Seismic Data Processing for Naval Intelligence

Alison Swanson[1], James Ryan[1], Amy Rumish[2], and Joseph Senne[2]

[1]University of New Hampshire, Durham, NH

[2]Naval Oceanographic Office, Stennis Space Center, MS

University of New Hampshire

ABSTRACT

Marine seismic reflection profiling is a technique that is widely used to gather information about the subsurface geologic structure of the ocean floor. This type of data collection involves the measurement of seismic waves that are created at the sea surface and reflected off the geological layers of the ocean floor. Those data are processed to yield a two or three-dimensional profile of the subsurface which represents the acoustic response of the Earth to the seismic source signal. The US Navy uses data collected using seismic reflection profiling to create a tactical advantage in any ocean environment. However, the raw reflection data is often noisy, making it difficult to interpret and requires processing to decrease the noise and increase the return signal. I am investigating several different methods to process seismic data to filter out unwanted noise and accentuate the original sound signal. Thus far, noise filtering using a trapezoidal band-pass filter and then amplifying the data using an automatically generated time-varying gain yields the clearest sub-bottom profile.

INTRODUCTION

In marine seismic reflection profiling, acoustical energy in the form of a sound wave is created by a source being towed behind a marine vessel. The sound wave travels down through the water column and interacts with the seafloor, penetrating into the layers of sediments and rocks below. The transmitted acoustic energy is reflected from the boundaries between various seafloor layers with different acoustic impedances, and travels back up to the sea surface [1]. The reflected acoustic signal is then received by a ship-towed hydrophone, and converted into digitized data that can be interpreted and processed accordingly. **Figure 1** demonstrates this reflection process in detail.

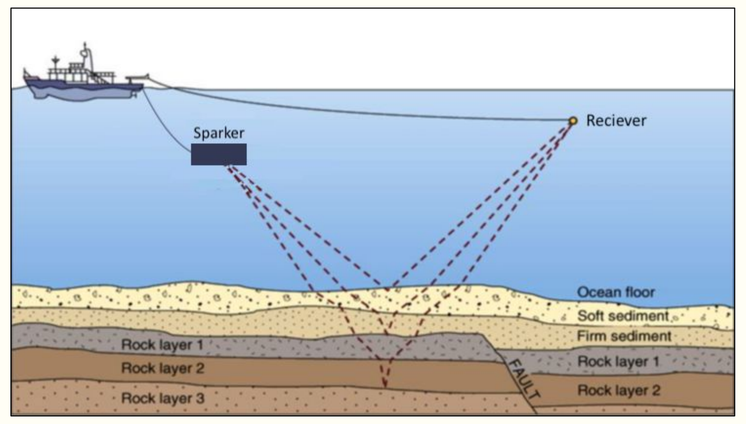

Fig 1: *The sparker sound source and the hydrophone receiver are both towed behind the research vessel. The acoustical energy from the sound source penetrates into the seafloor, reflecting off of the various layers and then returning to the sea surface [2[.*

The seismic reflection data referenced in my work was collected by the Naval Oceanographic Office (NAVOCEANO), from a fleet of seven T-AGS 60 class marine vessels. A SIG ELP100 sparker was used as the source of acoustical energy [3]. For my work, I used Matlab to develop a more efficient way to process seismic data for NAVO. Because of the large size of the datasets, the existing processing methods can take hours to run and provide useful data. I specifically tested scalar gain and time-varying gain, and band-pass, triangular, and boxcar filtering methods in order to yield a clear sub-bottom profile while minimizing the run time.

DATA PROCESSING AND ANALYSIS

Data Format: The Seismic Trace

Conceptually, a seismic wave front can be represented by "wavelets" travelling along a finite number of ray paths (**Figure 2**). Since the acoustical energy travelling through the water is considered a compressional wave, the magnitude of a wavelet represents the change in hydrostatic pressure as the wave encounters a geological boundary.

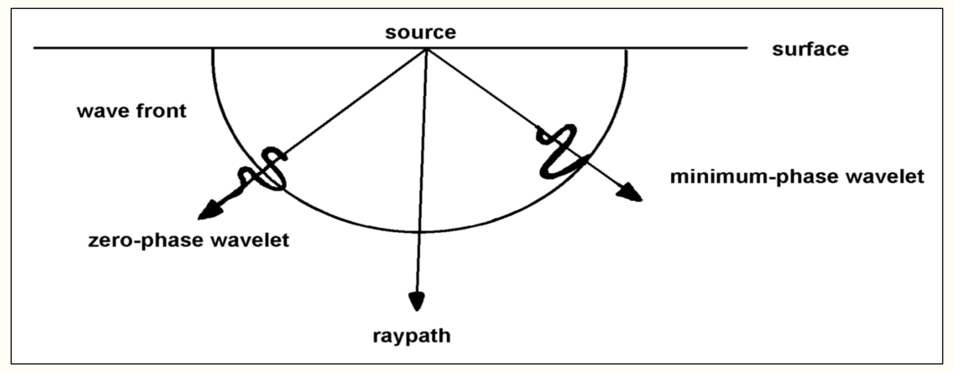

Fig. 2: *Wave fronts can be modelled by wavelets travelling along a finite number of ray paths. The magnitude of the wavelet represents a change in hydrostatic pressure [5].*

A reflection seismic profile is made up of a suite of individual seismic traces, which are a result of merging wave records from a range of angles, ray paths, and source and receiver positions [4]. The amplitudes of the traces are functions of both the reflection coefficients of the geological layers and the transmission loss [5]. **Figure 3** details the transition from an encountered change in acoustic impedance (a geological layer) to a seismic section made up of individual traces.

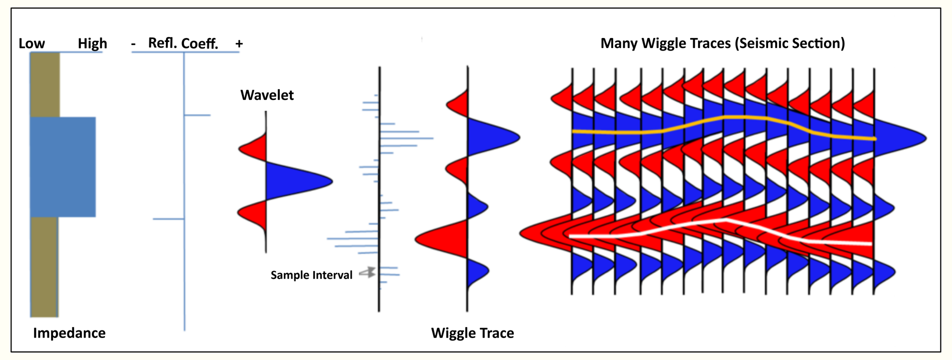

Fig. 3: *A trace is a representation of a change in acoustic impedance between two layers of sediment. When combined, the traces can form an image of the geological layering beneath the seafloor [6].*

Filtering Methods: Band-Pass vs. Triangular vs. Boxcar

Filters are applied to seismic data to enhance the signal to noise ratio and allow coherent seismic reflections to be visible. The acquisition instruments, wind, waves, and any biological interference are sources of noise that can distort and cloud the sound signal from the source. I compared band-pass, triangular, and boxcar frequency filters to see which method would yield the clearest sub-bottom profile. The results of the three filtering methods, along with the raw sub-bottom profile, are shown in the figures below.

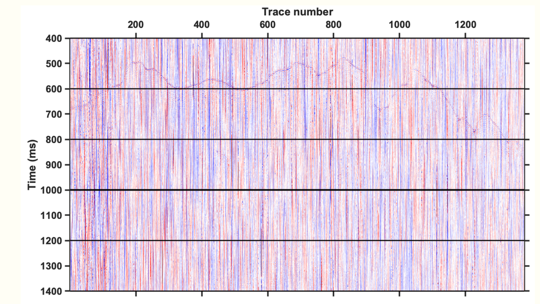

Fig 4: Raw Data

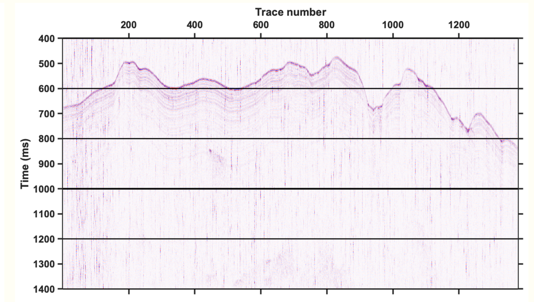

Fig 5: Boxcar Filter
Corner Frequencies: 75, 275 Hz

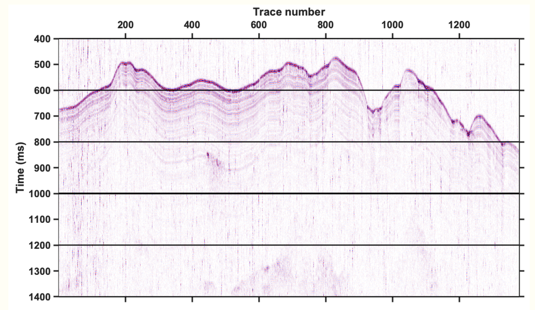

Fig 6: Triangular Filter
Corner Frequencies: 75, 150, 325 Hz

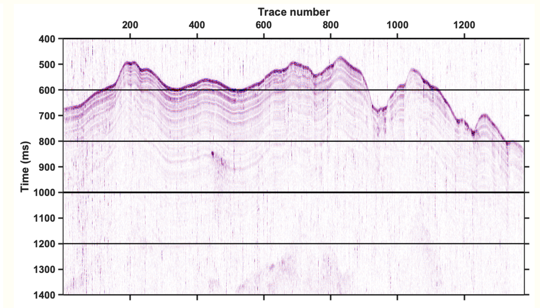

Fig 7: Band-Pass Filter
Corner Frequencies: 100, 150, 200, 250 Hz

Gaining Methods: Scalar vs. Time-Varying Gain

Gain is usually applied to seismic data because many data quality issues are related to the amplitudes of the traces. Trace amplitudes can be easily distorted, and high amplitudes on a plot can make it difficult to see necessary fine detail elsewhere. Applying a gain to the data can refine the filtering process and result in a more robust sub-bottom profile.

My seismic data processing method took two kinds of gain into consideration: scalar and time-varying gain. A scalar gain multiplies the amplitudes in each trace by a scalar value, as shown on the band-pass filtered data in **Figure 10.** Time-varying gain (also called automatic gain control) normalizes amplitudes across a whole trace, accounting for the increasing attenuation of the wavelet with time. This gain process is shown on the band-pass filtered data in **Figure 11**.

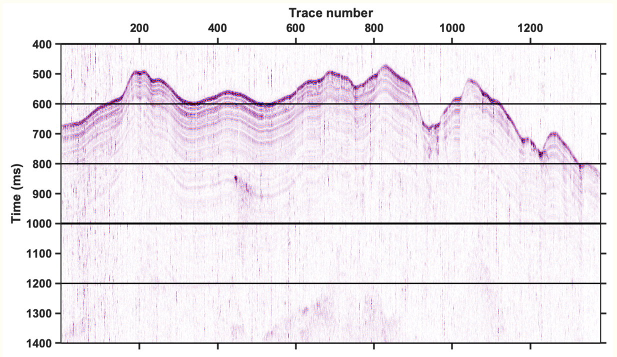

Fig 9: Original Band-Pass Filtered Data

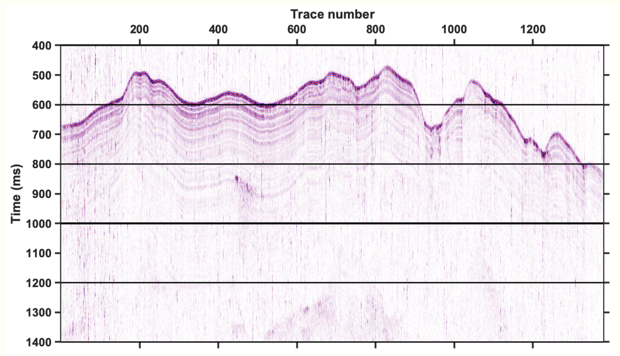

Fig 10: Scalar Gain of x10

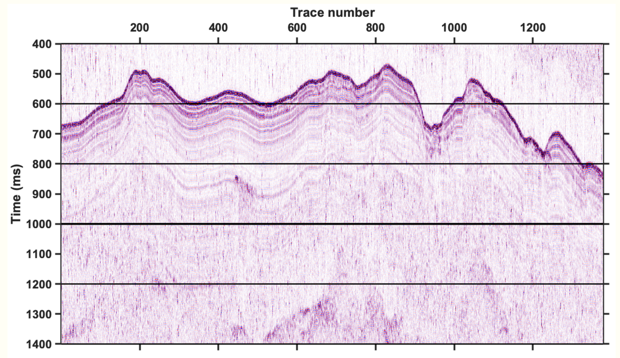

Fig 11: Automatic Time-Varying Gain

CONCLUSIONS

After completing the data processing and analysis with the selected filters and gain functions, noise filtering using a trapezoidal band-pass filter and then amplifying the data using an automatically generated time-varying gain yields the clearest sub-bottom profile. I applied this process to two more seismic datasets, shown in the figures below, for further confirmation that it would lead to the clearest sub-bottom profile.

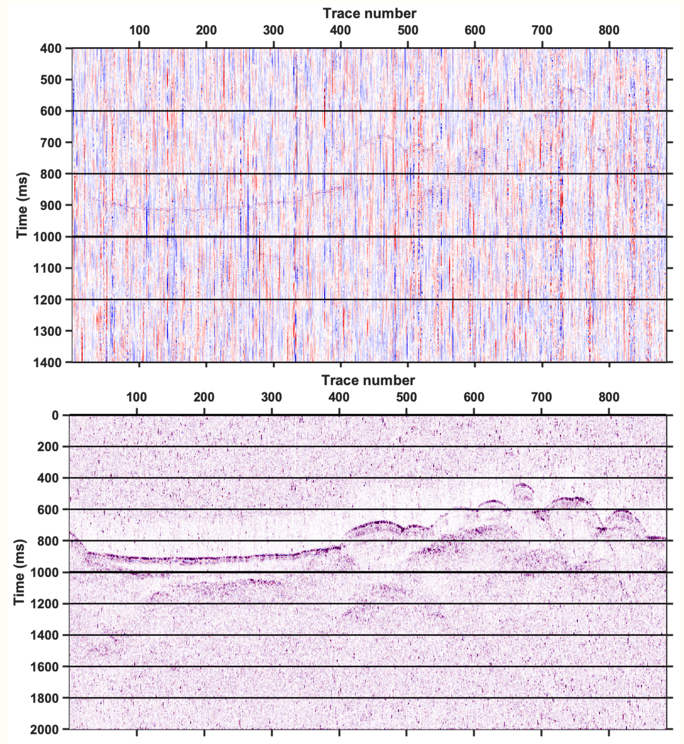

Fig 12: *(top) raw seismic reflection profile, (bottom) processed seismic reflection profile*

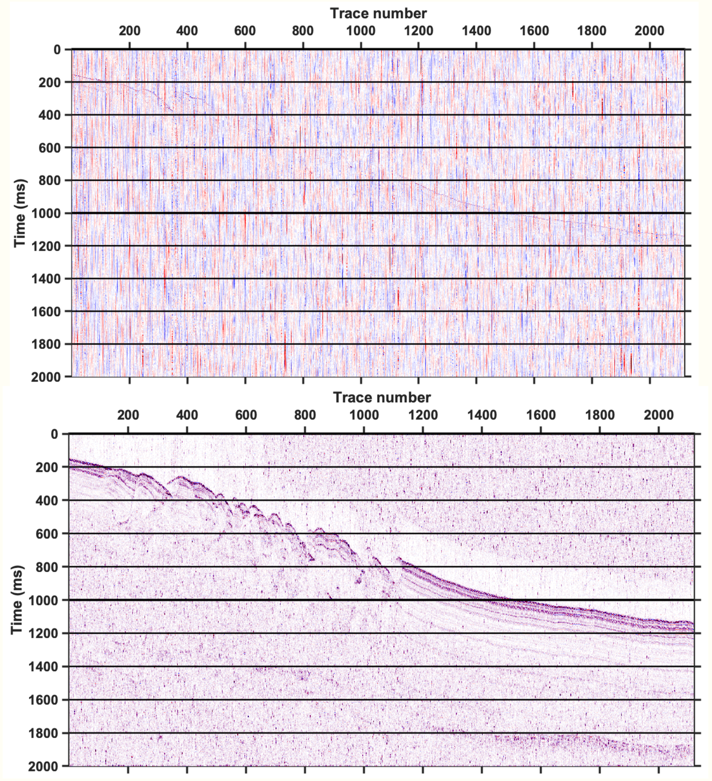

Fig 13: *(top) raw seismic reflection profile, (bottom) processed seismic reflection profile*

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