

# Decon comparisons between Burg and conjugate-gradient methods

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## ABSTRACT

In testing on several nearby data sets, three shown here, the Burg method of deconvolution exhibited no issues of numerical round-off. In every case it did exhibit whiteness, an aspect of the theory normally considered desirable. Prediction-error code based on conjugate gradients (actually conjugate directions) showed some minor issues. Output comparisons of the two were never perceptibly different on paper documents such as this. When those same PDF documents are viewed on a screen, differences might be noticeable with “blink” screen presentation. Doing no more than the number of iterations theoretically predicted (equal to the number of filter coefficients) gave differences generally noticeable with blink presentation. Tripling the number of iterations made the differences much smaller, sometimes differing at a mere handful of pixels. Although discrepancies were minuscule on the filtered data, the differences are quite clear in a spectral comparison. Differences tend to occur at the very high and very low frequencies that are weak in the field data.

## INTRODUCTION

The classical stationary linear least-squares deconvolution problem may be solved in a variety of ways. While testing our new sparseness deconvolution method (non-causal, non-linear, hyperbolic penalty) we had occasion to use some classic methods for comparisons. In particular, we used the Burg decon code (Claerbout, 1976) and the conjugate direction (CD) code (Pef in Claerbout and Fomel (2012)). In the absence of precision issues, the CD code is theoretically equivalent to the conjugate gradient method. Unexpectedly, during our early studies some astonishing differences appeared. Were these differences due to coding bugs, improper comparisons, or precision issues not previously recognized by us? Perhaps all. These two methods do differ in some fundamental aspects, principally but not entirely related to end effects. Another difference is that the Burg method assures a minimum-phase filter but that is not true of the regression methods in GEE, namely Pef.

## PRECISION AND ACCURACY

Focusing on precision we arrange our study so end effects are minimal and the stationarity assumption is not stressed. We are not attempting an exhibition of known theoretical differences, but we do intend to obtain for practical work, guidelines for dealing with poorly understood numerical-analysis issues.

Reflection data is not stationary; and it comes exhibiting diverse aspects [reference Yilmaz and Cumro shot profiles]. We chose simply to test with several of our current data sets of interest. Results with three of them are included here. To simulate stationarity, Kjartansson t-squared gain is applied. We also taper the ends of the trace to avoid any transients there. Additionally, we average spectra of hundreds to thousands of traces in each data set. This average spectrum is used to devise a single decon filter applied to every trace in the data set.

We were not aware of precision issues with the Burg method, neither were we aware that it has been tested under modern environments where high order filters are easily computed.

The conjugate-direction method in GEE has some issues likewise never investigated. Theoretically it converges in a number of steps equal the filter length, but this says nothing about precision. It is easy enough to do more iterations than required. Thus we have compared the theoretical number of iterations with triple that number. Accuracy greater still should be obtainable by an additional measure that we did not try. The algorithm proceeds by updating a residual. These updates might accumulate errors. Thus, the residual could be recomputed from time-to-time during iteration. The textbook program `Pef` in GEE is not doing that. We could have tested that additional grasp for precision, but we did not.

More fundamentally, the Burg method builds in the stationarity assumption and minimum phase (by assuring a sequence of reflection coefficients is bounded between  $\pm 1$ ). The `Pef` code (concerned with multidimensional data containing gaps) makes no such effort. It could predict a growing function which is obviously non-stationary. Does that mean the output of `Pef` could be non-white? Likely so, but we don't know if that is a practical issue.

## RESULTS

We began by using the usual Kjartansson  $t^2$  gain correction. One power of  $t$  is a geometrical divergence correction. The other power of  $t$  is the expected loss of bandwidth propagating through a constant- $Q$  medium. Not wanting to study the end-effect differences between the two methods (as they are already well defined by theory) we taper both ends of each seismogram to zero.

We compute the spectrum of each data set in the usual way. We average the energy spectrum of each trace, then take the logarithm of the average, and finally

shift the logarithm as a function of frequency to be zero at 40Hz.

### Log spectra of DATA2

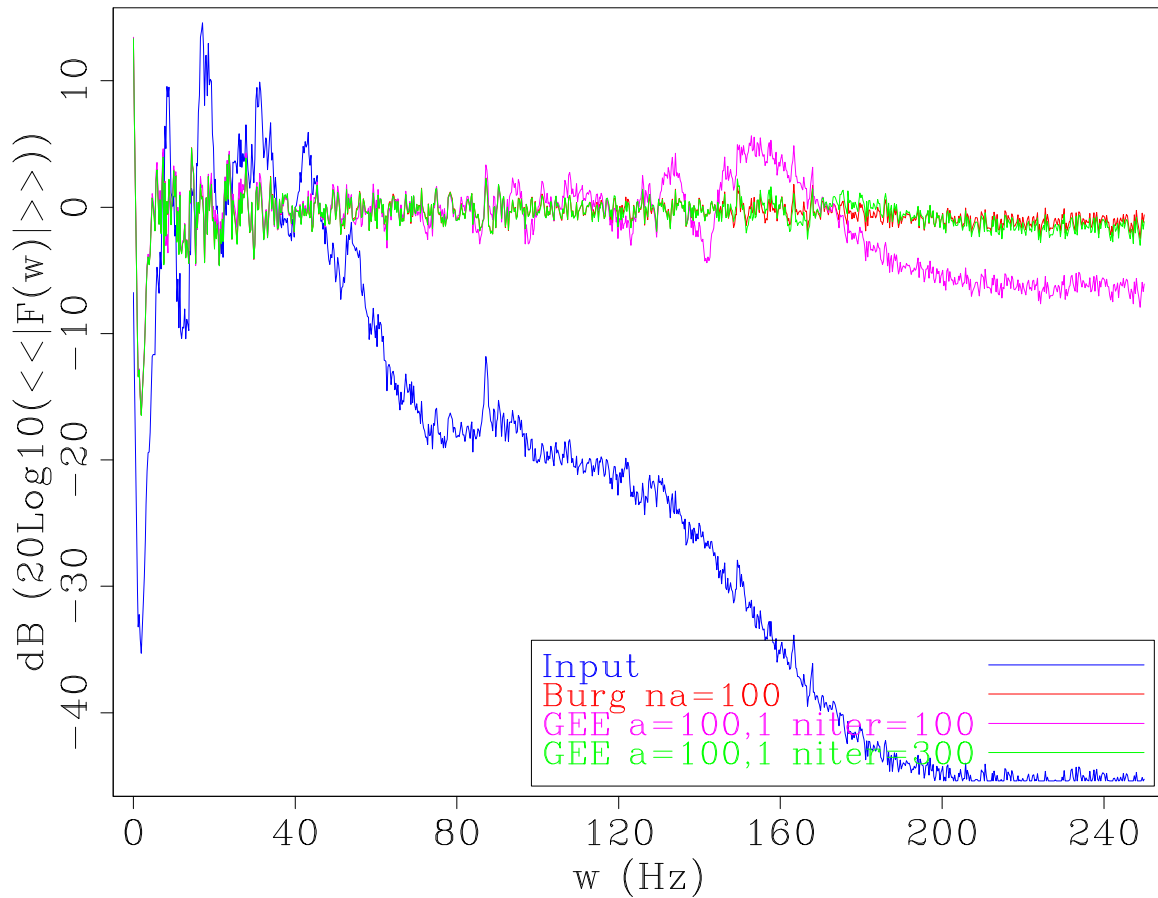


Figure 1: The log spectrum of the the Kjartansson data set and decon outputs by the three different methods. The wide ranging spectrum is that of the input data. The two near constant spectra are the Burg and the “triple iterated” CG decon outputs. By triple iterated we mean  $3\times$  the number of iterations theoretically required. The “not-so-near-constant” curve arises from CD with the theoretically needed iterations, namely, as many as the filter coefficients. This curve seems to resist the theoretical requirement to boost very low and very high frequencies (which in practice might not be a bad idea!). [ER]

### REFERENCES

Claerbout, J., 1976, *Fundamentals of Geophysical Data Processing*: Blackwell Scientific Publications.

Claerbout, J. and S. Fomel, 2012, *Image Estimation by Example: Geophysical Soundings Image Construction*: Class notes, <http://sepwww.stanford.edu/sep/prof/index.html>.

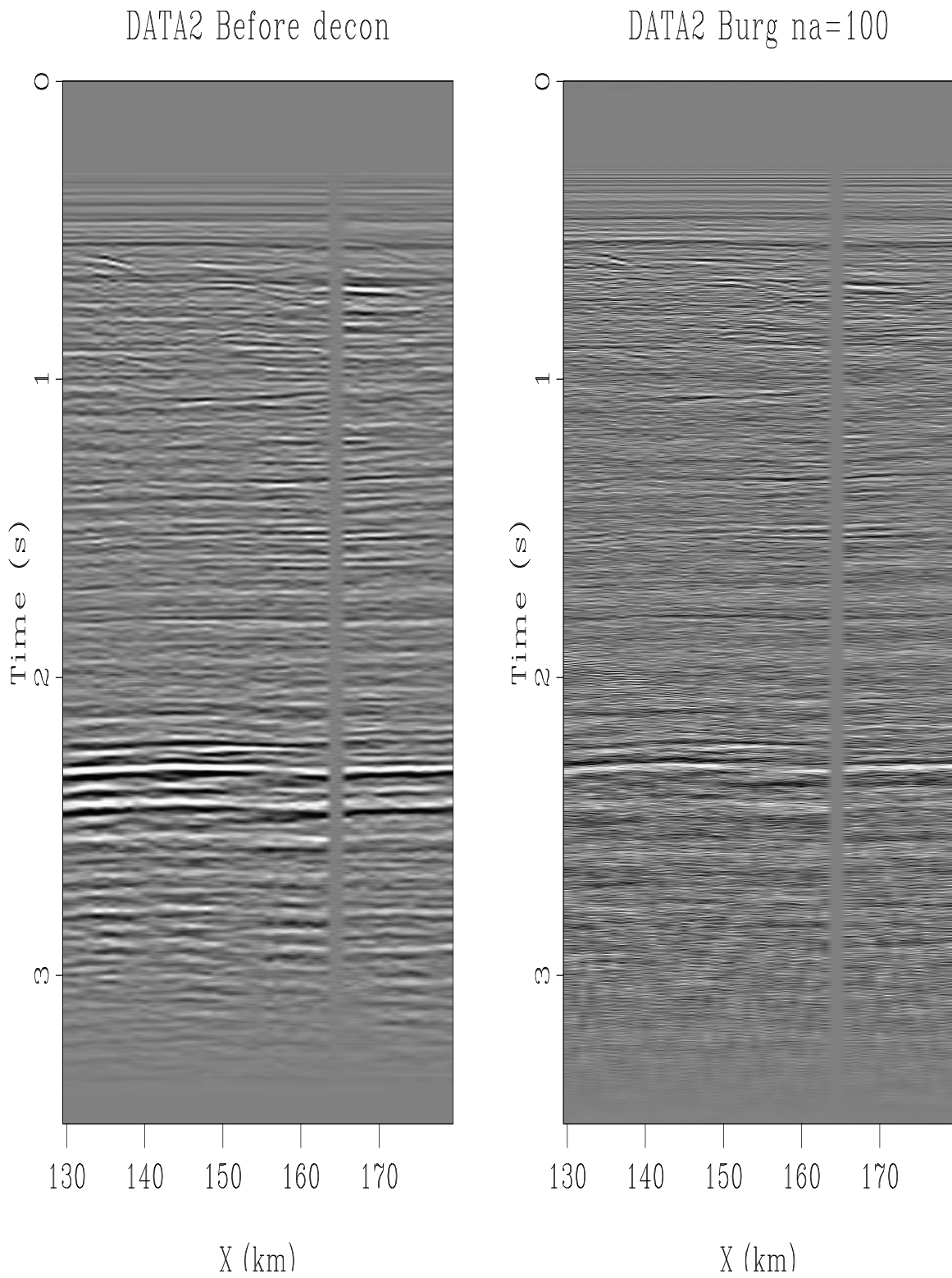


Figure 2: Left is a portion of the Kjartansson data set. Right is its Burg decon. Outputs of the CG Pef were on paper indistinguishable from Burg decon, but slightly distinguishable when alternately blinking on a screen. [ER]

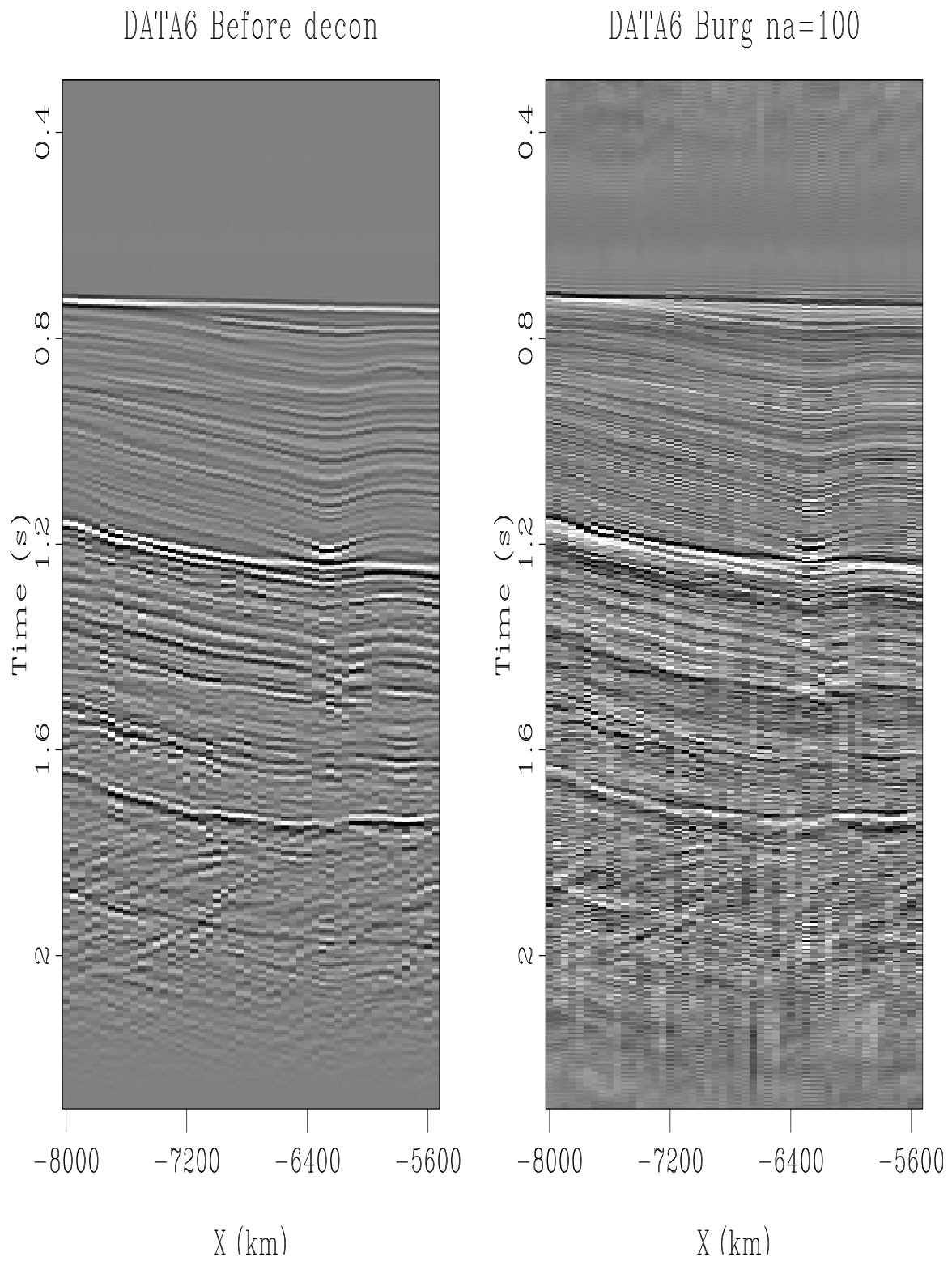


Figure 3: The Gulf of California data set. Unwelcome near-zero frequencies appear from trace to trace. These appeared with all decon methods. Apparent precursors to the water bottom are PDF document artifacts. [ER]

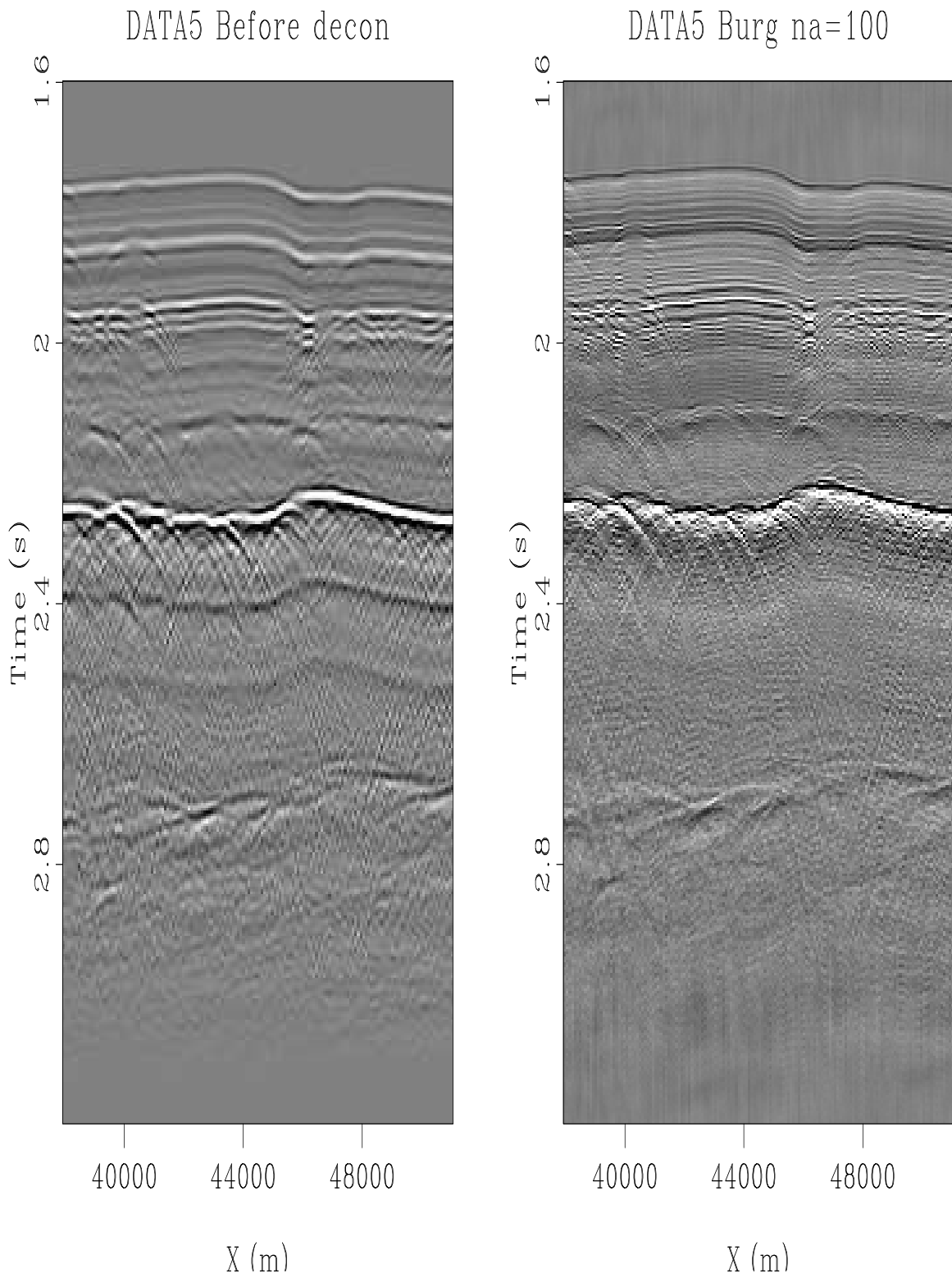


Figure 4: Gulf of Mexico data set. Suspicious low frequencies are strongest following the top of salt reflector at 2.3s but visible throughout the data. Seems likely someone filtered this data before it came to us. [ER]