

Understanding seafloor morphology using remote high frequency acoustic methods: an appraisal to modern techniques and its effectiveness

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The Earth works as integrated system of interacting bio-geo-physico-chemical processes which are influenced by the land topography and ocean bathymetry. Erosion and sedimentation rates are much lower in the ocean than on land. However, detailed bathymetry (measurement and charting of the ocean floor) reveals the morphology and geological history. The understanding of the related geological and geophysical parameters which shape the ocean floor, are also essential for living and non-living resource estimation. The ocean floor acts as interface between the oceanic lithosphere and hydrosphere, and the interaction (i.e., exchange of mass and energy) zone for the processes are provided by the boundary layers. Evidences of the interaction effects in terms of Geomorphology can be seen in the seafloor sediment of ripple marks and bioturbation. Similarly, Geological evidences can be seen in the development of manganese nodule and occurrences of pillow lava due to submarine volcanism. Generally, two basic processes which shape the seafloor are known as endogenic and exogenic. The large seafloor features (seamount, ridge crest, valley etc) related to the plate tectonics are due to the Endogenic processes i.e., those deriving their energy from the earth interiors. Small scale features (ripple / abyssal plain etc.) due to erosion as well as deposition of the sediment sediments are attributed due to the Endogenic processes i.e. those driven by the Sun.

The two third of the earth surface i.e. 362 million square km (70 %) is covered by the ocean. In order to understand the seafloor various methods like: application of remote acoustic techniques, seafloor photographic and geological sampling techniques are well established. Echo-sounding through use of hull mounted transducer became familiar during the II world war. Advantage of this technique lies with the rapid depth data acquisition. Due to the improvement of the material science, the designing of the low cost but high quality transducers become familiar during the year 1950. The high resolution single beam echo-sounder (higher frequency and narrower beam-width) was available in 1970. Besides single beam echo-sounding technique, which provides single data points beneath the sea due to single transmission, other high resolution remote acoustic techniques like side scan sonar and sub-bottom technique became popular. GLORIA side scan sonar (operating frequency: 6 kHz) as well as SEAMARC (operating frequency: 12 kHz) were used by USGS extensively during 1980's. Side scan sonar system

provides aerial view of the seafloor, however, did not provide accurate depth information. This is primarily due to the phase measuring techniques applied to ensure higher coverage.

Multi-beam echo-sounder is a recent successor to single beam technique. Seabeam-multi-beam system was available in 1980. Multi-beam technique utilizes multiple narrow beam transmission / reception for a single transmission providing better seafloor coverage. Initial 16 beam Seabeam system had limited coverage which was subsequently increased to 5-7 times of the centre beam depth. Numbers of beams were generally increased to 111 having high-resolution beam-width varying within the 1.5° - 2.2° . In India first multi-beam-Hydrosweep system was installed onboard Ocean Research vessel (ORV) Sagar Kanya (owned by Ministry of Earth Science, New Delhi) by the National Institute of Oceanography during the year 1990. Hydrosweep system used to form 59 receiving beams having 2.2° beam-widths which were covering the seafloor twice distance of the centre beam depth. Use of modern computers provide faster signal processing techniques connected with position fixing equipments (DGPS) which helps in collocating depth data with the beam position. Extensive bathymetric data acquisition and seafloor investigation were carried out under various scientific projects like: Survey for Polymetallic nodule, RIDGE. Recently, mapping program of the 2.172 million sq km area of Exclusive Economic Zone (EEZ) of India by use of the multi-beam system is undertaken by the National Institute of Oceanography, National Institute of Ocean Technology, and National Centre of Antarctic and Ocean Research, which is also funded by the Ministry of Earth Science, New Delhi.

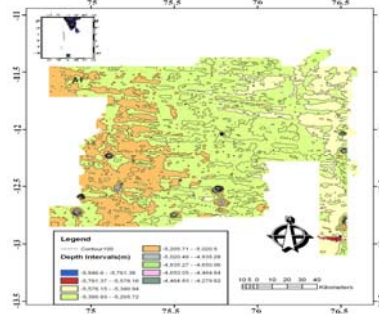
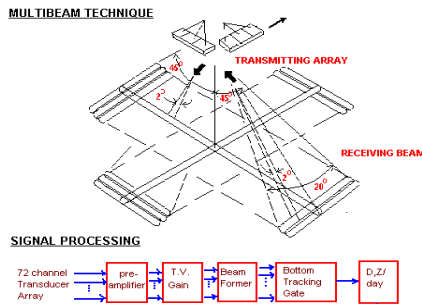
Apart from acquiring the depth data multi-beam systems were modified to acquire backscatter data during the later stages. Backscatter information of the seafloor provide textural aspect of the seafloor i.e., idea about the seafloor sediment material. This information along with the bathymetry for structural aspect is extremely useful to understand the seafloor. Backscatter strength values can match with the conventional side scan sonar system and provide side scan sonar data along with the depth data. Moreover, angular backscatter strength data can be utilized to apply quantitative seafloor roughness parameters like: seawater-floor interface as well as sediment volume roughness. Again, at NIO, modification in the Hydrosweep –multi-beam

system was made in 1995. Significant seafloor studies are carried out at the NIO during the last decade. Various seafloor segmentation techniques to classify the seafloor were initiated. Numerical based inversion

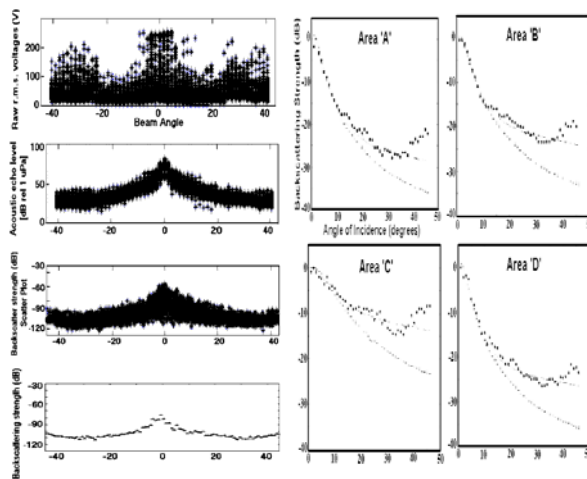
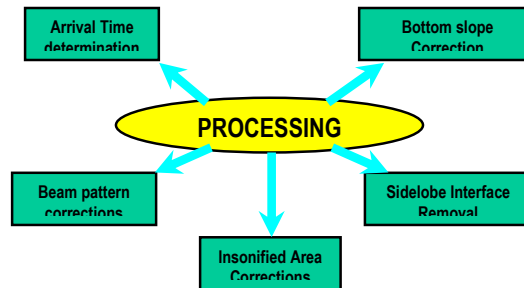
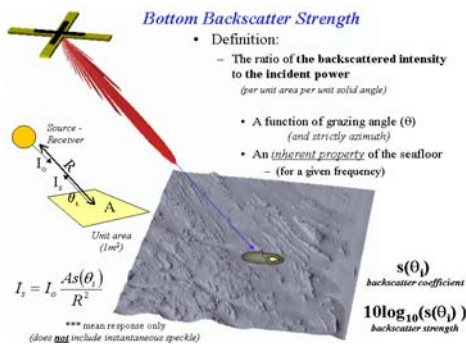
techniques along with the soft computational techniques were used. Present lecture will be attempted to cover modern techniques to understand the seafloor processes.

Multi-beam data acquisition, processing and interpretation algorithm

• Multi-beam echo-sounding technique at NIO



• Algorithm development for seafloor backscatter



- Chakraborty and Kodagali, 1999. Copyrighted software PROcessing BAckscatter SIgnal (PROBASI).
- Chakraborty and Kodagali, 1999. Copyrighted software A software package for INterpreting BAckscatter SIgnal (INBAS).
- Chakraborty and Kodagali, 2003. US patent: No. US 6,549,853 B2 "Method for determining seafloor roughness using multi-beam echo-sounder".

Composite roughness theory for sea floor using multi-beam

- Use of two theories for different angular regime
 - (a) Helmholtz-Kirchhoff theory (0 – 20°) angle
 - (b) Rayleigh-Rice theory (20- 45°) angle
- Developed splicing technique at 20° incidence angle techniques were applied in:

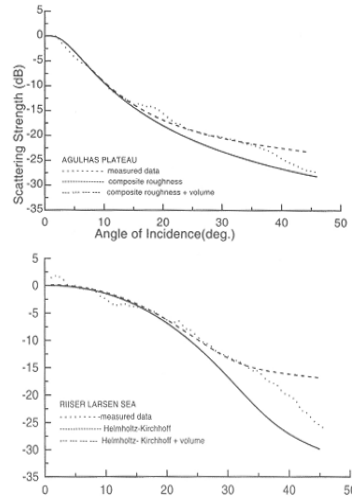
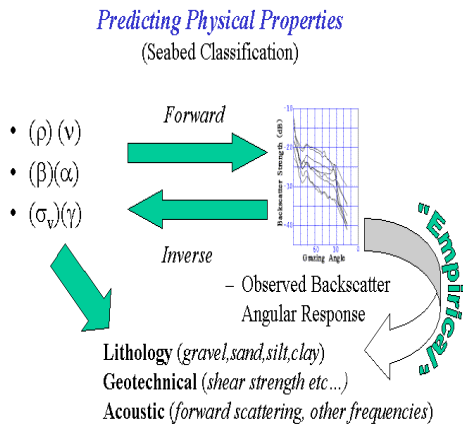


FIGURE 1 Angular backscatter strength of the Agulhas Plateau and the Riiser Larsen Sea areas.

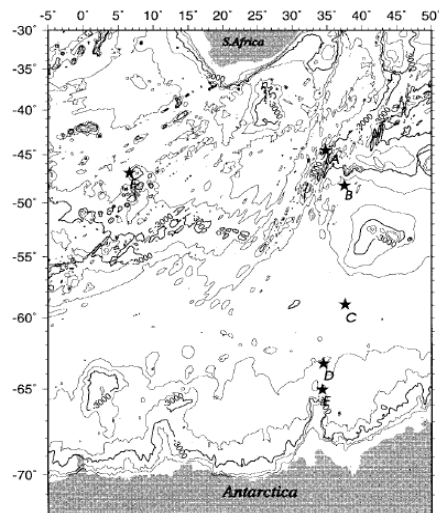
CIOB :

- 45 spot studies from 6,600 sq km indicates 51 % of the seafloor possesses negligible roughness.

Southern Oceans :

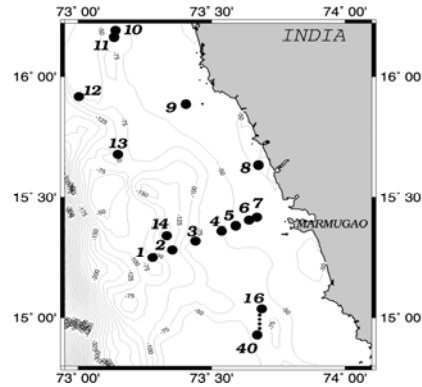
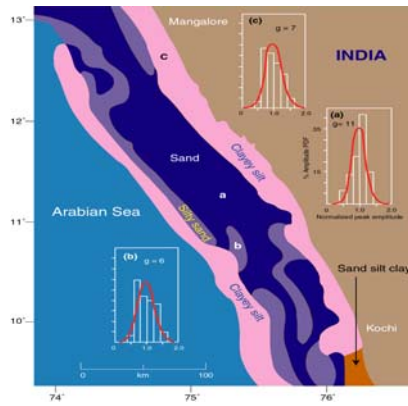
- First time report of the application of composite roughness theory for deep ocean floor studies using MB.

- Chakarabarty et. al. IEEE TGARS, 2000, 38 (5), pp. 2419- 2422.
- Chakarabarty et. al. Geo-Marine Letters, 2001, 20 (3), pp. 174-181.
- Chakarabarty et. al. Marine Geodesy, 2002, special issue 25 (1-2), pp. 19-26.
- Chakarabarty and Kodagali, Geo-Marine Letters, 2004, 24 (1), pp.08-13.

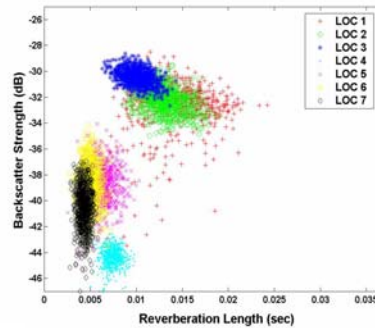
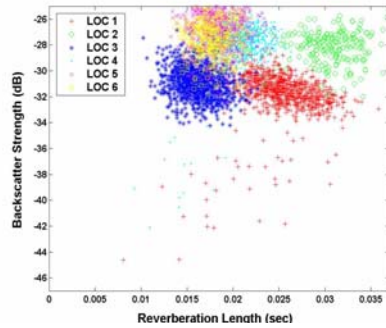


Seafloor studies in the western India continental shelf using backscatter signal

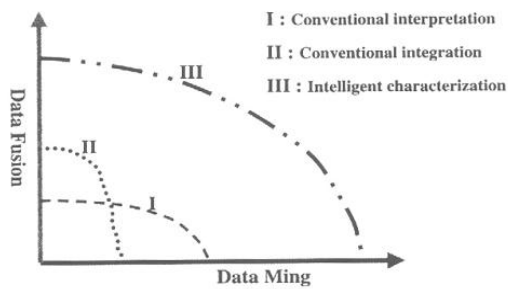
- First time high frequency backscatter experiment using single beam echo sounder over western continental shelf of India



- The numerical modeling techniques are very often not usefully applicable for real time seafloor studies.



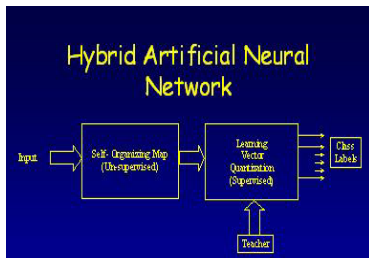
- Effective soft computational techniques



- Chakaraborthy and Pathak, Jour. Sou. Vib., 1999, 219 (1), pp. 51-62.
- Chakaraborthy et. al. IEEE TGARS, 2001, 39 (12), pp. 2722-2725.
- Chakaraborthy, LNAI 2275, 2002, pp. 245-250.
- Chakaraborthy et. al. IEEE GRSL, 2004, 1 (3), pp. 196-200.
- Chakaraborthy et. al. ICES JMS, 2007, vol. 2, pp.551-558.

Application of soft computational technique (ANN) for seafloor classification

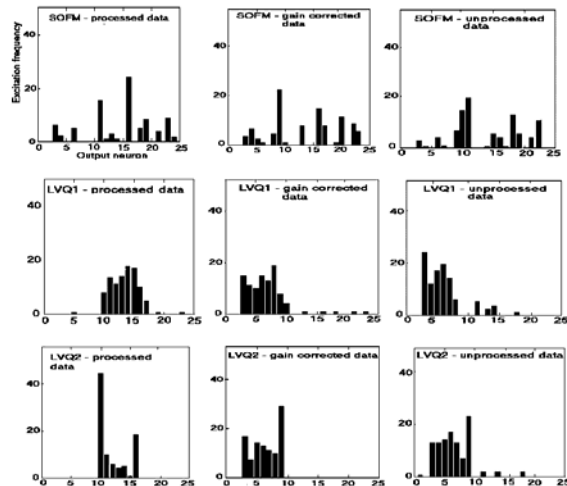
- ANN application for MB backscatter data



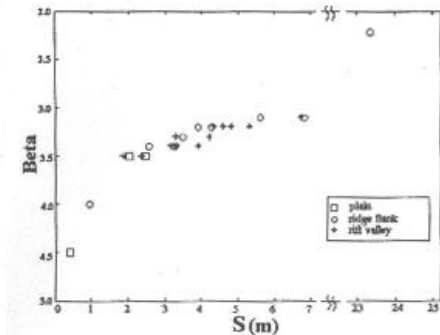
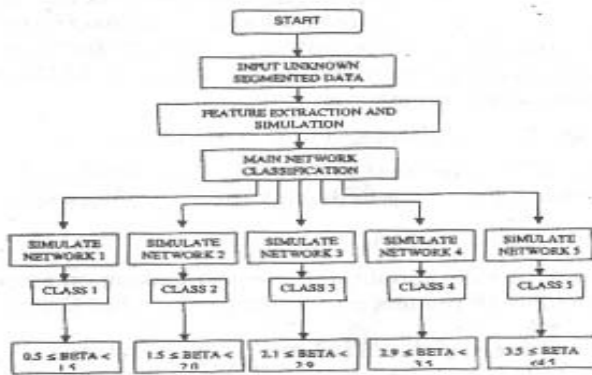
- Chakarabarty et. al. IEEE JOE, 2003, 28 (1), pp. 121-128.

US patent :

- Chakarabarty et. al., 2004, US patent: No. US 6,763,303 B2 "System for classifying seafloor roughness".

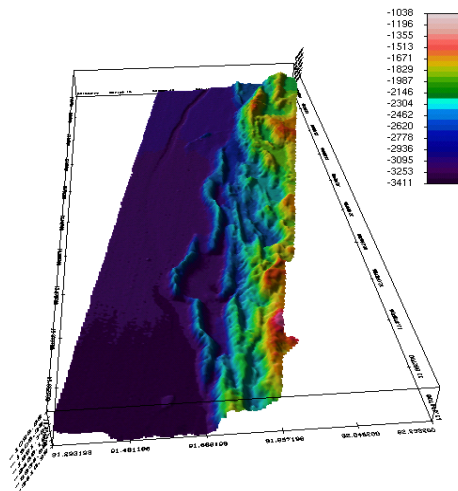


- ANN application on MB bathymetric data for seafloor classification



- Chakarabarty et. al. Current Science (Spl. Section: Mid-Oceanic Ridges), 2003, 85 (3), pp. 306-312.

3D perspective -DTM



Recent bathymetric Studies

Chakarabarty, B.; Mukhopadhyay, R., 2006. Imaging trench-line disruptions: Swath mapping of subduction zone. *Curr. Sci.*: 90(10); 1418-1421.

Chakarabarty, B.; Mukhopadhyay, R.; Jauhari, P.; Mahale, V.; Shashikumar, K.; Rajesh, 2006. Fine-scale analysis of shelf slope physiography across the western continental margin of India. *Geo-Mar. Lett.*: 26(2); 114-119.

Andreas Beyer, Chakarabarty, B., Schenke, H.W., 2007. Seafloor classification of the mound channel provinces of the Porcupine Seabight: an application of the multi-beam angular backscatter data. *Int. J. Earth Sci.* 96, 11-20

Chakarabarty et. al, 2007. Quantitative characteristics of the Indian Ocean seafloor relief using fractal dimension. *IJMS (spl. Issue on Fractals in Marine Science)*, 36 (2), pp. 152-161.