment lithology. In this work we have developed multi-beam backscatter data processing techniques for EM 1002 system. The employed technique in this work is discussed and steps are discussed in details. The processes data is suitable for image analyses for understanding of the seafloor features.

I. INTRODUCTION:

Analyses of multi-beam bathymetric data reveal interesting features. Apart from obtaining seabed topographic data, seabed characterization can also be implemented using multi-beam backscatter data acquiring simultaneously along with the bathymetric data [1]. Application of the quantitative side scan sonar based texture analyses of the seafloor are carried out extensively. However, similar use of multi-beam backscatter image data employment for seafloor characterization is limited from Indian Ocean region. Because, angular backscatter strength data show higher values towards the normal incidence angles especially for smooth seafloor compared to outer beam angles. Therefore, off-line corrections are essential to compensate outer beam backscatter strength data such a way that the effect of angular backscatter strength is removed. Moreover the effect of gain functions employed to the multi-beam is also to be removed apart from the effect of the large scale seafloor slope along and across track directions [2]. The techniques employed to backscatter strengths data of the multi-beam system provides normalized seafloor image which relatively normalized for studying seafloor sediment lithology [3].

EM1002 multi-beam echo-sounding system installed onboard Coastal Research Vessel (CRV) *Sagar Sukti* (a research vessel of National Institute of Oceanography, Goa), which primarily operates at 95 kHz frequency and possesses 111 pre-formed beams i.e., recording 111 depth values in a single ping. In addition to the depth, the system also provides quantitative seafloor-backscatter data, which is utilized to generate normalized backscatter imagery for the study of spatial distribution of fine scale seafloor roughness and textural parameter. Originally during the time of acquisition and consequent storage, individual angular backscatter strength data is corrected for number of losses and changes such as Time Varied Gain (TVG), propagation losses, predicted beam patterns and for the ensonified area (with the simplifying assumptions of a flat seafloor and Lambertian scattering). This data then gets recorded in a packet format called datagram stored for every ping [4]. Present paper discusses algorithm named as *PROBASI* (*PRO*cessing *BA*ckscatter *SI*gnal) II applied to raw backscatter data of the EM 1002 multi-beam system in order to develop normalized backscatter image data.

II. METHODOLOGY EMPLOYED:

In EM 1002 system online amplifier gain correction is accomplished by applying mean backscattering coefficients such as: BS_N and BS_O applied at 0° and at crossover incidence angles (normally 25°)

respectively. Consequently the raw backscatter intensities recorded in the raw (*.all) files are corrected during data acquisition for backscatter employing Lambert's law (Simrad Model) [4]. However, for lower incidence angles (within the 0-25°) it was determined that the gain settings in the electronics require a reasonably smooth gain change with incidence angle and hence the gain between BS_N and BSo is linearly changed. The sample amplitudes are also corrected suitably incorporating transmitted source level and transducer receiver sensitivity. Further, sonar image amplitudes though corrected online needs further improvement to generate calibrated images for the seafloor area. This is especially needed for incidence beam angles within the $\pm 10^\circ$ angles (to remove routine artifacts in the raw backscatter data near normal incidence angles) (Figure 1). Hence, post processing is needed to be carried out even for moderately rough seafloor. In addition to the artifacts close to normal incidence beams, the EM1002 multi-beam data show some residual amplitude due to beam pattern effect [1], and thus real-time system algorithm is unable to compensate such routine situations.

As discussed, the EM1002 multi-beam echo-sounder system automatically carries out considerable amount of processing on raw backscatter intensities. Even then, the data show some residuals, which are required to be corrected before further analysis. These fluctuations may be due to following factors as explained below:

SEABED ANGULAR RESPONSE:

The EM1002 multi-beam echo-sounder system normalizes the backscatter intensities in real-time using an incidence angle normalization algorithm. This algorithm will fail when seafloor is not really flat (as system assumes). Since slope varies across the swath, the incidence angles tend to change, which causes variations in backscatter strengths. This will reflect unusual features of geological in nature on the seafloor. This real-time algorithm will also fail as unable to compensate for different types seafloors as encountered during ship's motion. This effect is clearly seen at nadir resulting in strong backscatter intensities which follow the ship track lines.

TRANSDUCER BEAM PATTERN EFFECTS:

The beam pattern effects are basically present in the data and are caused by fluctuations in acoustic intensity among groups of elements of the transducer array. Thus in-turn caused due to differences in

power amplification between each of the receiving channels. Though, these fluctuations are small but results in vertically referenced effects.

At NIO, Exclusive Economic Zone (EEZ) survey group is continuously extending its intellectuality towards understanding of the seafloor geology and tectonic morphology of the seabed, hence there is intense necessity to have supporting data for bathymetric depths such as backscatter images. The available algorithms are found to be limited in application aspects from the scientific user point of view. Moreover output file formats are as decided by manufacturer, which brings incompatibility issues with other analyzing other systems such as ArcGIS etc [5]. Due to these problems, during the past we have developed algorithms for processing the backscatter intensities for other multi-beam systems (Hydrosweep -manufactured by STN ATLAS Elektronik, GmbH) [6]. In order to carry out further work using backscatter signal strength, the image data is essential. Along with the effective processing of the data, flexibility for storing the data in any Binary /ASCII required formats is also taken care. The software also provides a step by step output results recorded in files which can be plotted to check the improvements in data quality through off-line processing. In addition, the averaged swaths are stored in files for later usage during updating process. However, the developed algorithm also gives flexibility to either use suitably computed averaged swaths. Moreover, the developed algorithm is interactive to introduce the corrective parameters through the user to proceed with own processing analyses. Hence effort was made to have a processed imagery map for data acquired at NIO, which would support the seafloor geologic processes. The present software is written in C & C++ language and compiled on Dev C++ compiler.

In short the entire developmental activities are divided into four modules adopted through following procedure:

- A. Module-I: Initially the data was extracted from seabed image, raw range and beam angle, depth, attitude and position datagrams (EM Datagrams Manual). The module does heading, position and slope correction on data.
- B. Module-II: is a coarse method. The function of this module is to filter out maximum residuals or spikes in the backscatter strengths i.e., maximum removal of beam pattern effects.

- C. Module-III: is a fine method. The module utilizes iterative beam pattern removal method. Since the coarse method does the maximum job of removing center beam and beam pattern effects. Still smaller extent of beam pattern residuals remains with the data. This fine method helps in removal of such residuals more prominently (Figure 2).
- D. Module-IV: The noise is been an influencing factor on the quality of backscatter strengths. Since this type of data directly deals with the signal strength, sometimes the data gets recorded along with the noise occurring at the face of transducer. Hence the use of filters becomes very much necessary. This module uses combination of high pass and low pass filters.

There are different corrections steps which algorithm applies to raw backscatter intensities during normalization process. More detail study of the software is demonstrated using a flow diagram flowed by the stage by stage discussion in subsequent sections (Figure 1).

III. DATA EXTRACTION AND GEOMETRIC CORRECTIONS:

The batch file is made, which consisting of EM1002 echo-sounder's raw data (*.all) files those are required to be processed. The program first reads this batch file and extracts specific data such as backscatter strength, bathymetry, heading, position, beam angle etc. required during processing of backscatter intensities.

Following set of corrections are applied to the data in module I:

- *Heading correction:*

Initially during acquisition, the data is corrected for motion but when ship turns sharply to change the survey track it is found that the data is not compensated properly for heading. This may be due to latency problem. Hence the developed algorithm applies heading corrections as and when required. It actually compares for initial and next heading data and accordingly calculates for the required heading offset.

- *Position correction:*

Sometimes due to unavailability of shore station or GPS satellite, the accuracy of used DGPS differs, and at times the system record wrong positions. Due to this the backscatter strengths are

recorded with wrong position indicating data from unknown locations. Therefore, such positional jump needs to be corrected before further analysis. To avoid such problem, the heading corrected data is monitored for any positional deviations and if necessary the same are corrected using previous and the next ping data.

- *Bathymetry slope correction:*

Bathymetry slope has a significant effect on the backscatter strengths. Since the seabed slopes varies across the swath, the beam incidence angles will also be changing. This will cause the shift in positioning of the beams on the seabed. This shift will not be taken care by the system as it assumes the flat seafloor for all types of seabed during online data acquisition. Thus there will be image distortion, therefore, above correction is made during processing the raw backscatter strengths.

- *Lambert's law removal:*

As discussed in preceding sections [4], the raw data is treated with number of corrections in real-time. Hence, to obtain raw backscatter intensities one have to revert back the process of certain corrections, which is not necessary with other algorithms related to multi-beam backscatter data. Therefore, further analysis is performed using raw backscatter strengths. Once the effect of Lamberts's law is eliminated, the raw backscatter strengths appear to be one given below in Figure 2.

The corrections applied in module II related coarse corrections are given in steps:

This method incorporates three things:

- Normalizes backscatter strengths to 10° incidence angle.
- Angle wise averaging of backscatter strengths.
- Removes beam pattern from normalized data.

The heading, position and slope corrected backscatter strengths data are received within this module. The function of this module is to filter out maximum residuals or spikes in the backscatter strengths. Working of this module involves as:

Initially, arrays “A” (size 800x111 data points) and “B” (size 111 data points) are used for storing the backscatter strength values and for averaging the backscatter strengths respectively. Array “A” reads the swaths for entire line or 800 pings (whichever is closest) and array “B” moves within the array “A”, thereby averaging and storing average swath for 800 pings. The process continues for entire area and array “B” is updated at every arrival of new average swath. Finally an average swath is calculated for entire area having total of 111 beams. Once the process is completed for full area the reference 10° beam (port/starboard) backscatter strength is chosen [7], and the average difference swath is found by subtracting full swath from reference beams. Hence a resultant difference swath is found which is then used to correct the backscatter strengths by allowing it to run over the entire area during replay. This gives the output as given in the flow diagram (Figure 1) under coarse method.

Similar corrections applied in module III related to fine corrections are given below:

The module utilizes iterative beam pattern removal method. Since the coarse method does the major job of removing center beam and beam pattern effects. However, still to some extent small beam pattern residuals remains with the data. Fine method helps in removal of such residuals more prominently. In this case the same arrays “A” and “B” are used. Initially the data is read in array ‘A’ and each swath is compared to 10° reference beam, and the difference is then stored in another array “B” of size [111 beams]. The next ping is read and the difference with 10° reference beam is found and the array “B” is updated. This process continues till the end of the data. The difference so found is averaged and stored within the same array “B”. The resultant averaged difference is then applied for the entire area. As the array moves over the area swath by swath, it refines the data from any residuals of beam pattern nature. Hence the output is obtained which is represented by the plot of backscatter v/s beam angle given in flow diagram under fine method.

Noise removal corrections applied in module IV is given below

The noise is been an influencing factor on the quality of backscatter strengths. Since this type of data directly deals with the signal strength, sometimes the data gets recorded along with the noise occurring

at the face of transducer. Hence the use of filters becomes very much necessary [8]. The module IV uses combination of high pass and low pass filters. The module uses the same size of array 800x111. The data is first read into this array and a percentage of filter value is chosen which tends to be at the higher side. The upper and lower limit for high pass filter (HPF) is calculated and it starts moving over the data within the memory. When HPF comes across any backscatter strength which exceeds the limits as specified, it flags that pixel and gives a new value as “0” dB. Thereafter, the same data enters the low pass filter (LPF), where the window of 3x3 pixels moves over within the memory and searches for any pixel which is flagged or represented by “0” dB. Once found, the average of neighboring pixels (excluding the flagged once if exists within the window) is calculated and given it to that flagged pixel. This process goes on for the entire area. When entire area gets completed, the pointer to the output file is initialized and the new value for the filter is calculated depending on past filter factor and backscatter strength fluctuations. Hence again the same process continues to the backscatter strengths data until the fluctuations within the adjacent beams are minimized and, are within the limits specified in the program. The output of the module is given in the flow diagram under noise removal (Figure 1). The final output of the entire process show overall removal of the angular backscatter as well as beam pattern effects.

IV. CONCLUSIONS

In this work we have developed multi-beam backscatter data processing techniques. The technique employed in this work is shown in the flowchart (Figure 1) and steps are discussed critically in this paper. The raw backscatter data produced on-line using EM 1002 multi-beam system shows the artifacts in Figure 2. The significant improvement in the image data after employing necessary corrections mentioned in this work is shown (Figure 3). The processes data is suitable image analyses for understanding of the features.

ACKNOWLEDGEMENTS

We acknowledge Dr. Satish Shetye, Director, NIO, for permission to carry out the work. The data and work were carried out under the Exclusive Economic Zone mapping (GAP 2002) and Ocean Acoustic program (GAP 2248) of the Ministry of Earth Sciences, New Delhi, and NIOT, Chennai respectively. This is NIO contribution no.xxxx.

REFERENCES:

- [1] Hughes Clarke JE (1993) *The potential for seabed classification using backscatter from shallow water multibeam sonars*. Proc Inst Acoustics 15(part2):381–387.
- [2] Chakraborty B and Kodagali, V Baracho J (2003) *Sea-Floor classification using multi-beam echo sounding angular backscatter data- a real time approach employing hybrid neural network architecture*. IEEE J. Ocean Eng. 28, 121-128.
- [3] Mitchell, N.C. Somers, M.L. (1989) *Quantitative backscatter measurements with long range side-scan sonar*. IEEE J.Oceanic Eng., 14, 368-37.
- [4] Hammerstad, E (2000). *EM technical note, backscattering and seabed image reflectivity (Personal communication)*.
- [5] Anon, 1998. Using ArcMap (ESRI version 8.3), ESRI Inc., USA.
- [6] Chakraborty, B, Kodagali, V N (2003) *Method for determining seafloor roughness using multibeam echosounder*, 6,549,853 B2 US Patent.
- [7] Beyer, A, Chakraborty, B., Schenke, H.W. (2007) *Seafloor classification of the mound channel provinces of the Porcupine Seabight: an application of the multibeam angular backscatter data*. Int. J. Earth Sci. (Geol. Rundsch) 96, 11-20.
- [8] Chavez, P.S., (1986) *Processing techniques for digital sonar images from GLORIA*. Photogramm. Eng. Remote Sens. 52, 1133-1145.

FIGURE CAPTIONS:

Figure 1: This figure shows stepwise flow diagram of various backscatter processing stages.

Figure 2: Figure showing raw backscatter data of ten track lines.

Figure 3: Figure shows processed output obtained using algorithm for above backscatter data.

Figure 1:

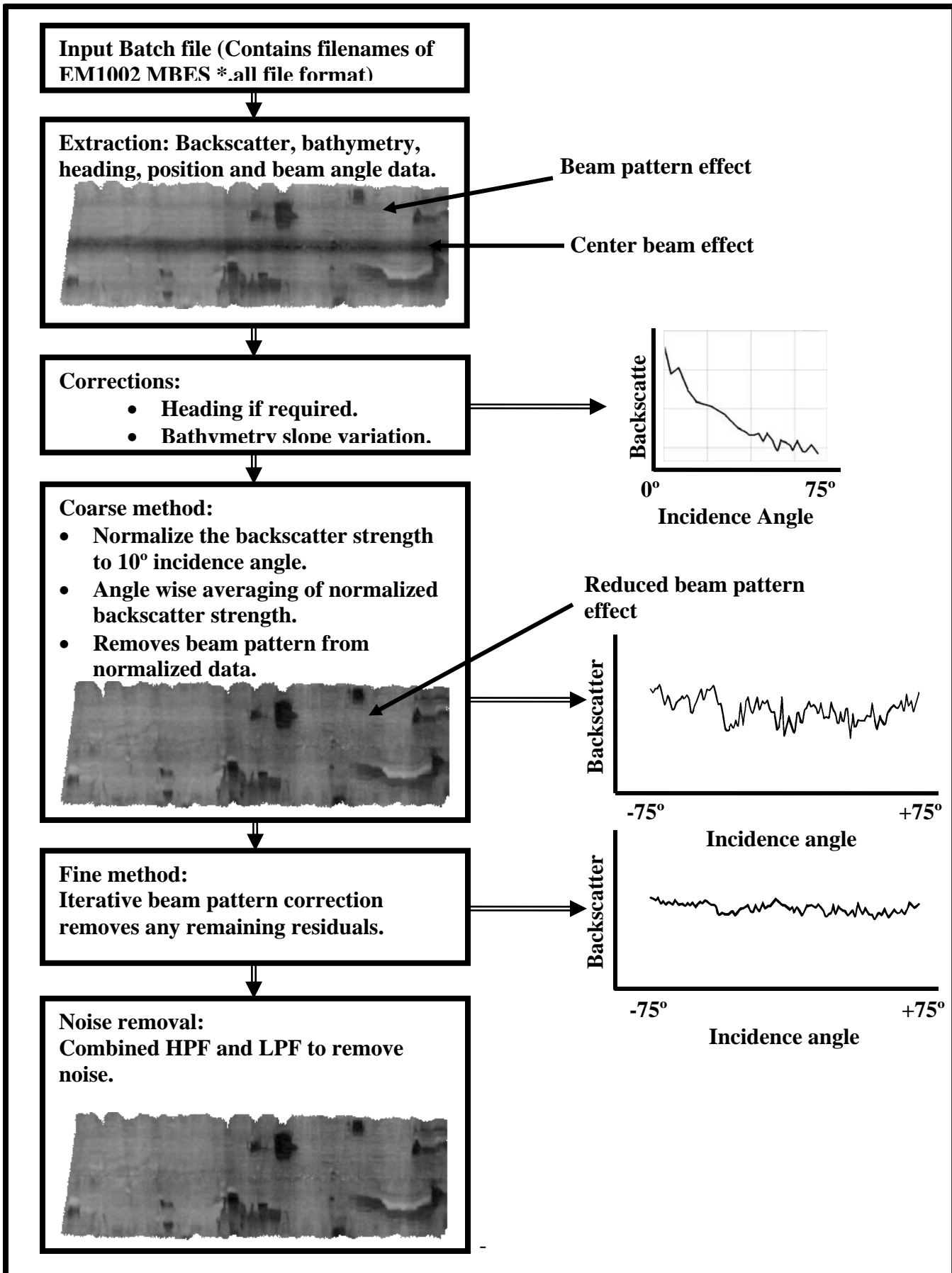


Figure 2:

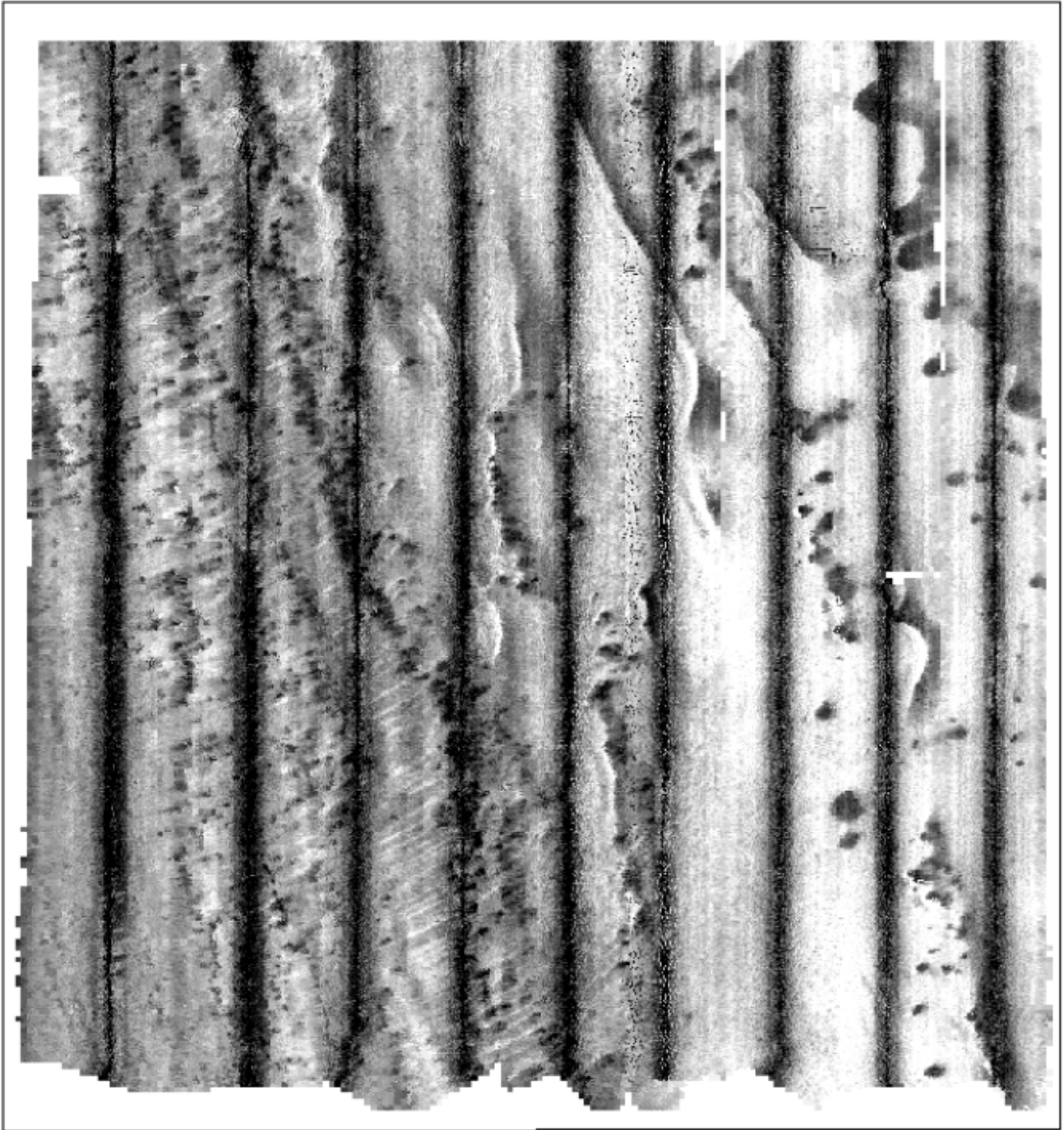


Figure 3:

