Converted wave processing in the EOM domain

Thais A. Guirigay and John C. Bancroft

ABSTRACT

A new approach for converted wave prestack migration and velocity analysis has been developed, which is based on the consideration of prestack migration by equivalent offset and common scatter points (CSP). During the process, a converted wave velocity V_c is estimated from the hyperbolic moveout on CSP gathers. Moveout (MO) correction and stacking complete the prestack migration.

Equivalent offset migration is performed by applying moveout and stacking a CSP gather. A limited converted wave CSP (LCCSP) gather can be formed if we replace V_p and V_s with an equivalent velocity V_c, where V_c is valid only for zero offset data. However, we can extend its application when there is an acceptable small error in the estimated traveltime.

For a given trace with acceptable time error, there may still be enough energy to form a reasonable LCCSP.

DISCUSSION

Converted wave processing assumes the downward propagating energy is a P wave and reflected energy is a S wave. The processing methods consist of computing the total travel time by adding the source time to a scatterpoint time (*ts*) and the scatterpoint time to the receiver time (*tr*), using the appropriate P and S velocities for each leg of the ray path.

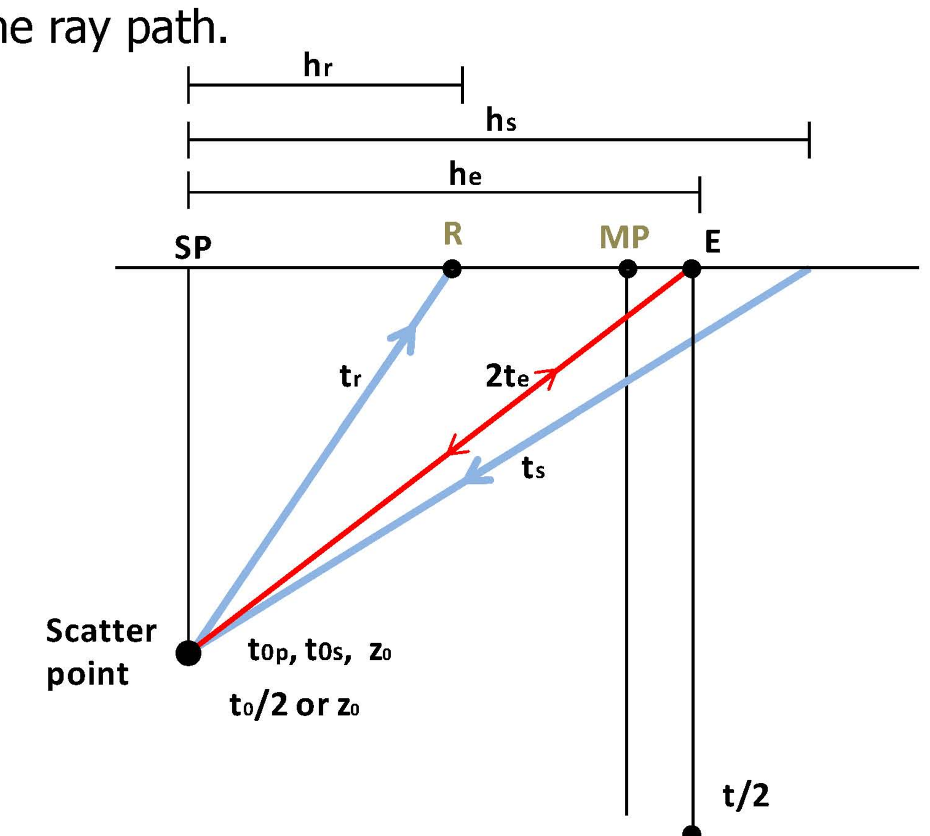

FIG. 1. The raypaths and travel times for a scatter or conversion point.

$$t=\frac{1}{V_p}\sqrt{z_0^2+h_e^2}+\frac{1}{V_s}\sqrt{z_0^2+h_e^2}=\frac{1}{V_p}\sqrt{z_0^2+h_s^2}+\frac{1}{V_s}\sqrt{z_0^2+h_r^2}$$

Combining the velocities, we obtain:

$$t=\left(\frac{1}{V_p}+\frac{1}{V_s}\right)\sqrt{z_0^2+h_e^2}=\frac{2}{V_c}\sqrt{z_0^2+h_e^2}$$, where:

$$V_c=\frac{2V_p}{1+\gamma} \quad \text{and} \quad \gamma=\frac{V_p}{V_s}.$$

The velocity V_c is used to apply moveout correction to the converted wave CSP gathers.

$$t_{p\text{-}s}=\frac{1}{V_p}\sqrt{z_0^2+h_s^2}+\frac{1}{V_s}\sqrt{z_0^2+h_r^2}$$

$$t_c=\frac{1}{V_c}\sqrt{z_0^2+h_s^2}+\frac{1}{V_c}\sqrt{z_0^2+h_r^2}$$

$$\Delta t = t_c - t_{p\text{-}s}$$

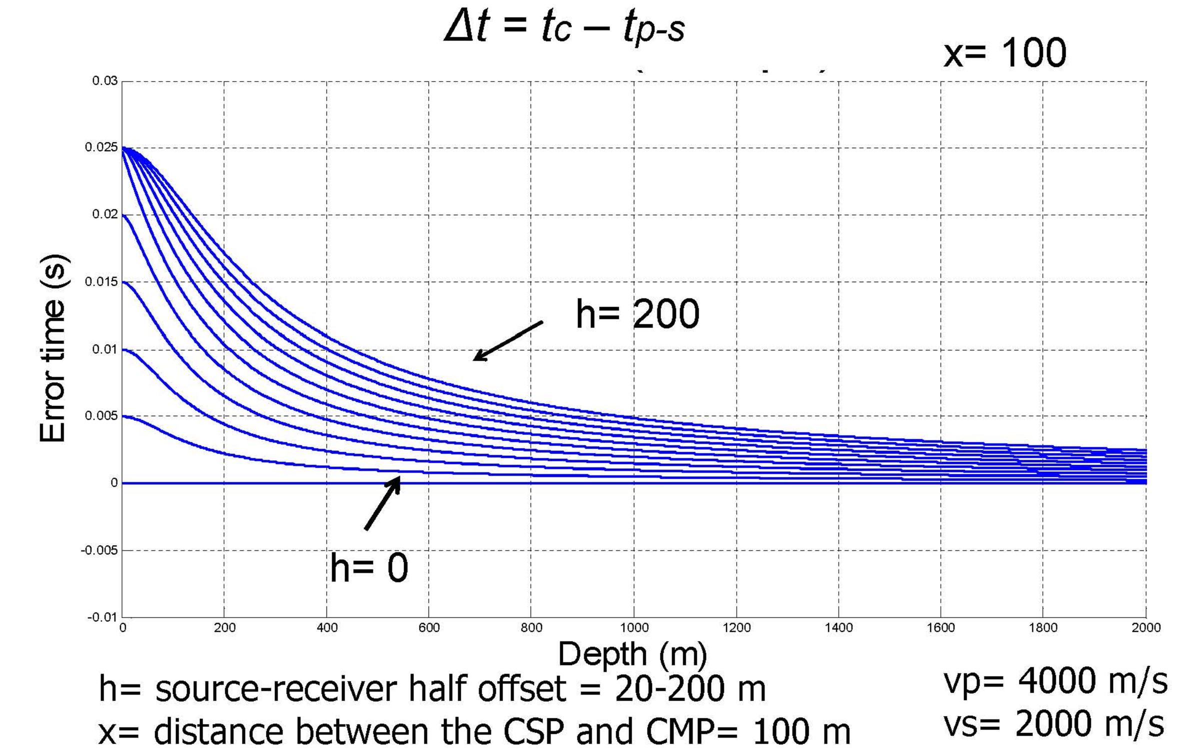

FIG. 2. Error times for different source-receiver half offsets *h* (from 0 to 200), in increments of 20 m for constant velocities *Vp* = 4000 m/s and *Vs*=2000 m/s. The distance between the CSP and CMP is 100 m.

We assume a vertical array of scatterpoints between 0 and 100 m depth, that are at a spatial location of x=0. We assume a fixed value for a half-offset h. Two-way traveltimes were then computed to and from the scatterpoints as a function of x and z. This was repeated for tc and the plots are shown:

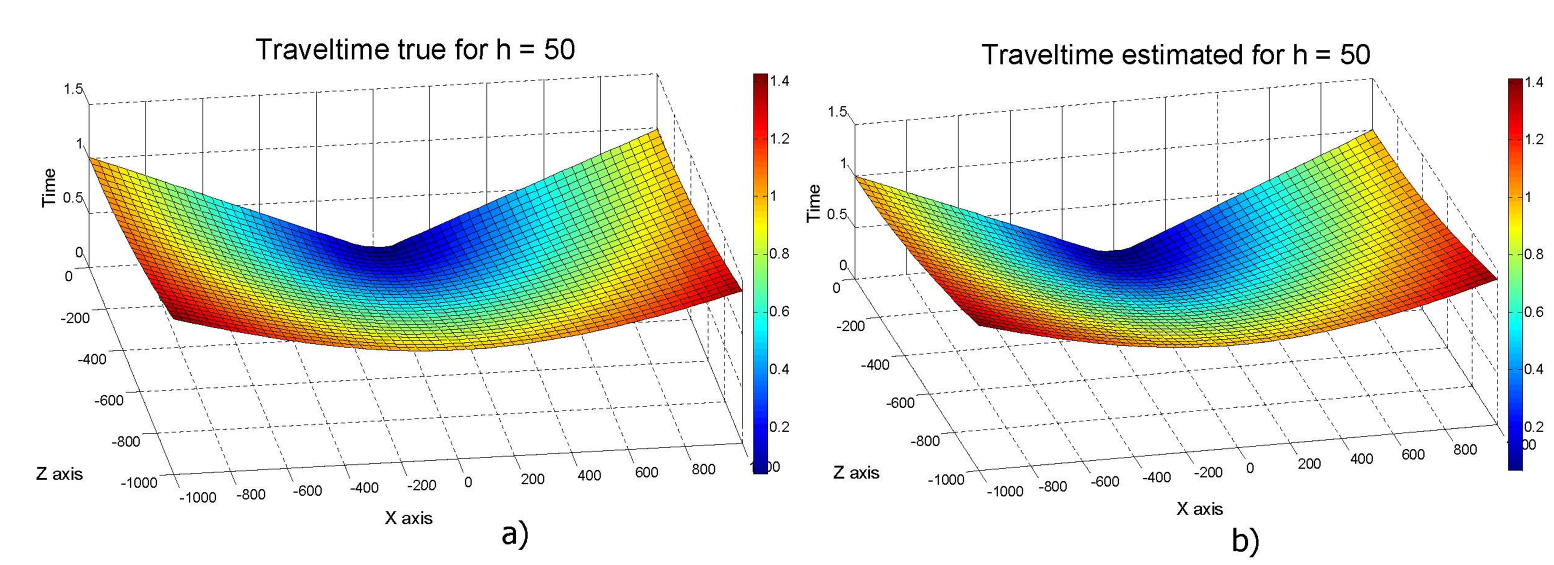

FIG. 3. Travel time for one vertical array of scatterpoints at x=0, with a) the true traveltimes and b) the traveltimes computed assuming a constant converted wave velocity for h=50 m.

The difference in the two traveltimes is difficult to see. The following plot shows the difference in traveltimes and the magnitude of the difference in traveltimes.

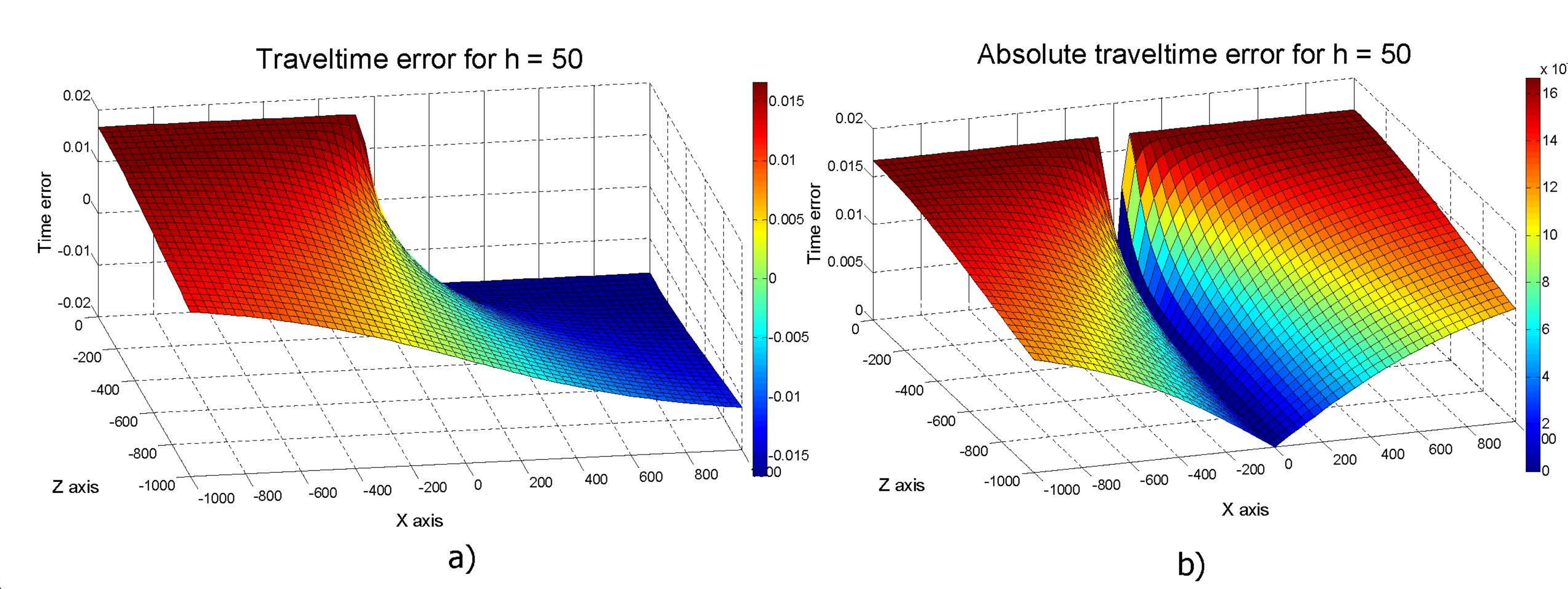

FIG. 4. Traveltime differences with a) the actual time and b) the magnitude.

The following figure represents the traveltime error on a CSP gather.

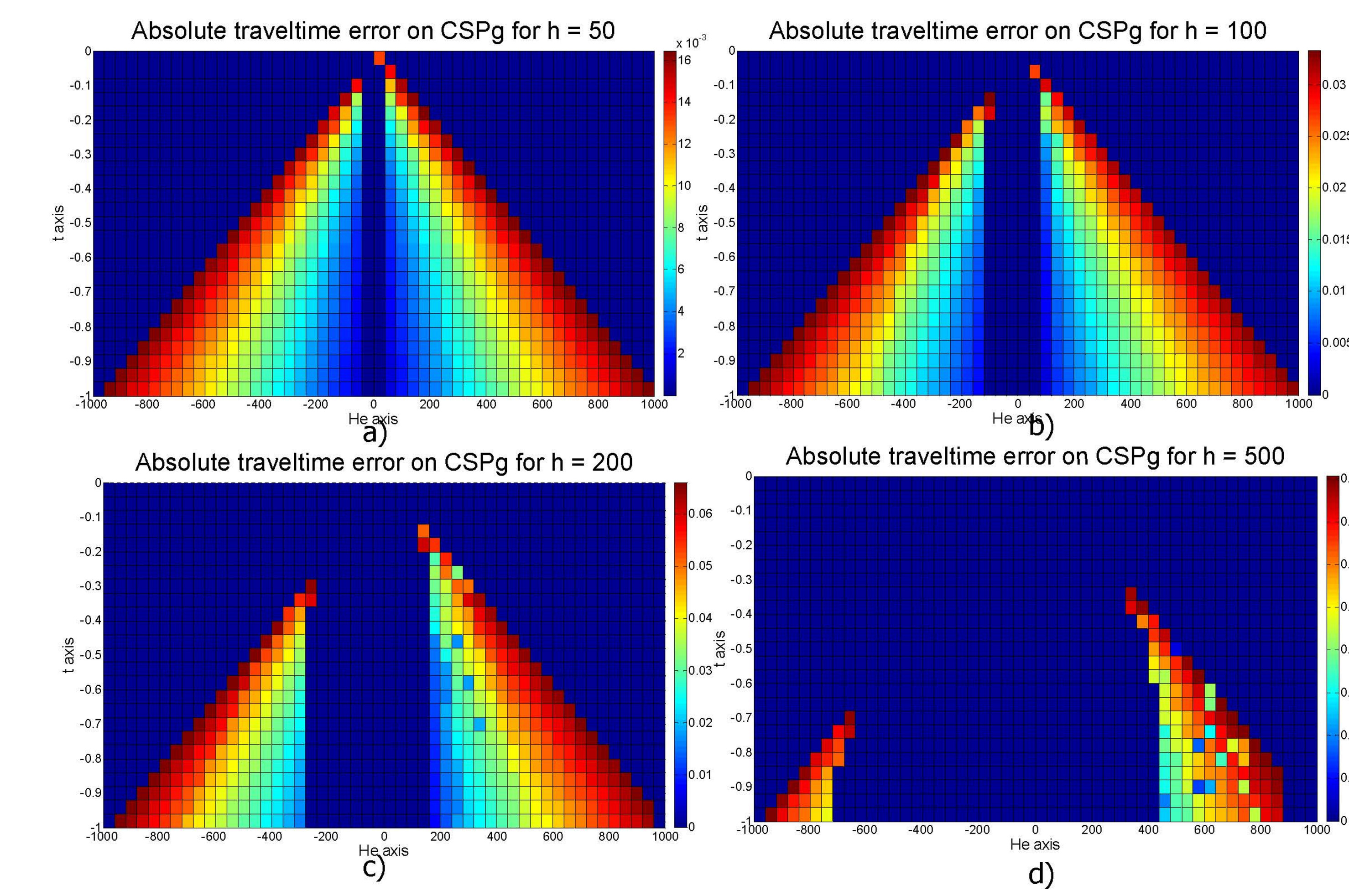

FIG. 5. Traveltime difference on a CSP gather for various half offsets h equal to a) 50 m, b) 100 m, c) 200 m, and d) 500 m. Note that the values on the colour bar vary for each figure.

CONCLUSIONS

Converted wave prestack migration by equivalent offset is based on the principles of Kirchhoff migration and uses equivalent offsets to form limited converted wave CSP (LCCSP) gathers.

The double square root equation for prestack migration can be reformulated with appropriate P and S velocities for each leg of the ray path. Using the relation between these two velocities, a converted wave velocity can be estimated from the hyperbolic moveout on the CSP gathers.

An acceptable time error may be defined to form a LCCSP gather by assuming a constant converted wave velocity. The intended application is to rapidly form a LCCSP gather to provide an initial velocity model for converted wave prestack migration using the equivalent offset method.

The range of acceptable traveltime errors is dependent on the P-wave velocity and an assumed S-wave velocity. However, the gather formed is independent of those velocities, and a more accurate S-wave velocity (or γ) is estimated.

ACKNOWLEDGEMENTS

We thank the sponsors of the CREWES Project for their support.