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Geological Survey of Canada

Open File Report

Title: Review of: Effects of Small Scale Roughness on Acoustic Reflectivity Measurements on the Newfoundland Shelf

by

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Review of: Simpkin, P.G. Effects of Small Scale Roughness on Seafloor Reflectivity Measurements on the Newfoundland Shelf

D.S.S. Contract # 09SC.23420-3-M839

Larry A. Mayer

Simpkin presents a carefully considered and well written analysis of a rather unique data set that clearly demonstrates the potential of quantitative acoustic data for the remote determination of seafloor roughness. The simultaneous collection of subbottom, sidescan and photographic data provided the opportunity to 'ground truth' a previously developed (by Cochrane, Dunsinger et al.) technique for the quantitativie evalutation of seafloor roughness. After a brief discussion of the historical basis for this work, Simpkin reviews the theory behind the estimation of coherence spectra. This review, summarizing the work of Cochrane et al., is accurate and appropriate for a report of this nature. Included in this review are discusssions of potential sources of error (e.g. echo misalignment) and of mechanisms for improving the reliability of the calculations.

Data base and geologic setting:

The discussion of the data base and description of the geologic setting is adequate. A brief description of bottom samples is given, but no mention is made of how the samples were taken. Depending on the sampling technique, the described samples may, or may not, accurately represent the surficial seafloor conditions. Another key factor in the ability to 'ground truth' seismic data is the accuracy with which the position of the ground truthing data (e.g., sidescan or photographs) can be determined relative to the location of the seismic data. Simpkin addresses this issue and concludes that there is an along-track uncertainty (between photos and seismic data) of approximately 25 meters and an unknown across-track uncertainty. While the collection of simultaneous information provides higher quality data than previously available for this sort of analysis, the positioning uncertainties ascribed to this data set put severe limitations on the analysis of the data and must certainly be addressed in future studies.

Data preparation and manipulation:

Simpkin's choice of ensemble and window length are reasonable and well supported by his arguments. He modifies Cochrane's approach to filtering and designs a high-pass filter that better meets the specific objectives of this study and appears to have better overall performance than Cochrane's. A significant difference between Simpkin's results and Cochrane's is the presence of a well defined spectral null in Simpkin's data that is not present in Cochrane's. This is particularly disturbing inasmuch as the same algorithmns were used to calculate the spectra. Simpkin carefully analyzes this 'null' and, through the use of synthetic response calculations, concludes that the null results from interaction between the boomer plate and an internal hydrophone not used in Cochrane's study. The presence of this null can have important ramifications on the analysis of coherence data and thus, a proper understanding of its origin is essential. Though Simpkin's explanation is quite plausible, more detailed study of the 'null' phenomenon is necessary if this technique is to be pressed to its quantitative limits.

Results:

Qualitative comparisons of power, cross, and coherence spectra show reasonable and probably meaningful trends, although a close comparison of the roughness estimates obtained from the photographs with those values calculated from the acoustic data (Simpkin's Table 4.1) reveals a disappointing correspondence; neither the absolute values nor the relative variations between the photographic and acoustic data show a high degree of correlation. Given the number of assumptions and estimates necessary to derive these values, however, this lack of correlation is not unreasonable. Particularly troublesome is the lack of direct height information from the bottom photgraphs necessitating an indirect determination of height based on lateral dimensions and empirically derived relationships. Since Heezen-Hollister relationship used in this study was derived from deep-sea photographs (where depositional processes are quite different) it may not be directly applicable to this data set. Also, it is difficult to know what rms roughness to use for gravel deposits. The inappropriate choice of this value could cause significant errors.

Added to the above-mentioned sources of error are the positioning uncertainties previously discussed and the question of the lateral resolution of each system. Photographs provide one scale of resolution of bottom features, sidescan another, and the seismic data yet another. Are valid comparisons being made? Simpkin briefly addresses these issues, but before further work is done, these problems should be studied in some detail.

Realizing the limitations of his data and the fact that it is <u>changes</u> in bottom roughness that are of the greatest concern,

Simpkin develops a technique for the continuous display of coherence data. This is unquestionably the primary contribution of this report. The coherence display takes one step back from an absolute quantitative result, but, in doing so, allows the eye to detect subtle features that are not as readily noticable in numerical data. The trends in coherence displayed in the continuous data are reasonable and, in general, correlative with the photographic results (there are interesting discrepancies with the sidescan data but this may be due to the differences in lateral resolution discussed before). While there is much more work to be done along these lines, this initial result clearly demonstrates the potential of the technique.

Recommendations:

Simpkin has presented a carefully conducted study of the ability to use quantitative acoustic data to determine seafloor roughness. In particular, he has developed a technique for the continuous display of coherence data that appears to have potential as a real-time indicator of changes in seafloor roughness. His ability to 'ground truth' his results is limited, however, by the numerous sources of error introduced by positioning uncertainties, differences in lateral averaging scales, and assumptions made in the analysis of the photographic data. If this work is to continue (and I think that enough evidence has been presented to warrant its continuation) I would recommend the following:

1- A carefully controlled field experiment should be planned. Several small (perhaps 500m x 500m) areas with characteristic roughness features should be surveyed. DTS tracks should run in several directions spaced at most 1 Fresnel zone apart resulting in complete insonification of the bottom and a test of the angular dependence of the coherence estimates. Overlapping sidescan records (at several frequencies - if possible) should be collected along with overlapping <u>stereo</u> photos of at least part of the area. Ideally all data would be collected at the same time with the sensors on the same vehicle, but realistically several vehicles will have to be used. Nonetheless, positioning uncertainties can be all but eliminated if each vehicle were navigated within the same transponder network. For a survey of this size positioning accuracies (relative - which is whats important here) of on the order of 1 meter are achievable. Several transponder navigated <u>box cores</u> should be collected to 'ground truth' the photographs. The stereo photos can be analyzed photogrametrically resulting in a detailed contour map of the region (with a contour interval of centimeters if time and money are available). These detailed surveys of small, well defined areas then become the ground truth against which the roughness estimation

techniques can be evaluated. Also, before these surveys are conducted, the system parameters (source signature, beam pattern, etc.) should be carefully documented in order to provide a handle on the role of instrumental artifacts (e.g. the spectral null) in the coherence calculation.

2- An error anlaysis (e.g. sensitivity study) should be performed on the existing (and new - if collected) data set permitting a quantitative estimate of the sensitivity of the results to the errors associated with each variable. The results (e.g. γ^2 and γ_R) should be reported with well defined error limits.

3- An evaluation of lateral resolution associated with each of the roughness-determining techniques (sidescan, photos, subbottom) is essential to insure that valid comparisons are being made.

The completion of recommendations 1 - 3 will hopefully remove many of the ambiguities presently associated with the Grand Banks data. If, after completion of recommendations 1 - 3, poor correlation still exists between the different means of estimating seafloor roughness, then the fundamental theoretcal considerations have to be re-evaluated. If these controlled experiments produce encouraging results, attention may then be turned to the more ambituous goal of producing an underway sediment classification scheme. In particular efforts may be directed towards:

1- improving the means of displaying coherence and the delineation of the most sensitive and useful metrics for roughness determinations (as discussed by Simpkin).

2- the evaluation of other statistical schemes - particularly Empirical Orthonormal Functions (EOF's) as a means of separating coherent (reflected) from incoherent (scattered) energy.

3- the investigation of the contribution of the subsurface to surficial roughness estimates and estimates of subsurface roughness.

4- the incorporation of reflectivity, roughness and attenuation metrics into an underway sediment classification scheme.

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by

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