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Comparison of amplitude and frequency content of VDS files with different compression tolerances

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Abstract Summary

The purpose of this work is to explore the conversion of seismic files from SEGY to VDS (Volume Data Store) and analyze the impact of different wavelet compression tolerances in the amplitude and frequency contents of the seismic data. This study was conducted through a SEGY to VDS conversion benchmark with a set of Brazilian public data from Sergipe and Santos basins. The methodology of the benchmark consisted in performing quality control of the SEGY files, converting them into VDS using wavelet compression method with different tolerances, and generating amplitude and frequency spectra. As a result, it was possible to compare the variation of the VDS spectra in relation to its original SEGY and qualitatively evaluate the difference associated with the selected tolerances.

Introduction

In the last years, with the exploration and development of new and existing oil and gas fields, the demand of the industry for seismic data has considerably increased. Whether in acquisition, processing and imaging, or interpretation, advances in technology allow the generation and consumption of large amounts of data. With that, the requirement for high-performance computing and data management systems has also increased, leading to the search for optimized solutions for data storage and access.

In that context, the Bluware Volume Data Store (VDS™) was conceived in 2003 to overcome the inherent limitations in existing seismic formats. Adopting concepts developed in the gaming industry, where interactive performance is critical, the VDS is a powerful and flexible storage format for multi-dimensional signal data (The Open Group and Bluware, 2025). It can be stored both on premises and on a cloud object store, making it well-suited for any workflow and environment, such as the OSDU® Data Platform (cloud-native), where it was defined as the seismic data standard in 2022 (Bluware, 2022).

Apart from being suitable for any storage environment, converting seismic data to VDS format allows compression at different rates while preserving the original SEGY headers information. Its structure, organized in brick format (Figure 1), enables random access to data, enhancing the usage of deep learning techniques and complex processing and interpretation workflows. Features such as these result in optimization on storage and performance, especially on cloud environments.

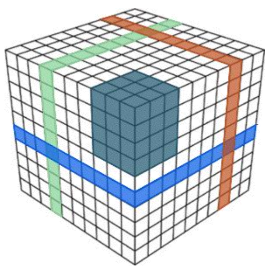

Figure 1: VDS normally stores data as cubes (dark blue), which allows fast random data access. It is also possible to duplicate the data as 2D-slices (red, green, bright blue) along one or more axes, which allows very fast slice-based access (The Open Group and Bluware, 2025).

A conversion from SEGY to VDS format can be set up using different parameters. The selection of each parameter will vary depending on the use case for that data, whether it is for archive, daily usage, high-performance visualization or other. The present work aims to evaluate the impact of compression tolerance on the signal content of real seismic data through the analysis of amplitude and frequency spectra of VDS files generated with different tolerances.

Method and Theory

The conversion of seismic data from SEGY to VDS format is performed through the application of a wavelet transform based on the embedded zerotree wavelet algorithm (Shapiro, 1993). An effective image compression algorithm that allows the quantization and compression of pixels through their transformation into functions coefficients. The compression, using lossless or lossy encoding, is well-suited for floating-point data that has some smoothness or continuity, while still preserving sharp boundaries (The Open Group and Bluware, 2025).

A SEGY conversion using lossless wavelet compression generates a VDS where all data content is stored without any loss and can be decompressed back into SEGY format in its original state. This is achieved by additionally storing the difference between the original and the wavelet compressed data. It can be relevant for data preservation, where some storage cost reduction can be achieved while still enabling fast data access when not applying the lossless difference. Lossy compression, on the other hand, leaves out the difference between the compressed data and the original, which leads to much higher compression ratios. Since using lossy compression is generally much more efficient, it is essential to investigate what level of compression can safely be applied to seismic data. However, it is important to highlight that, in terms of data content, compression can be understood as a bandpass filter, meaning that, at low rates, the data removed does not contain real or relevant information and can be considered as noise.

The compression quality is governed by the compression tolerance parameter. According to The Open Group and Bluware (2025), this value is the maximum deviation from the original data value when the data is converted to 8-bit using the value range. A value of 1, for instance, means the maximum allowable loss is the same as quantizing to 8-bit, however, the average loss will be much lower, as it will, in general, be an order of magnitude lower than the allowable loss (The Open Group and Bluware, 2025). By specifying high tolerances, the data will be highly compressed, use little storage space, but artifacts might be introduced. Conversely, less compression will use more storage space while preserving data accuracy (The Open Group and Bluware, 2025).

The goal of this work is to evaluate the loss of data using different compression tolerances on conversion from SEGY to VDS. To perform it, the workflow consisted of: (1) data selection and quality control; (2) conversion using lossy wavelet compression method with tolerances of 0.01, 0.1, 1, 10 and 100; and (3) analysis of amplitude and frequency spectra from SEGY and VDS files. The data selected comprised of public seismic volumes from Sergipe and Santos basins. The conversion process was executed using Bluware proprietary software, Headwave™, which also enabled the visualization of the volumes and generation of the spectra for analysis.

Results

Figure 2 presents the amplitude spectra of a PSDM volume from Libra field in the Santos basin. It shows the overlapped spectrum of the input SEGY and each VDS generated with the selected tolerances. It is possible to notice a displacement of the VDS spectrum in relation to the SEGY in different ranges, especially on the edges. This becomes more evident for the VDS generated with higher tolerances, such as 10 and 100, which shows some differences even in amplitudes around 0. As mentioned before, this behavior is expected, as conversions using higher tolerances will preserve less data accuracy due to higher compression.

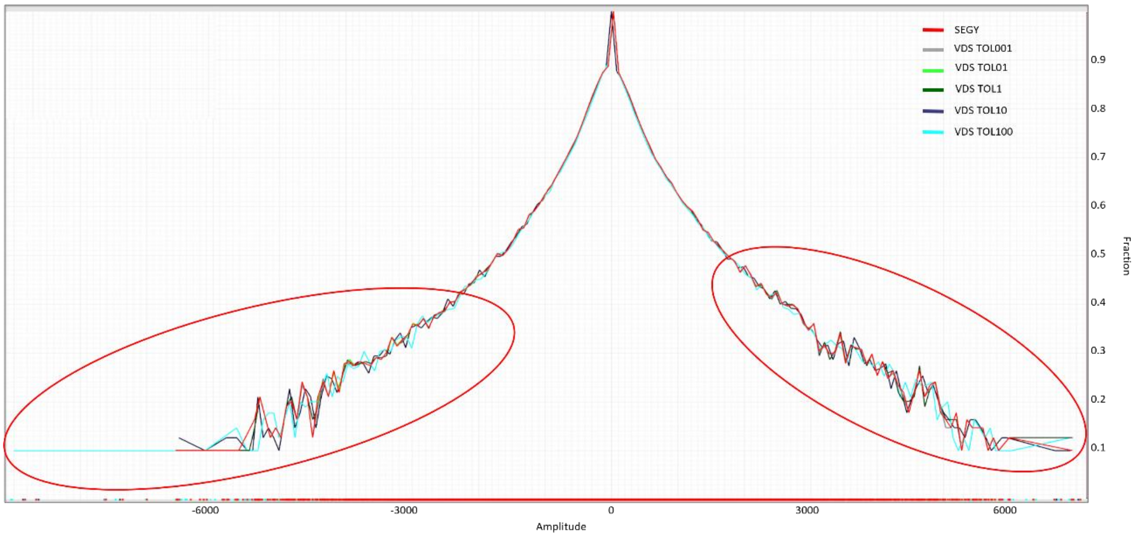

Figure 2: Overlapped amplitude spectrum of SEGY and VDS files of a PSDM volume from Libra field. The red circles indicate the amplitude range where the VDS amplitude varies more in relation to SEGY.

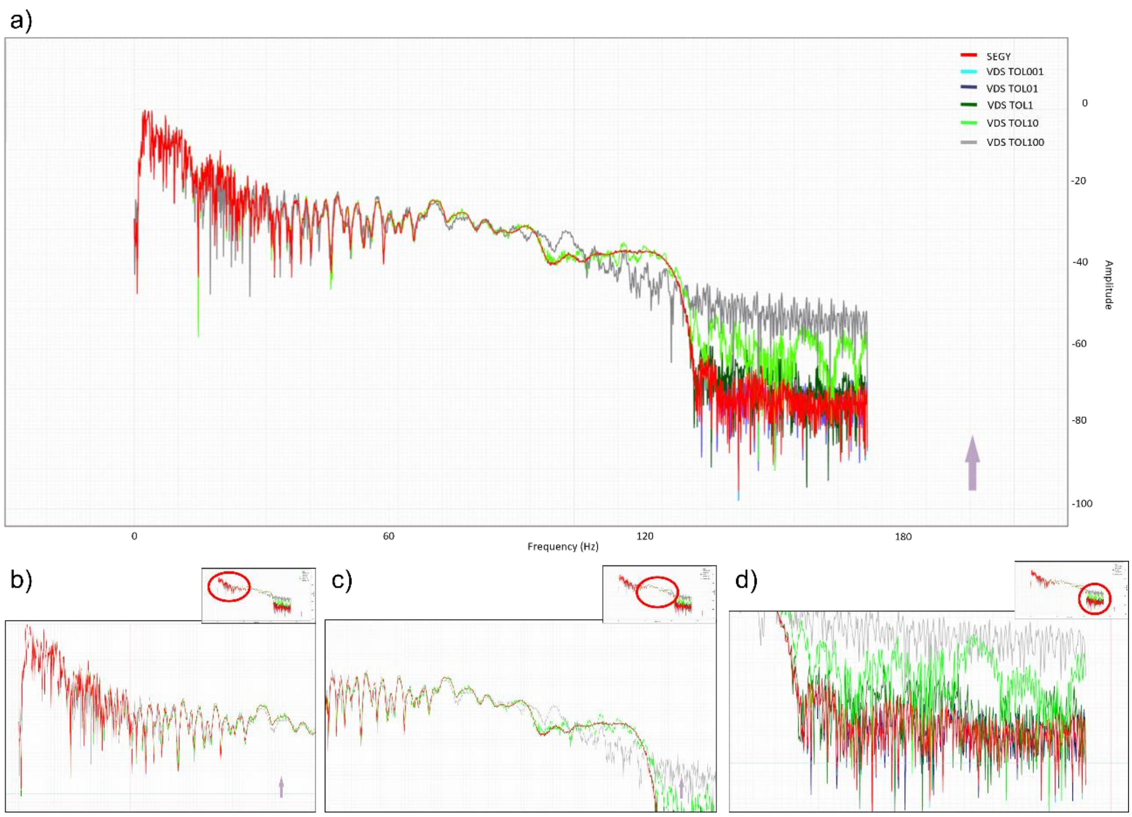

Figure 3: Full frequency spectrum of SEGY and VDS files of a PSDM volume from Libra field overlapped in a) and zoomed sections at low frequencies in b), medium frequencies in c) and high frequencies in d).

Figure 3 shows the frequency spectra of the SEGY and VDS files from the same data. Similarly, the VDS that shows greater difference in relation to SEGY are the ones generated with tolerances of 10 and 100. It can be observed, mainly in the zoomed sections (Figure 3b, 3c and 3d), that at low frequencies the mismatch is smaller, and it increases along with the frequency.

According to Rosa (2018), due to limitations of the seismic method, at the end of the data processing of a typical marine survey, the maximum useful frequency obtained rarely reaches 100 Hz. Analyzing Figures 3a and 3c, it can be noted that, although the frequency spectrum of the VDS generated with tolerances of 10 and 100 presents more significant differences in relation to their input SEGY, these differences become more evident at frequencies above 90Hz, that may not be useful for further processing and interpretation.

Conclusions

The Bluware Volume Data Store (VDS™) proposes an evolution for seismic data standards that supports cloud optimization on storage and performance. The choice of parameters for conversion will depend on the usage of the data and the target balance between reduced storage and signal fidelity. The selection of the compression tolerance parameter in a conversion from SEGY to VDS is directly related to the compression quality of the data and to its accuracy preservation. The results showed that converting SEGY with lower compression tolerances yields to VDS that has similar frequency and amplitude content to its input, while the usage of higher tolerances leads to greater variation on the signal data. Although considerable differences were observed between the SEGY and VDS spectra, especially at high compression tolerances, they were located mostly in ranges that may not harm processing and interpretation workflows. Further evaluation can be performed with the use of the generated VDS as input for such workflows to assess the real impact on the final products of seismic projects.

Acknowledgments

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