The experimental comparison of conventional and differential semblance velocity analysis on several 2D exploration data sets

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ABSTRACT

The differential semblance method employs an objective function, which measures the error in moveout between neighboring traces. Differential semblance velocity estimators have well-defined and smooth high frequency asymptotics compared to the conventional velocity analysis. Numerical experiments with CMP gathers and layered models illustrate theoretical properties of DS objectives. (reference from that paper) and also comparison with conventional velocity analysis.

INTRODUCTION

The earth velocity model is composed of a long wavelength scale velocity and a short wavelength scale velocity. Given a good reference velocity containing the long wavelength scale velocity, one may obtain the short-scale velocity components by migration. Within the Born approximation, the core problem is to find an accurate reference velocity, which is to determine the kinematics of waves. DS is an automated velocity method, which flattens image gathers by minimizing the mean square difference of neighboring traces. The goal of the work described in the report is to evaluate DS for:

- Accuracy
- Ease of use
- Reliability of NMO-based DSO using synthetic and field data sets

THEORY

A conventional velocity analysis uses a collection of trial velocities. Each trial velocity is taken to be a constant function of depth and is used to moveout correct the data. Typically the events in the middle of the gather are nearly flattened, whereas the early events are under-corrected and later events are overcorrected. This is typical because the amount of moveout correction varies inversely with velocity, and the earth's velocity normally increases with depth. A measure of the goodness of fit of the NMO velocity to the earth velocity is found by summing the CDP gather over offset stacking power. Presumably, the better the velocities match, the better (bigger) will be the sum. The process is repeated for many velocities. Computer analysis allows one to see peaks in the data, which correspond to stacking velocities. These peaks can be represented in several ways depending on the program used. A weighted average velocity or RMS velocity is used to analyze waves that follow paths to receivers that are offset from the source. Computers perform the analysis using a collection of trial velocities that can be manually or automatically picked.

The DSO method is an automated hyperbola flattening method. One does not need to select the peaks manually. The program stops when the iteration goes to the final interval velocity, whose corresponding RMS velocity flattens the hyperbola. A natural binning scheme for this theory is the common mid point gather. For a layered model, the dataset has a single CMP. When lateral variation of velocity and reflectivity is weak, it can approximate the data as CMPs from slowly changing layered models. So the data set changes from a volume in (s,g,t)-space to a plane in (m,h,t)-space.(s,g is source and receiver location, m is midpoint, and h is the half offset). The velocity parameter is simply the interval velocity $v(z,m)$, whereas the reflectivity is $r = \frac{\delta v}{v}$,which is treated as a perturbation of v. DS deals only with constant density acoustics, so the forward modeling operator F[v] is invertible (modulo smoothing operators) on each CMP. Denote by G[v] an approximate inverse operator for F[v] on each data bin. G[v] produces a prestack reflectivity volume. Each binning scheme also implies a notion for neighboring bins: that is, neighboring source positions, offsets…Denote by W an operator approximating the derivative or gradient in the bin parameters. The definition of F[v] incorporates a cutoff or mute, as does that of G[v]. To control the additional artifacts caused by the differentiation in the bin direction, ϕ is introduced to be a more severe mute factor than the ones in F and G, which eliminates the local edge effects.

So define differential semblance $J_0[v]$ by:

$$J_0[v] = \frac{1}{2}\left\|\phi W G[v] S\right\|^2$$

Here S is the data, the double bar is the L^2 norm or root mean square, i.e the integration of the square of quantity inside over t and h, followed by square root. The inverted reflectivity G[v]S should be h-independent, according to the semblance principle.(J_0 is “raw” differential semblance because it does not make any special provision for dealing with noise.) The following models are the numerical experiments for DS.

PROCEDURE

The velocity parameter is simply the interval velocity $v(z)$. V is defined by using a partially irregular grid (see Dussaud and Symes 2004). V is built through several controlling points, including the depth and its corresponding velocity at each point. This is defined as the initial estimated velocity for the NMO correction, which varies with the initial velocity-depth models. Normally, a linear velocity model is a good first guess; if the data could not be flattened with a linear model, then we would put in some more control points and try to estimate a more complicated (not linear) model. So the controlling points are changed based on whether the data is flattened or not.

We use acoustic 2D constant density linearized simulator program to obtain a shot gather, given a velocity-depth model, which are converted to a single CMP gather. The program is trying to find the most accurate reference velocity model, the variation range of which is from minimum velocity to maximum velocity based on the initial estimated one; the iteration goes until finally: the value of $J_0[v]$ does not change much and $\delta J_0[v]$ is very small, ideally close to zero; and the hyperbolic reflection should be flattened; otherwise, the initial velocity should be modified until finally the seismic event is flattened until we get the final accurate NMO velocity.

MODEL 1: constant stratified media, the so-called "block velocity"; the velocity does not change in each block.

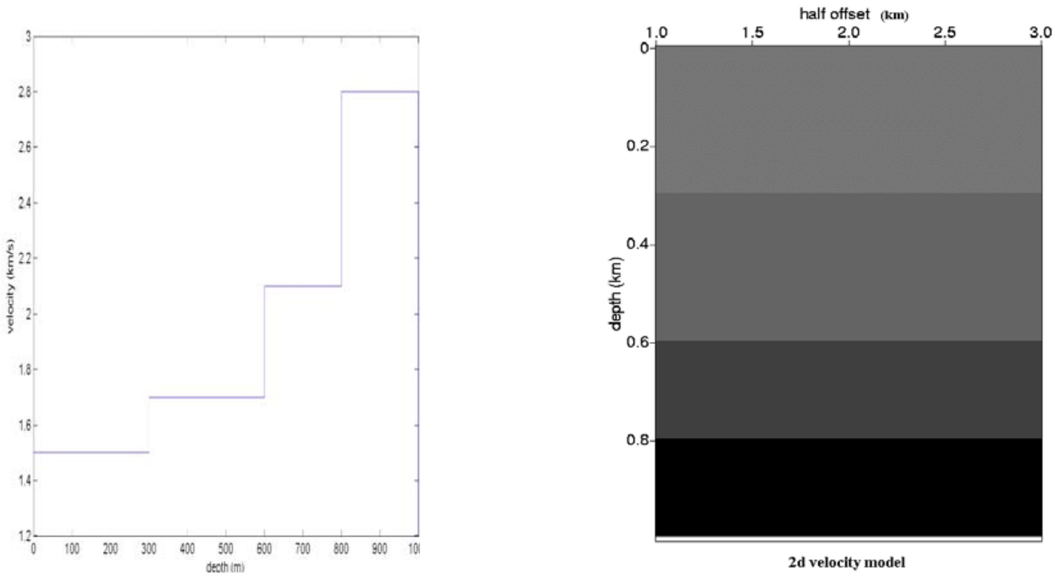


Figure 1.1 Block velocity and its tomography

So we get the CMP gathers and the corresponding corrected CMP gathers as followings:

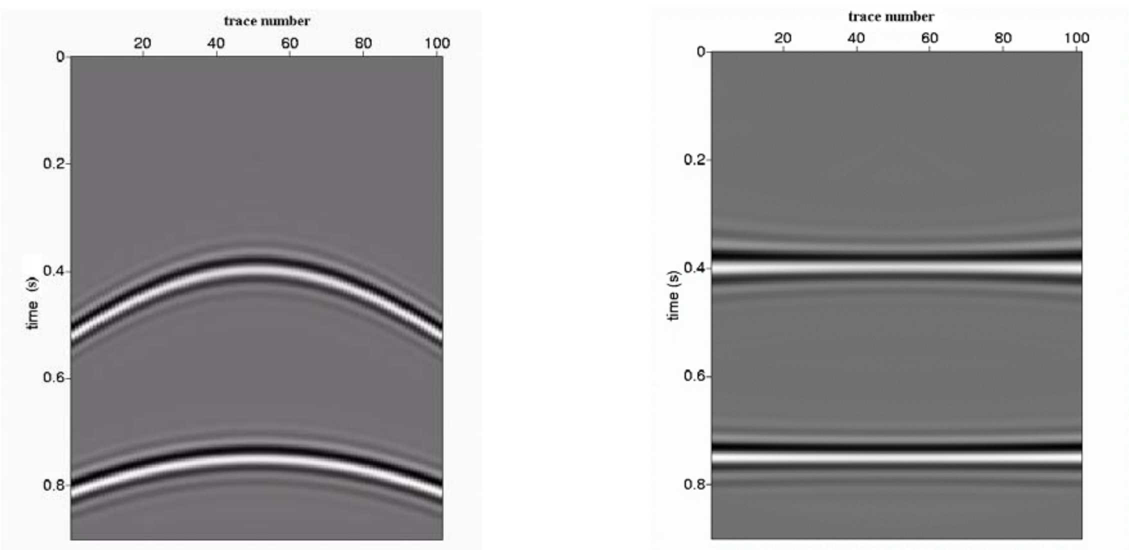


Figure 1.2 CMP gather and the corrected one

At the time around 0.5s and 0.8s, there exist two strong reflections. It's clear to see that after the NMO correction, the hyperbolic reflection is flattened.

MODEL 2

Linear background velocity +short -scale random noise

Using the linear background model and random perturbation (as the earth velocity model is the combination of a linear background velocity and a high frequency short-scale perturbation, which is the born approximation).The relationship is defined as:

Velocity=background +h* perturbation (here h=0.01,1);

We take the following examples with h=0.01(perturbation is chosen as random noise)

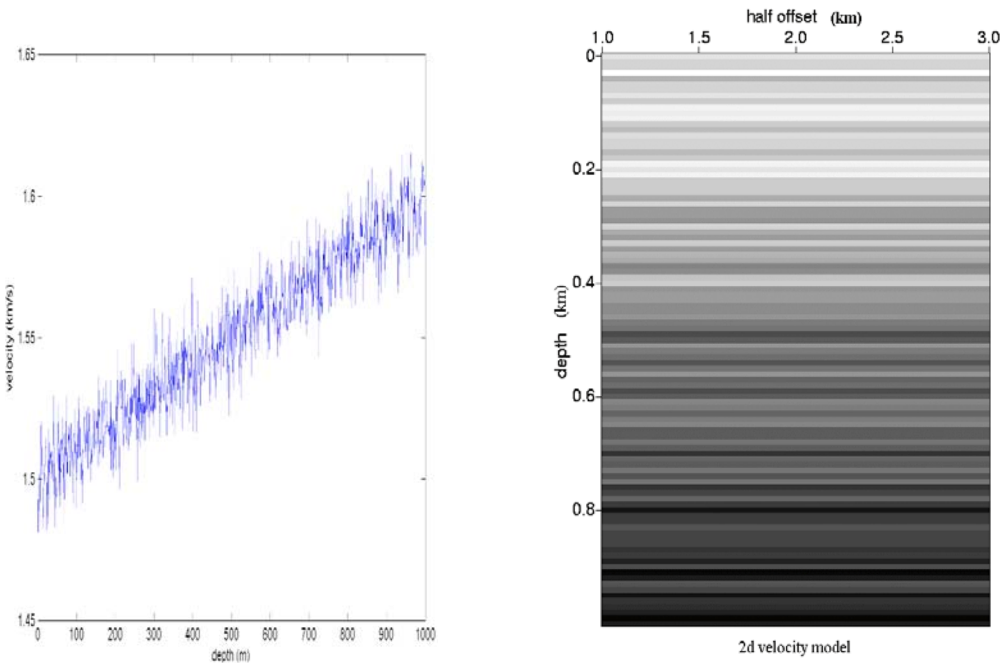


Figure 2.1 linear background velocity model with short-scale random noise and its 2d velocity model

We choose the muted CMP gathers as the followings with h=0.01 and h=1 separately:

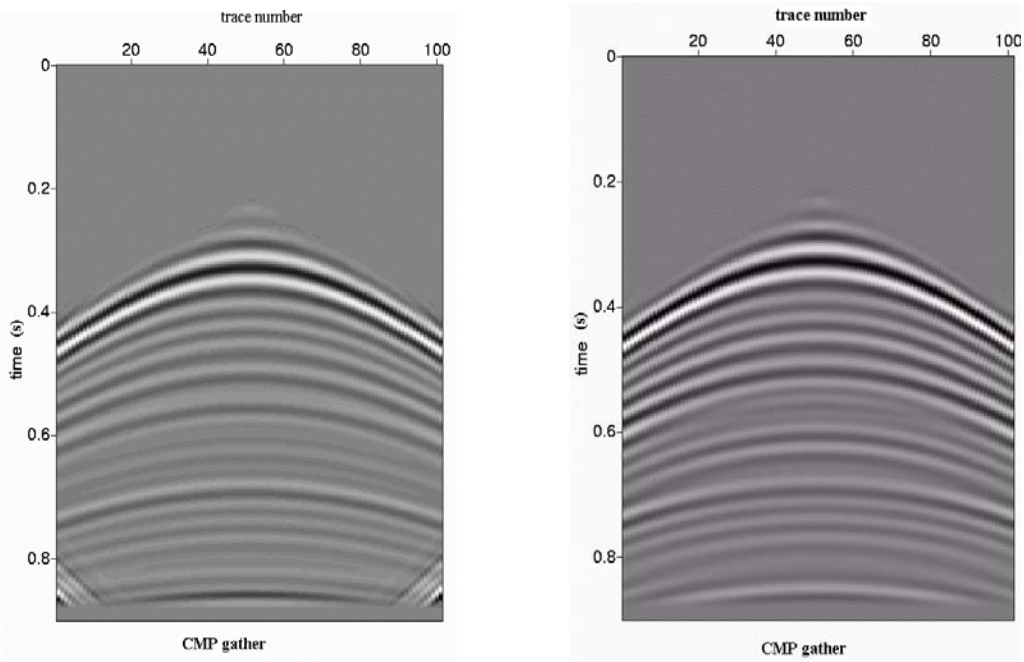


Figure2.2 CMP gathers with h=0.01 (left) and h=1 (right) respectively; from the graphs, we can clearly see that with the increasing h, the multiples reflection takes a larger part of the data.

The corrected CMP gathers are as followings: (still taking h=0.01 and h=1 as examples)

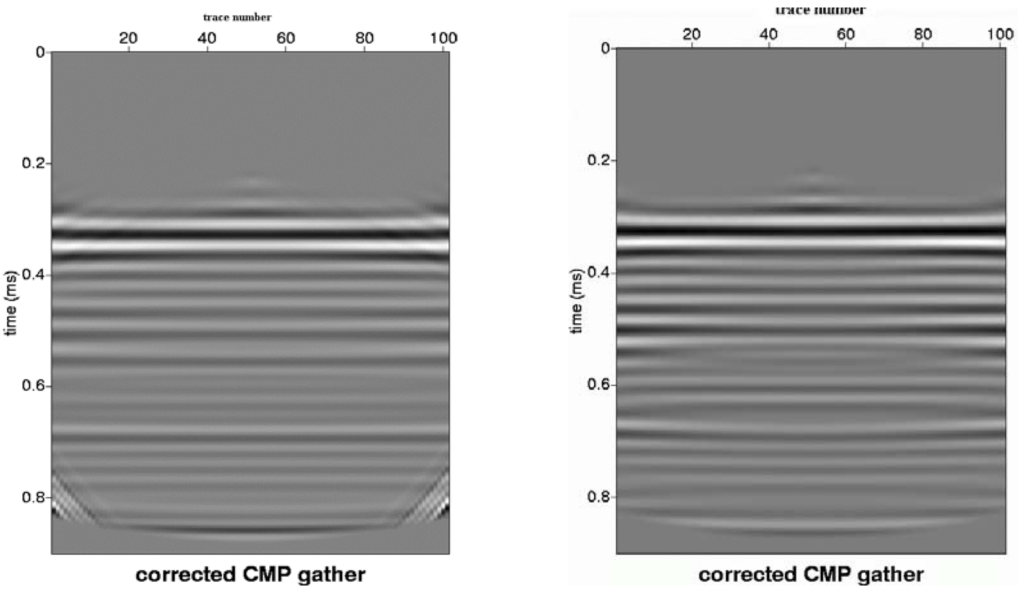


Figure 2.3 corrected CMP gather

We can tell those reflections caused by the multiples since some travel time hyperbolic reflection is over-corrected while some is under corrected. Moreover, by comparing different NMO velocities with different values of p, we found that the estimated velocities are getting smaller as the multiples reflection becomes larger. That means, with more multiples, we need smaller velocities to flatten the hyperbolic reflection since they have more travel time than primary waves.

Comparison of DSO-estimated RMS velocity with velocity scan (h=0.01(left); h=1(right));

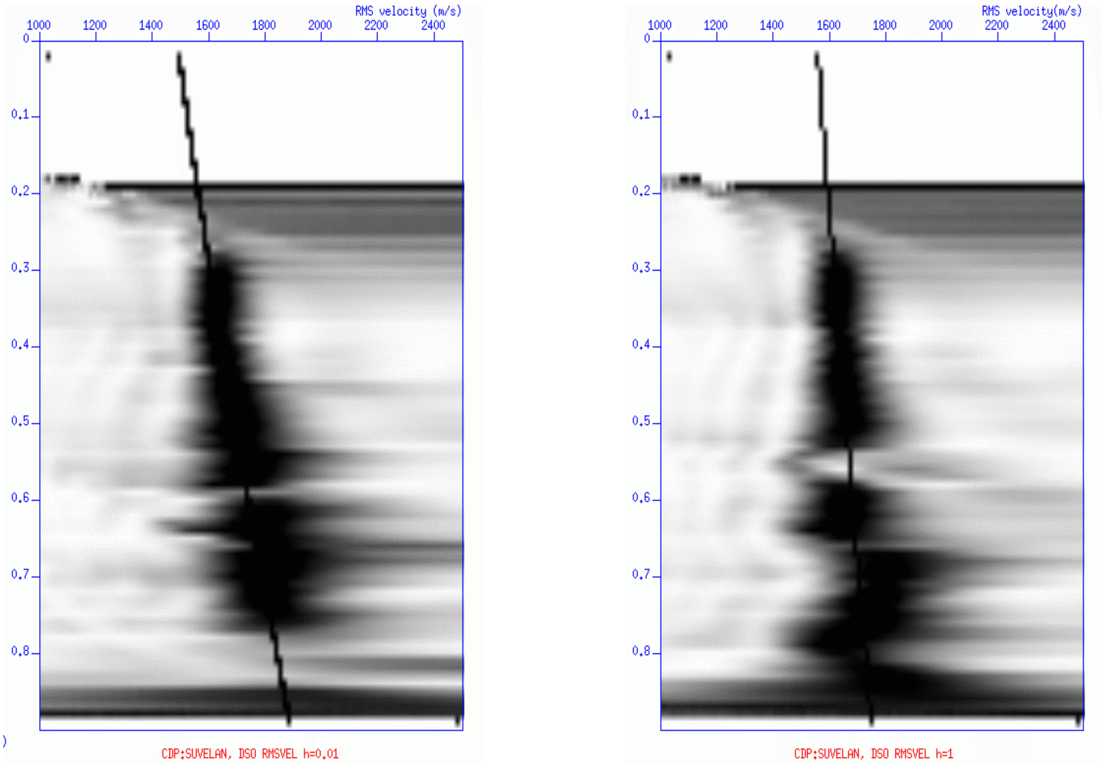


Figure 2.4 Comparison of DSO-estimated RMS velocity with velocity scan

We can see the RMS velocity on the right(h=1) is slightly smaller than the one on the left just because the multiples reflection takes a larger part of data for h=1.

MODEL 3

Marmousi velocity Model (left)

We slice this 2d velocity model at offset 5600m, and get v(z) (right)

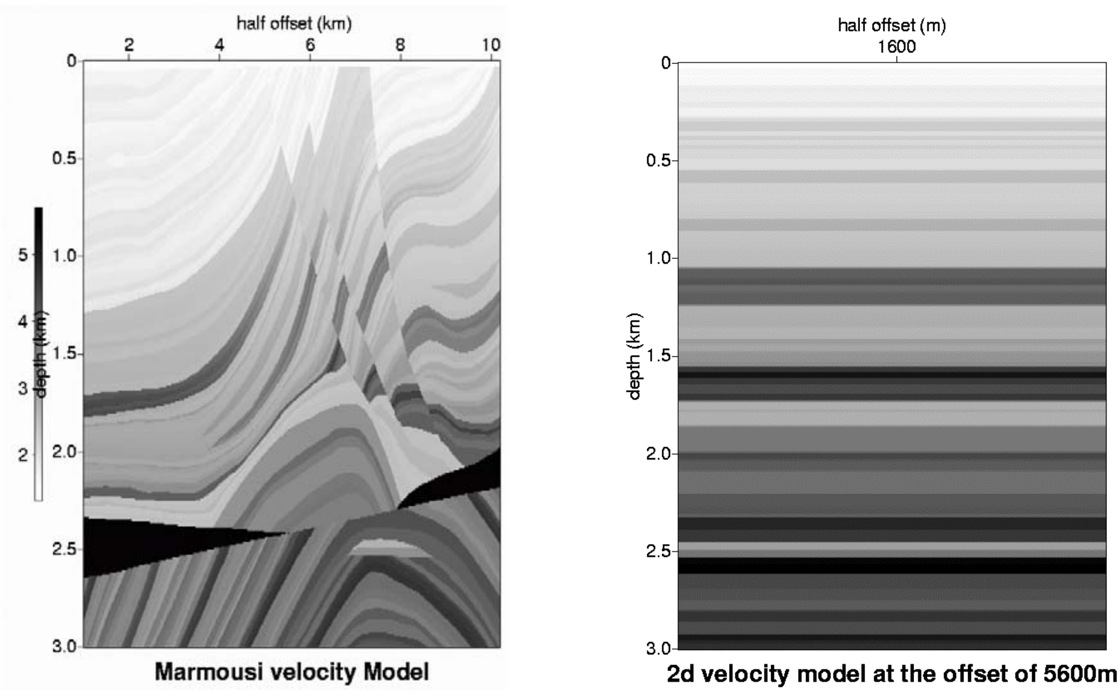


Figure 3.1 the Marmousi Model and sliced velocity model from the offset 5600m

The CMP gathers with and without short-scaled perturbation are as the followings:

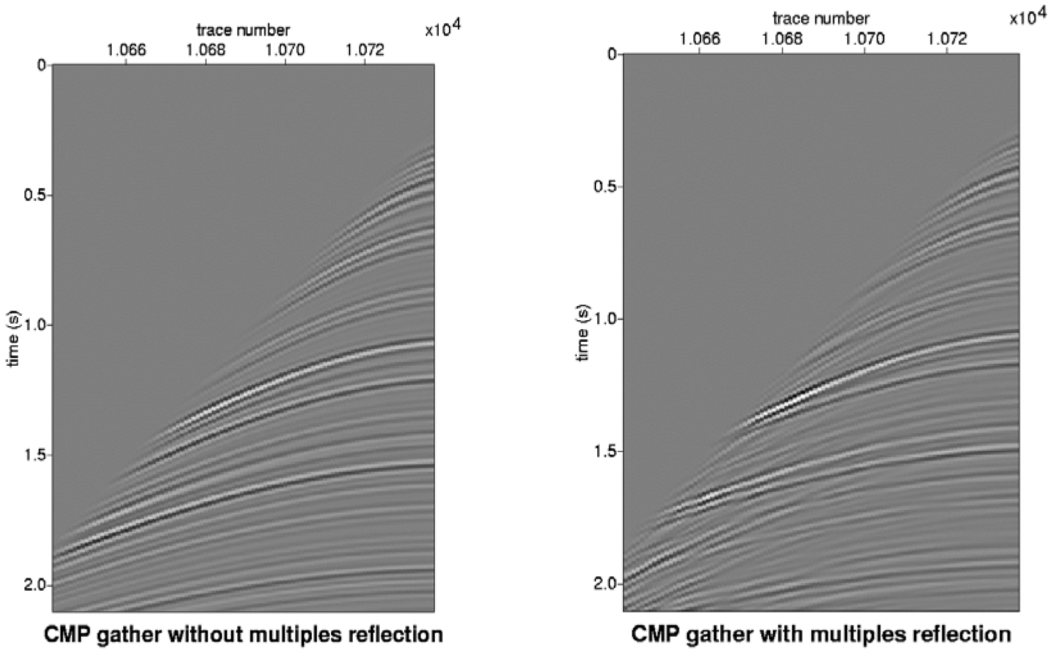


Figure 3.2 CMP gathers obtained by two velocities with/without perturbations.
We can clearly see more multiples on the graph (right).

After DSO:

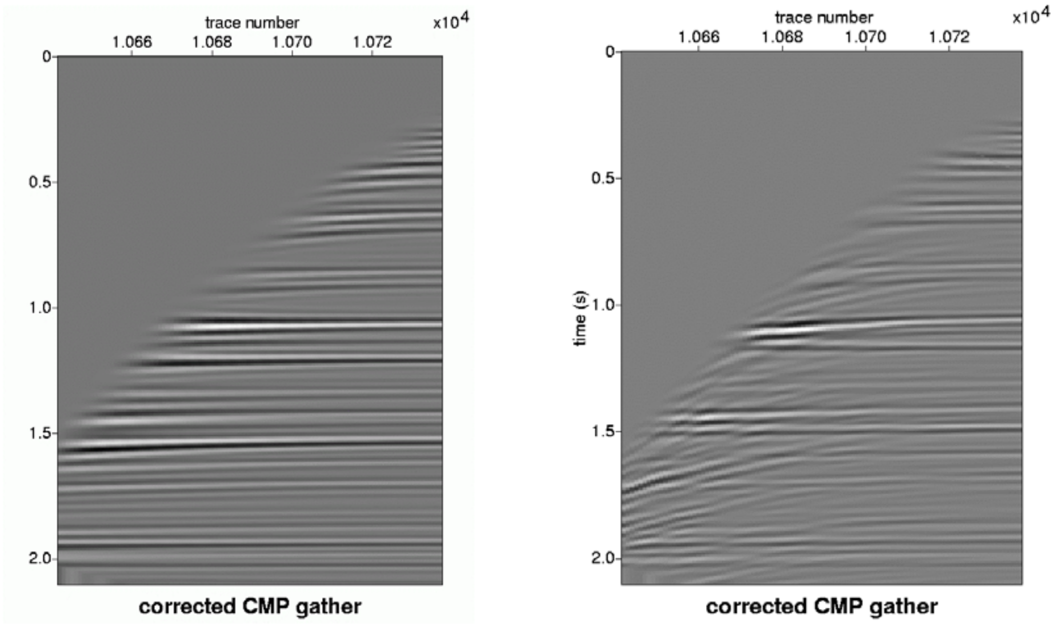


Figure 3.3 The corrected CMP gathers

The CMP gather on the left side is straightly flattened; the CMP gather on the right side, we can see clearly that some of events are over-corrected and some are under-corrected, this is just because of the multiples reflection, which needs smaller velocities to flatten the hyperbola compared to the primary reflections.

We also compare of DSO-estimated RMS velocity with velocity scan:

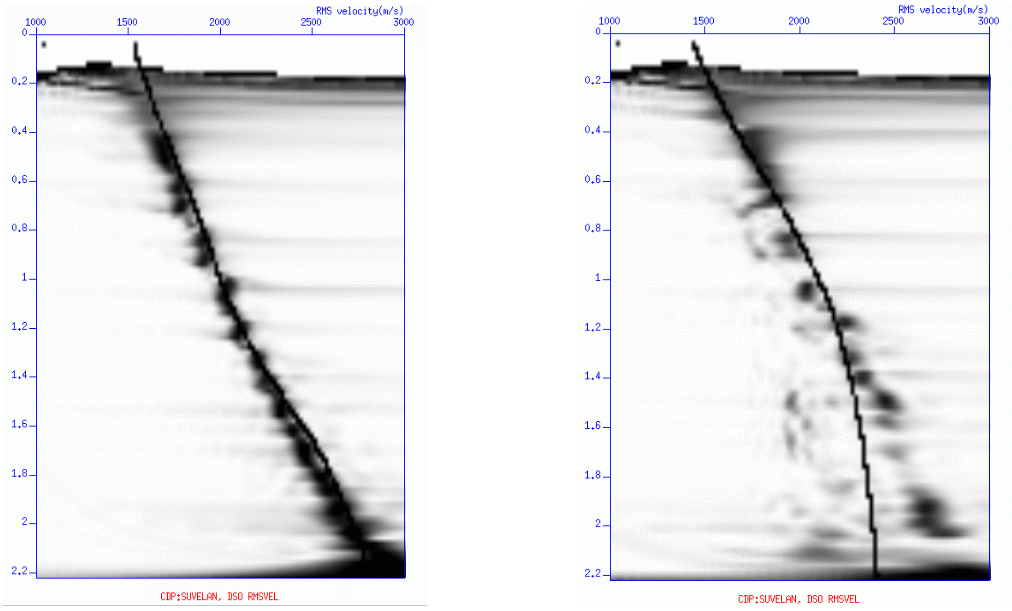


Figure 3.4 Comparison of DSO-estimated RMS velocity with velocity scan

From these two experiments, we can see :

- NMO-DSO is very accurate with primaries-only data, accuracy degrades as multiple reflection energy increases.
- General pattern: with conflicting moveout peaks, DSO finds intermediate path, overcorrecting some events and under correcting others.

MODEL 4

Multi-CMP gathers: 21 CMPs from Shell line 1

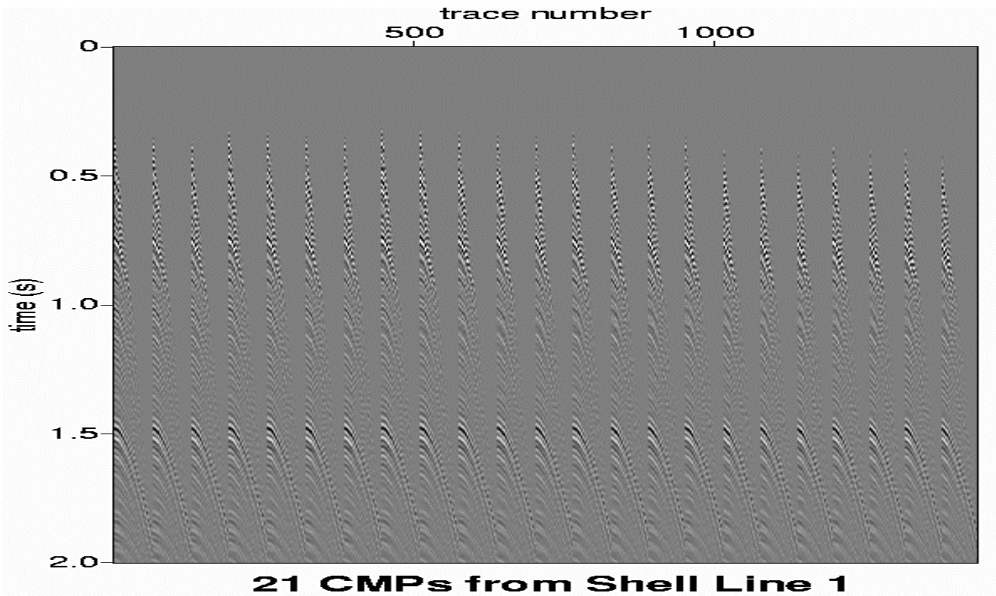


Figure 4.1 21 CMPs from Shell Line 1

To see more clearly, taking the first CMP gather:

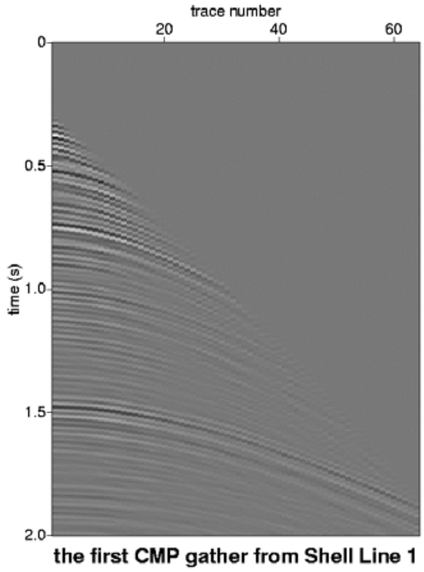
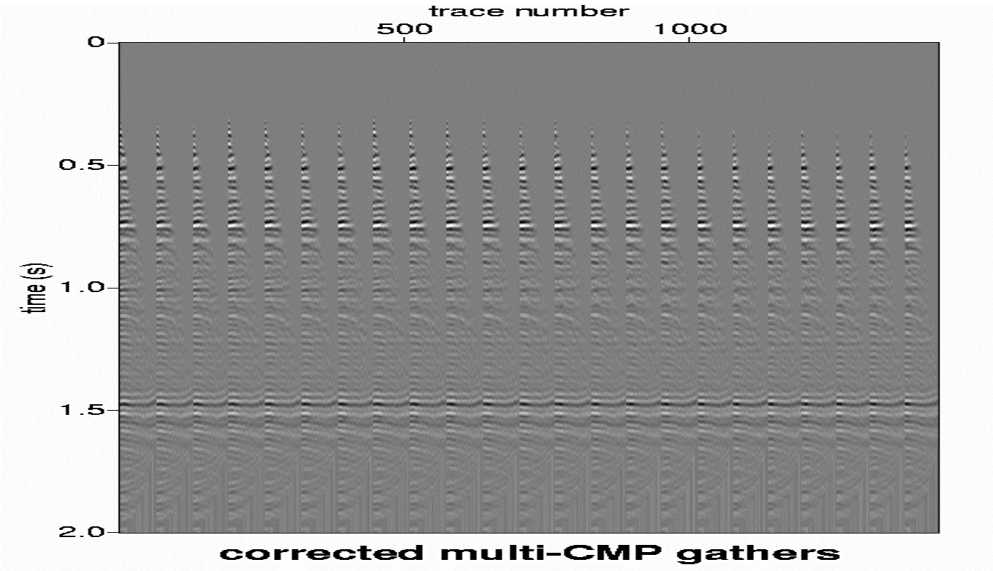


Figure 4.2 the first CMP gather chosen from Shell Line 1

Here ,we use multiple CMPs to constrain velocity simultaneously, after DSO:



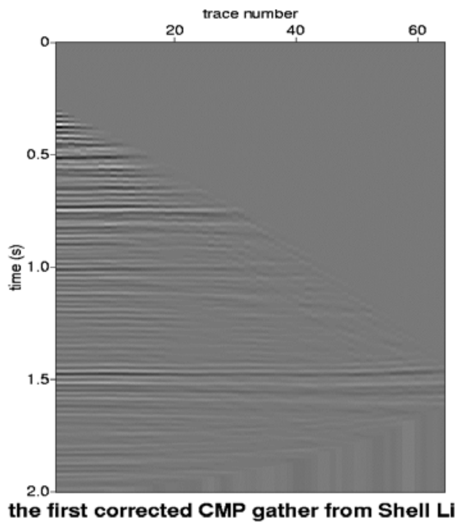


Figure 4.3 the corrected 21 CMPs and the first corrected CMP

Comparison of DSO-estimated RMS velocity with velocity scan is:

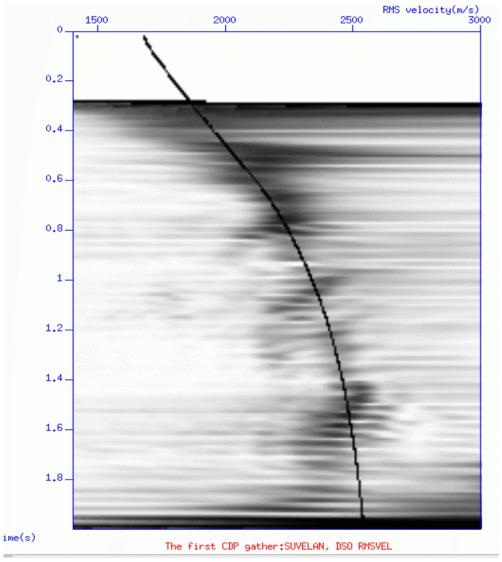


Figure 4.4 Comparison of DSO-estimated RMS velocity with velocity scan

We can see from the graph the slow events, likely pegleg multiples are present and that DSO-based RMS velocity appears to seek compromise between primary and multiple moveout velocities, just as with synthetics.

CONCLUSION

- Differential semblance works as well with field data as with synthetic data;
- Multiple reflection energy degrades accuracy
- Use of standard data formats eases problem setup, manipulation of data before and after inversion using SU.

REFERENCE

[1] K.Araya and S.Kim, C. J. Nolan and W.W.Symes. Velocity Inversion and High Frequency Asymptotics, The Rice Inversion Project, 1999

[2] E.Dussaud and W.W.Symes. A sparse paramerization method for smooth velocities, The Rice Inversion Project, 2004