Determination of velocity smoothing operator for prestack Kirchhoff depth migration by Common Scatter Point (CSP) gathers

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ABSTRACT

Optimum smoothing is required in ray based prestack Kirchhoff depth migration to handle complex velocity models. It also ensures numerical consistency and validity of modeling of finite difference data using ray tracing methods. Conventional approaches to find an optimum smoothing operator for the velocity field are based on visual inspection of the final full Prestack Depth Migration image (PSDM) which is a time consuming and an expensive operation. In this work, to find an optimum smoothing operator, we propose to compare the modeled Common Scatter Point (CSP) data computed from a ray tracing method with corresponding CSP gathers from the real data.

WHY SMOOTHING?

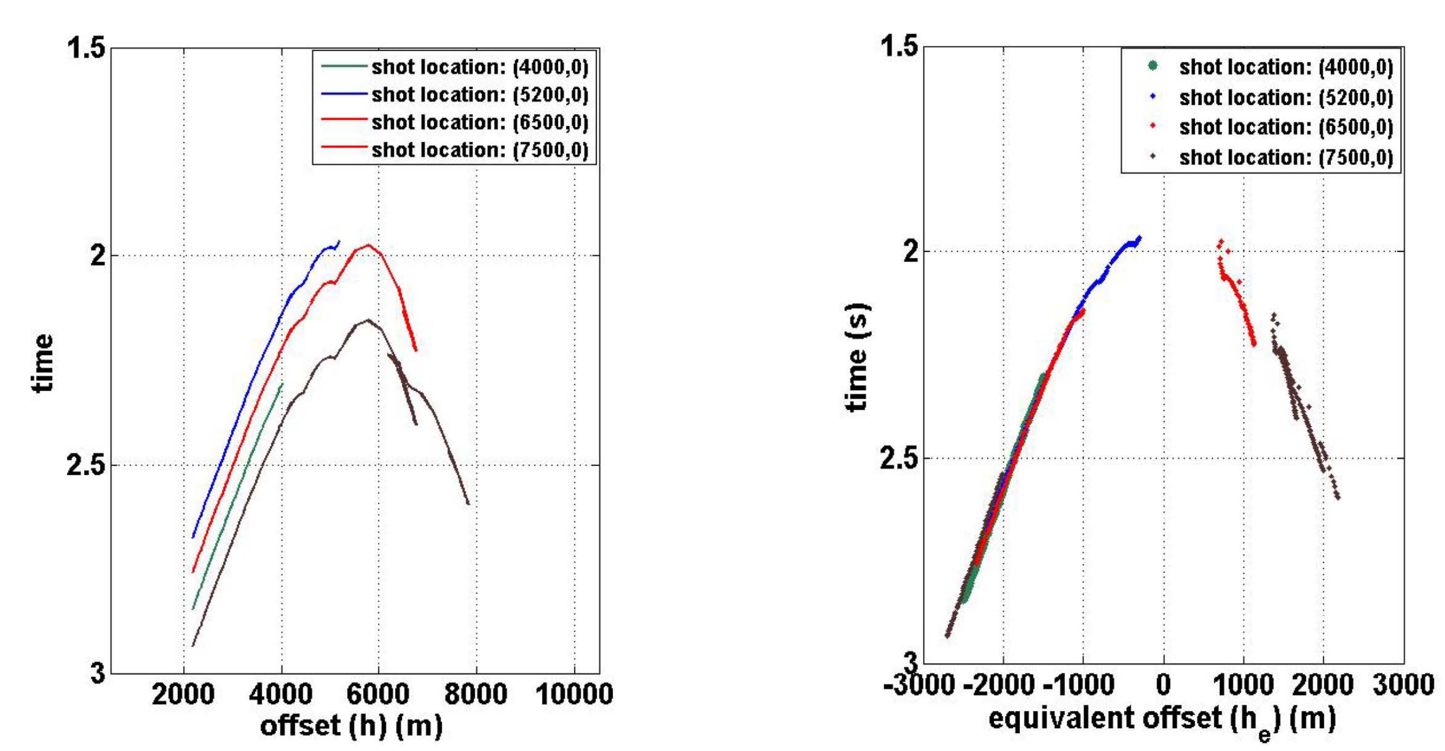
- The foundation of ray tracing techniques is based on the high frequency assumption of the wave equation. So, the spatial variations of velocity and its derivatives should be small with respect to the wavelength of the signal under consideration (Gray, 2000, Gajewski, et. al., 2002).
- Smoothing is a process which also occurs in the propagation of real seismic waves since the earth serves as a low pass filter during propagation (Gajewski, et. al., 2002).
- Optimum smoothing of the velocity model is required to maintain consistency between the ray based data and the real seismic data.

METHODOLOGY

Bancroft et al.(1994) introduced Equivalent Offset Migration (EOM) as a prestack Kirchhoff time migration algorithm that maps scatterpoint energies based on the Double Square Root (DSR) equations into the equivalent offset domain. It produces CSP gathers as an intermediate product, which need a Normal Move Out (NMO) and stack process to create a final migrated image.
In our approach, instead of creating PSDM, we modeled the CSP gathers using a ray tracing algorithm and compared it to CSP gathers from the real data.

NUMERICAL EXAMPLE AND RESULTS

For the forward modeling of the CSP gathers, we analyzed scatterpoints from the Marmousi velocity model, which has highly complex structure (Versteeg, 1994).



(a) (b)

FIG. 1. Feasibility of CSP gather modeling for the Marmousi model by simulating one scatterpoint response in four shots location in (a) the offset domain and in (b) the equivalent offset domain. It shows that in the complex structure of Marmousi the CSP data mapping is reasonable in the left side of the gather.

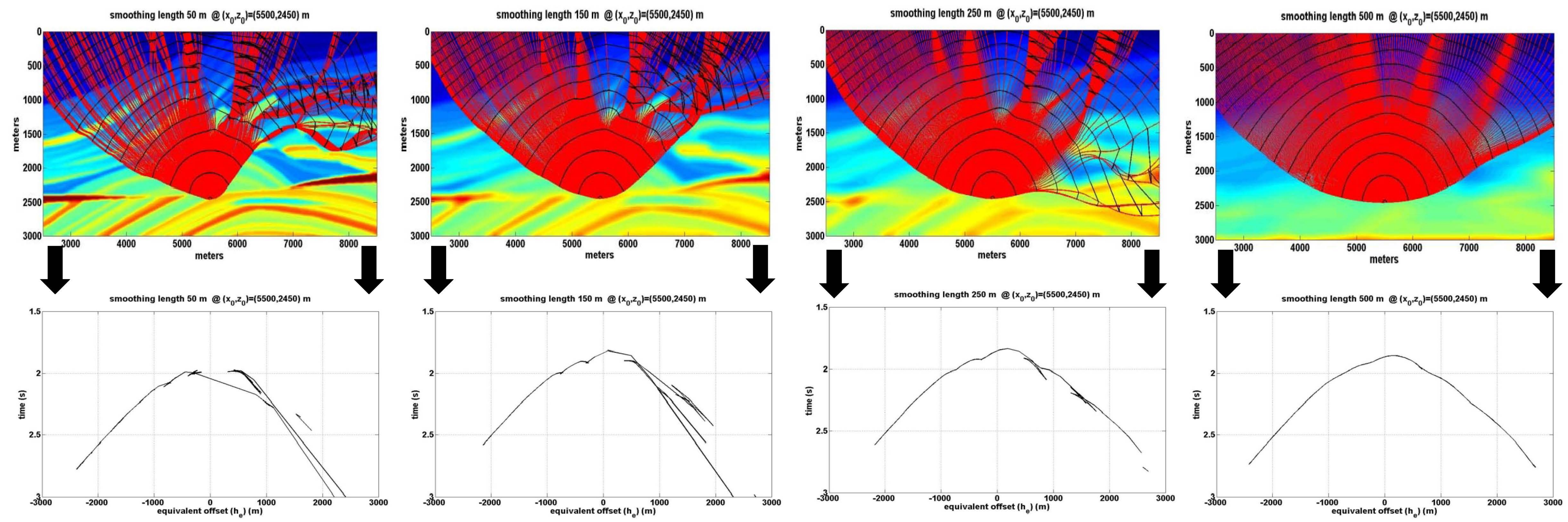
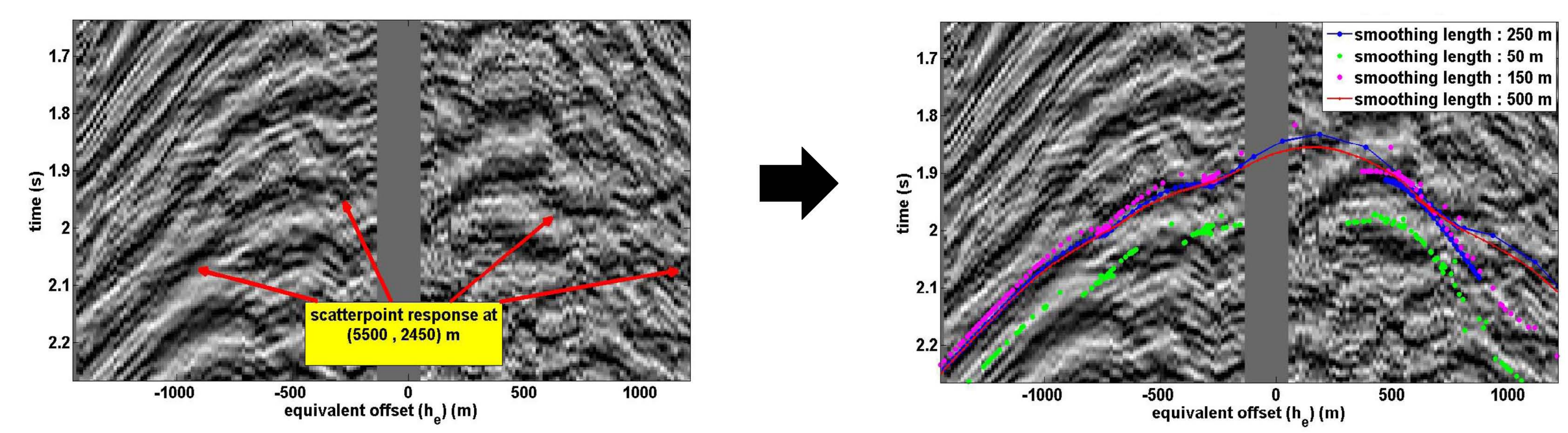
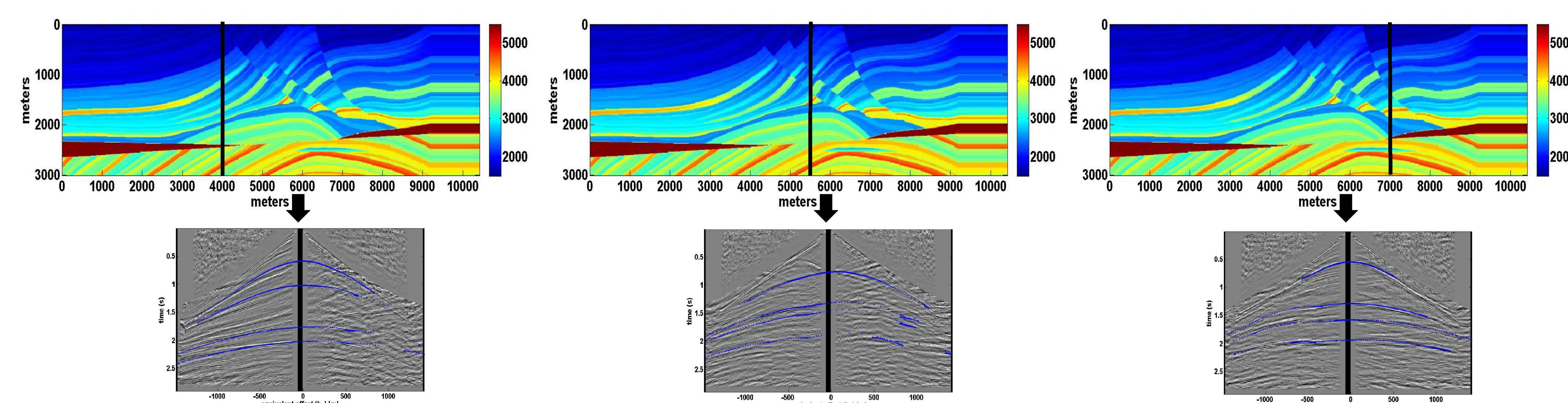


FIG. 2. Wavefronts and traveltime of scatterpoint response at (5500,2450) m of the Marmousi model are computation by ray tracing method. Here, four different smoothing operators are used. The results illustrate the effects of smoothing operators on scattering of the rays, distorting the structure of the earth model, losing of the accuracy in the velocities and time shift in the traveltime of the rays.



(a) (b)

FIG. 3. This figure shows a detailed view of modeled CSP, and a CSP gather formed at (5500, 2450) m of the Marmousi model. As shown by red arrows in (a) target CSP response is compared with (b) modeled traveltime curves using the different smoothing operators shown in figure 2. Here, the blue curve has an optimum fit to the corresponding NMO path.



(a) (b) (c)

FIG. 4. This figure shows an overall view of modeled CSP gathers (blue curve) and the real data CSP gathers for (a) 4000 m, (b) 5500 m and (c) 7000 m of the Marmousi model. The traveltime curves are computed from scatterpoints located at different depths with optimum smoother operators that range from 150-250 m.

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