Modal Inversion SW06 Experiment

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LONG-TERM GOALS

Develop methods for rapid assessment of sediment properties relevant for acoustic propagation in a range-dependent shallow water environment.

OBJECTIVES

Modal dispersion data have been used in inversion schemes that estimate sediment properties in a range-independent environment. This method has been extended to include range-dependent environment. In the Shallow Water 2006 experiment data were collected to perform inversions using both mode dispersion data and mode eigenvalues. The overlapping data sets collected during the experiment provide a direct means of comparison and evaluation of compressional wave speed profile estimates from mode dispersion data and mode eigenvalues

APPROACH

Inversion scheme that uses the modal dispersion data for estimating sediment acoustic properties in a range independent environment has been described in the literature [1, 2]. This approach has been modified to determine the sediment properties in a range-dependent environment as outlined in [3].

MODAL INVERSE METHODS EXPERIMENT (MIME)

During 2006, a series of experiments were conducted in the general area of the Hudson Canyon off the coast of New Jersey. One component of the experiments was Modal Inverse Methods Experiment (MIME). The objective of this part of the experiment was to validate modal inverse methods, i.e. one based on modal eigenvalues and the other that uses modal dispersion data, for the estimation of the sediment acoustic properties.

In order to obtain mode dispersion data broadband signals were transmitted using J-15-3 source. These sources have good response in the band of 50 Hz-600 Hz. Broadband signals (Linear frequency modulated signals) of duration 0.5 seconds and in the band 40 Hz – 290 Hz were transmitted from this source. The signaling scheme at each source location consisted of repeated transmission of the LFM signal. The signals were transmitted every 3 seconds and the total transmission time was approximately 12 minutes. The broadband transmissions were made on Julian Days 216, 217, and 218. The locations of these transmissions were approximately along two arcs. The data were collected at six receiver locations. Out of these six, five were single hydrophone units (SHRU 49-53) and the sixth was an array (SHARK) which had 48 elements (16 element vertical array and 32 element horizontal array). The locations of the transmissions and the receiver units are in the top left panel of Figure 1.

During the course of the experiment, the sound speed structure in the water column was obtained using a CTD chain. In addition the ships sub-bottom profiler was used to determine the bathymetry.

RESULTS

A. Estimation of travel time

The first step in the estimation of the range-dependent sediment properties is the determination of the travel times of the modes. This is done by the time-frequency analysis of the received signal. In our analysis we have concentrated on data collected on Day 217 and Day 218. Though the data for Day 216 had good SNR, it was noted that during the time of the transmissions on this day strong internal wave activity was present in the region which affected the propagation of the modes and hence caused errors in the determination of the mode arrival structure.

Mode travel times are determined by performing time-frequency analysis of the signal acquired at the receiver. Short Time Fourier Transform (STFT) is one of the techniques used to perform time-frequency analysis. Time-frequency resolution of the STFT is independent of location in the time-frequency plane. A modification to STFT termed D-STFT makes the tiling in the time-frequency plane dependent on the dispersive character of the propagating waves. This leads to more accurate estimations of modal arrival times. A brief description of the method and the procedure used for the application of this method are described in [3]. All mode travel time estimates were obtained using D-STFT.

B. Geo-acoustic Inversion

In order to determine the range-dependent compressional wave speed in the region between the source and receivers, the region was divided into 11 regions. The division of the regions into eleven regions are shown in the top left panel of Figure 1. For estimating sediment compressional wave speed profile for the six regions 41, 42, 51, 52, 61 and 62 mode travel time data obtained from transmissions made on day 217 were used. The shot locations were Pings 13, 14, 15, and 16 of Day 217 and receiver locations were that of the Shark vertical array, SHRU 51 and SHRU 53. For estimating the sediment properties of the remaining five regions, data obtained on day 218 were used. The shot locations were pings 7 and 8 of day 218 and the receiver locations were that of the Shark vertical array, SHRU units 50, 51, 52 and 53.

In performing the inversion, the sediment was assumed to be horizontally stratified. A total number of 16 layers with each layer thickness of 2 m was assumed. The only unknown was the compressional wave speed in the layer. The layers were terminated by a half space. The density in the layer was assumed to be 1.6 gm/cc and in the half space 1.8 gm/cc. The attenuation in the sediment layers were ignored.

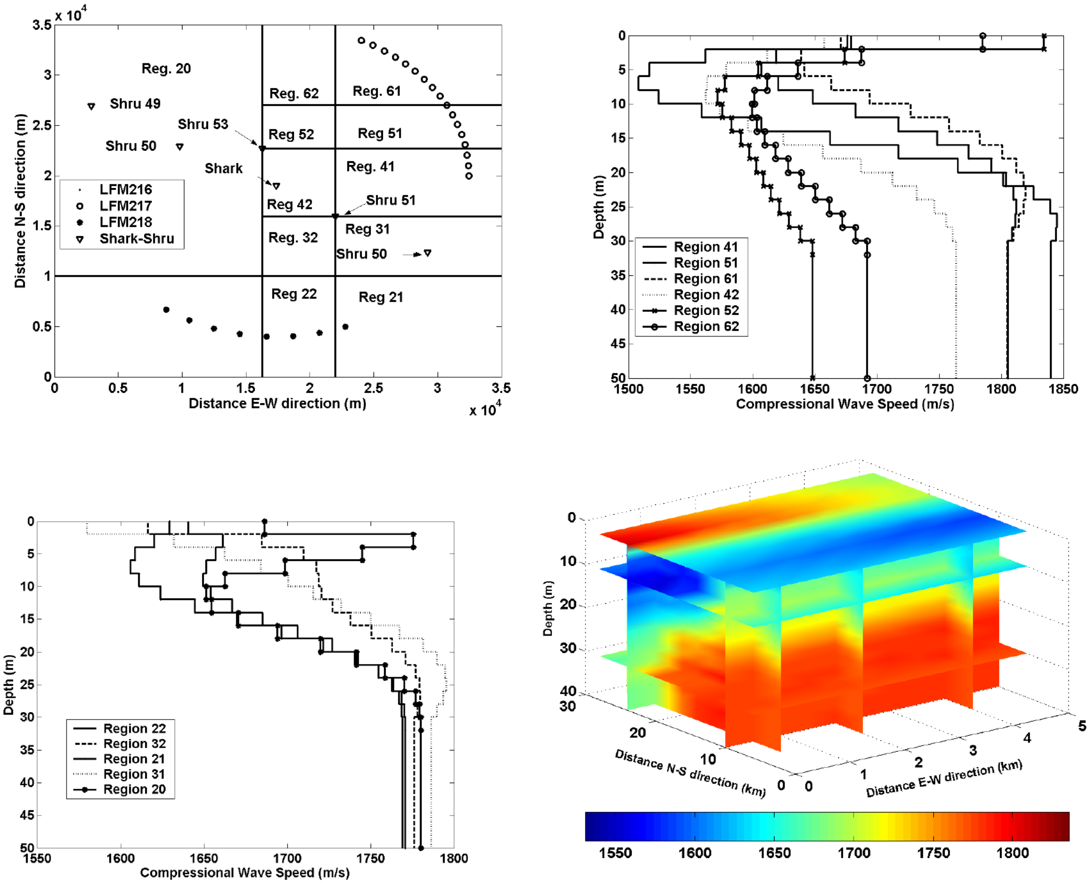

Figure 1. The top left panel shows the eleven regions for which the compressional wave speed profiles were estimated. The figure also shows the location of receiver units and shot location. The shots 13, 14, 15 and 16 on day 217 are in the NE region with shot number increasing from the top. The shots 7and 8 on day 218 were in the southern region with the shot number increasing from the west. The top right panel shows the compressional wave speed profiles for six regions and the bottom left panel shows the compressional wave speed profiles for the remaining five regions. The bottom right panel shows a 3D represention of the compressional wave speed for a volume representing the region 21, 22, 31, 32, 41, 42, 51, 52, 61 and 62. This was obtained by interpolation of the profiles of the ten regions.

In order to compare the performances of inversions using vertical array and horizontal array data, the sediment compressional wave speed at the location of the Shark array was done using the mode travel time determined from data acquired at the horizontal array elements. The distance of the horizontal array element closest to the vertical array is 3 m and that of the element farthest from the vertical array was 468 m. The elements of the array are approximately straight and lie in the north-south direction. The group speed of the modes were obtained by estimating the mode travel time to two elements on the horizontal array. Knowing the distance between these elements and the distance of these elemets from the source the group speed of the modes were obtined. The compressional wave speed profile was then estimated using the mode group speeds. The profiles obtained by this method is similar to the profile for region 42 where the horizontal array is located. This shows the consistency of the inversion method.

C. Validation of the results

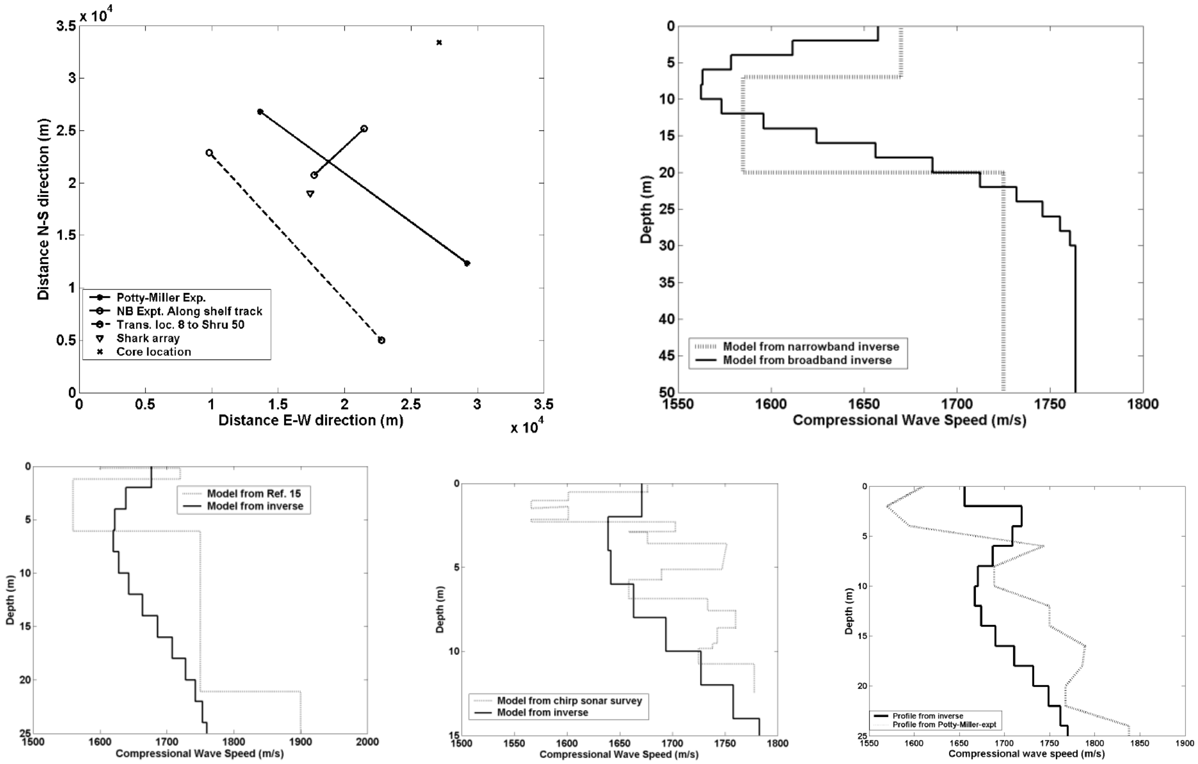

Figure 2. The top left panel shows locations other experiments conducted in the experimental area by other investigators. The top right panel compares the compressional wave speed profile obtained from inversions using modal eigenvalues (Ref. 4) and mode dispersion data. The bottom left panel shows the compressional wave speed profile proposed for general area of SW06 (Ref. 5) and the average profiles from inversions based on mode dispersion data. The bottom middle panel compares the profile from core data(Ref. 6) with that obtained from mode dispersion data and the bottom right panel compares the compressional wave speed profile obtained by Potty and Miller (Ref. 7) with the profile obtained by inversion of mode dispersion data. The tracks along which the data for the Potty-Miller experiment was conducted and the track for mode dispersion experiment were parallel to each other and are shown in the top left panel.

In order to validate the results the mode travel time data obtained from the model was compared with the values obtained from experimental data and good agreement between the two was observed. Additionally the models obtained form mode dispersion data were compared with results from other experiments. The location of the experiments are shown in the top left panel of Figure 2. In the top right panel of Figure 2, we compare the model obtained from modal eigenvalues with the model obtained from mode dispersion data. General agreement between the two models is seen. In the bottom left panel the average compressional profile from the mode traveltime inversions is compared with a compressional wave speed model suggetsed in Reference 4. This model is based on core/chirp survey data collected in the area by many investigators. Again the general agreement between the two models is observed. In the bottom middle panel we compare the model estimated from mode dispersion data with the model obtained by a core (Reference 5). The bottom right panel compares the model from data collected by obtained by another investigator during SW06 experiment with the model obtained by this investigator. The transmissions were along parrelel tracks as seen in the topleft panel of Figure 2. Again general agreement between the two model is observed.

CURRENT WORK

As indicated earlier, during transmissions on Day 216 strong inernal wave activity was observed. The possibility of estimating the time evolution of water column sound speed structure during these transmissions using the data acquired on that day is being investigated. The work is currently in progress.

IMPACT/APPLICATIONS

The data collected during this experiment will enable validation of the proposed method for estimating range-dependent sediment compressional wave speed from modal dispersion data. Using a distributed set of receivers and a moving broadband source it will be possible to estimate the compressional wave speed profiles over a wide area. This will therefore be a useful tool for rapid environment assessment.

RELATED PROJECTS

A number of investigators were involved in the SW06 experiment. The analysis of their data will also lead to estimation of sediment properties. A direct comparison between the different inversion methods can therefore be done.

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