Numerical modeling of elastic waves propagation in isotropic vertically inhomogeneous media.

Sitamai W. Ajiduah*, Gary F. Margrave and P. F. Daley
sajiduah@ucalgary.ca

SUMMARY

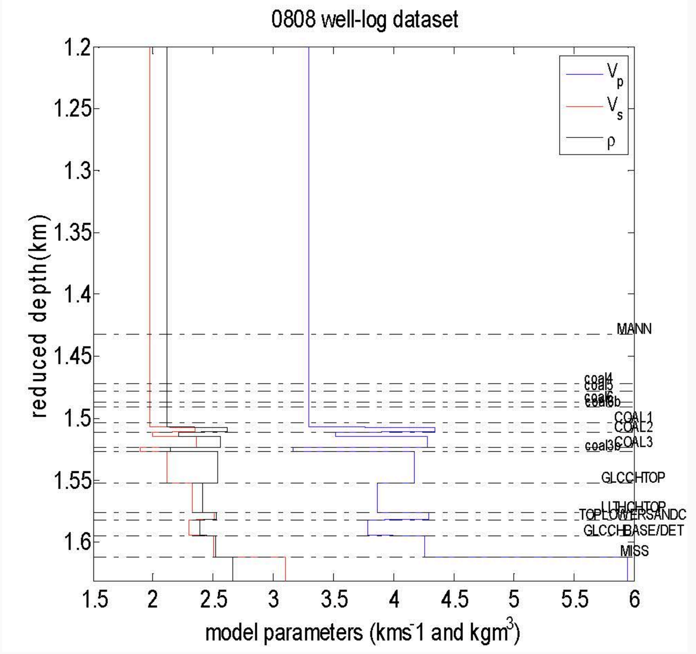
A method for calculation of complete theoretical seismograms for coupled P-Sv wave propagation in a vertically inhomogeneous media has been studied. Called the AMM method (for Alekseev-Mikhailenko), it is based on a combination of partial separation of variables via a finite Hankel transform over lateral coordinates and finite-differencing in time and depth. Results of theoretical seismograms for an isotropic vertically inhomogeneous model are presented in this paper and the effects of incidence angle and free-surface on component amplitudes are also investigated. Amplitudes from the AMM computations are compared with computations from the exact Zoeppritz equations for angles up to 60 degrees. All the computed amplitudes from AMM methods matched Zoeppritz amplitude at near vertical incidence up to 10 degrees (0.5km source-receiver offset). The P-P AMM and the P-P Zoeppritz amplitudes have the same trend for all pre-critical and post-critical angles; at the critical angle, Zoeppritz predicts an abrupt rise in amplitude while the AMM amplitudes show a gradual rise with a maximum beyond critical angle. The P-S amplitudes predicted from Zoeppritz matched with P-S AMM amplitudes only at near offset.

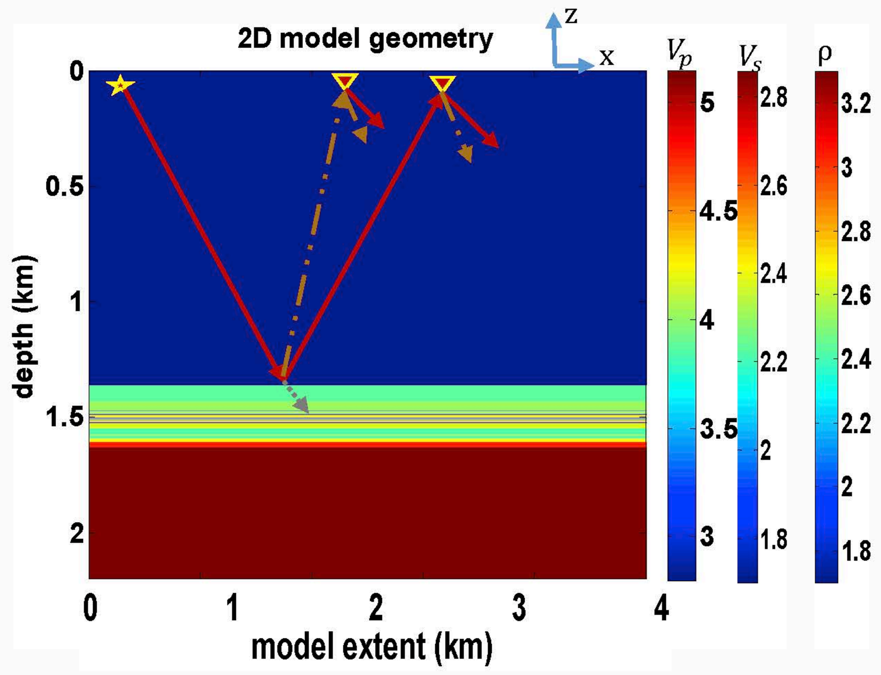
INTRODUCTION/METHOD

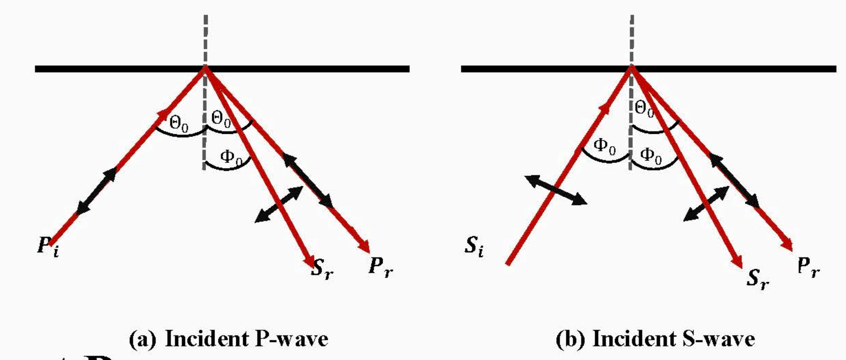
We carried out synthetic computation of elastic waves for an isotropic media using the AMM method and conducted several numerical analyses to correct for spherical divergence, surface effects at the receivers and wavelet effect in order to estimate reflection coefficients from the synthetic data. Previous and detailed work on the AMM method can be found in Martynov and Mikhailenko (1979), Alekseev & Mikhailenko (1980), and Daley, et.al. (2008, 2012) and in CREWES volumes. Many reports by P. F. Daley in the recent CREWES volumes compile insightful discussions on this methods in details as well as its practical implementation. This method is as fast as most finite-difference programs in two spatial variables and time, with the benefit that grid dispersion may be almost entirely eliminated (to within 2 or 3%) (Pascoe et.al., 1988) by utilizing a band-limited source pulse and establishing the number of terms to adequately approximate the infinite series that comprises the inverse finite integral transform (In addition, out-of-plane spreading is included, which is not the case for a pure finite-difference scheme in two spatial variables and time. The compute time of the AMM method unlike the reflectivity method (Muller, 1985) is independent of the number of layer. This is an added advantage of using the AMM method. After the wavefields have been computed, the amplitudes are corrected for geometric spreading, receiver-emergence angle effect and for surface conversion at the free surface. We used the Dankbaar (1987) equations to compute the free surface coefficients for data whose receivers are at the free surface.

CONCLUSION

We have compared the AMM wavefields with ray theory and amplitudes from Zoeppritz equations after correction for geometric spreading, wavelet effect and surface conversion effects. We infer that AMM is practically implementable and can provide a good advantage for computing elastic wavefields for multicomponent processing and a good forward modeling kernel for an inversion algorithm.





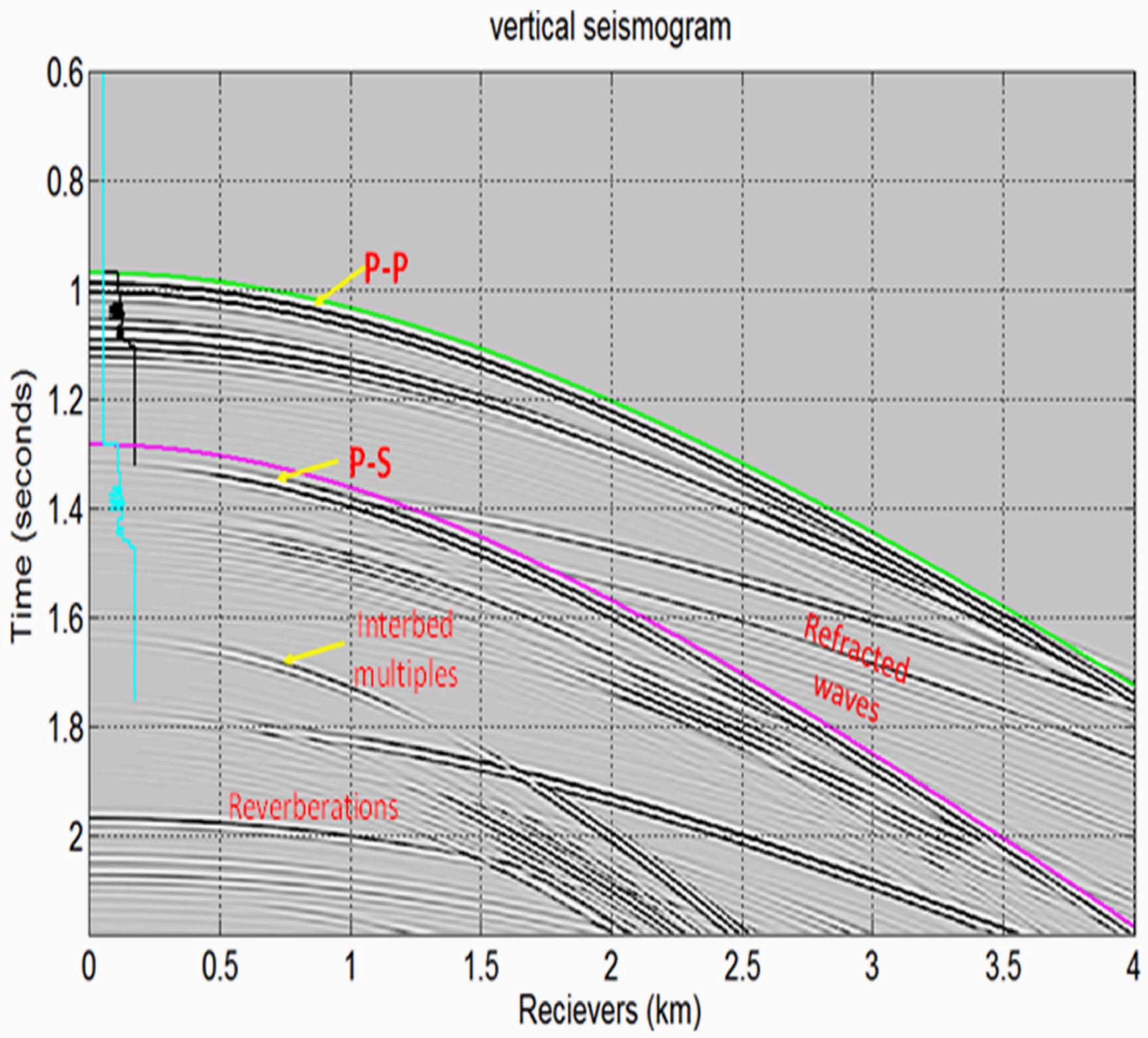


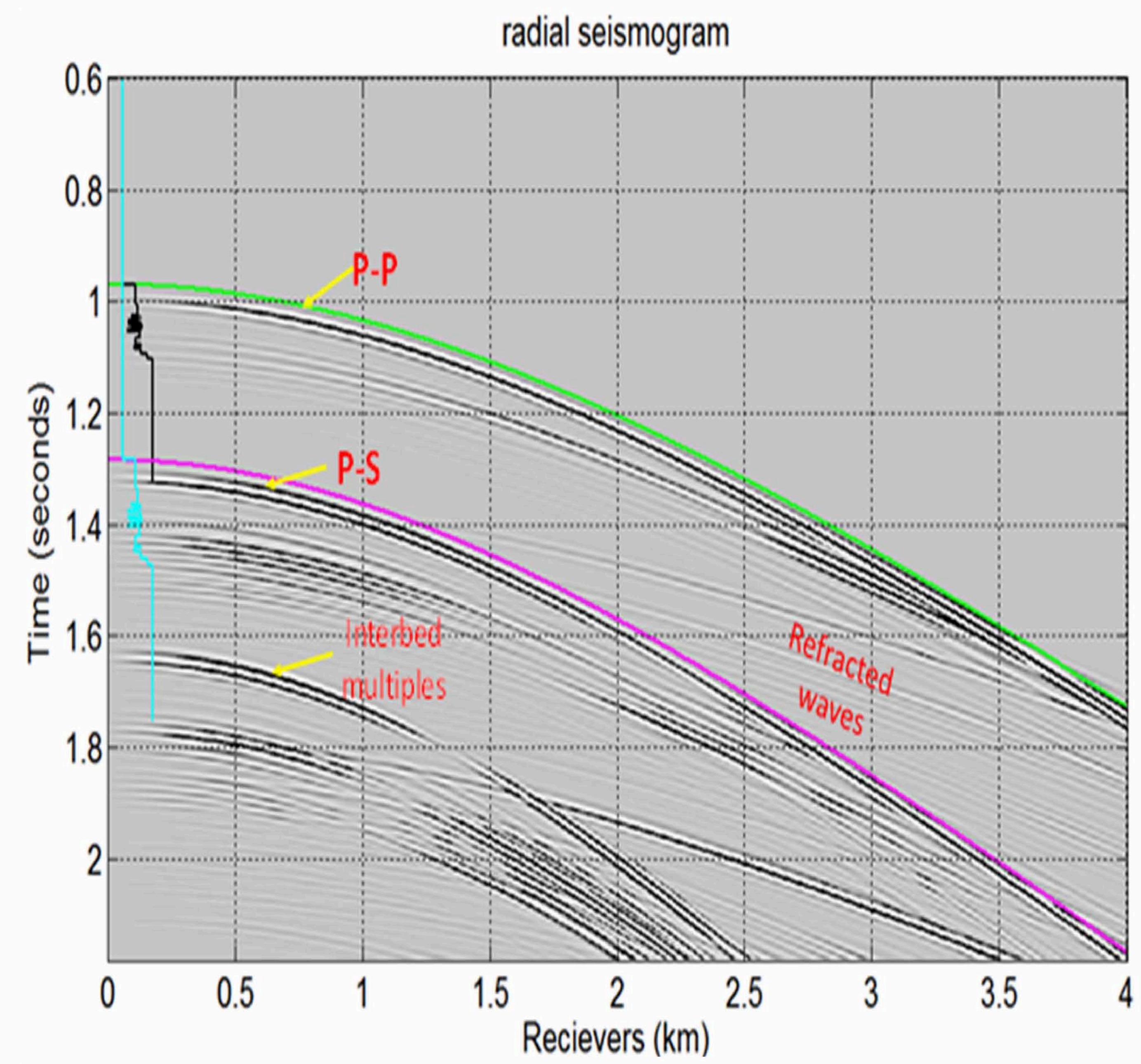
Incident P-wave

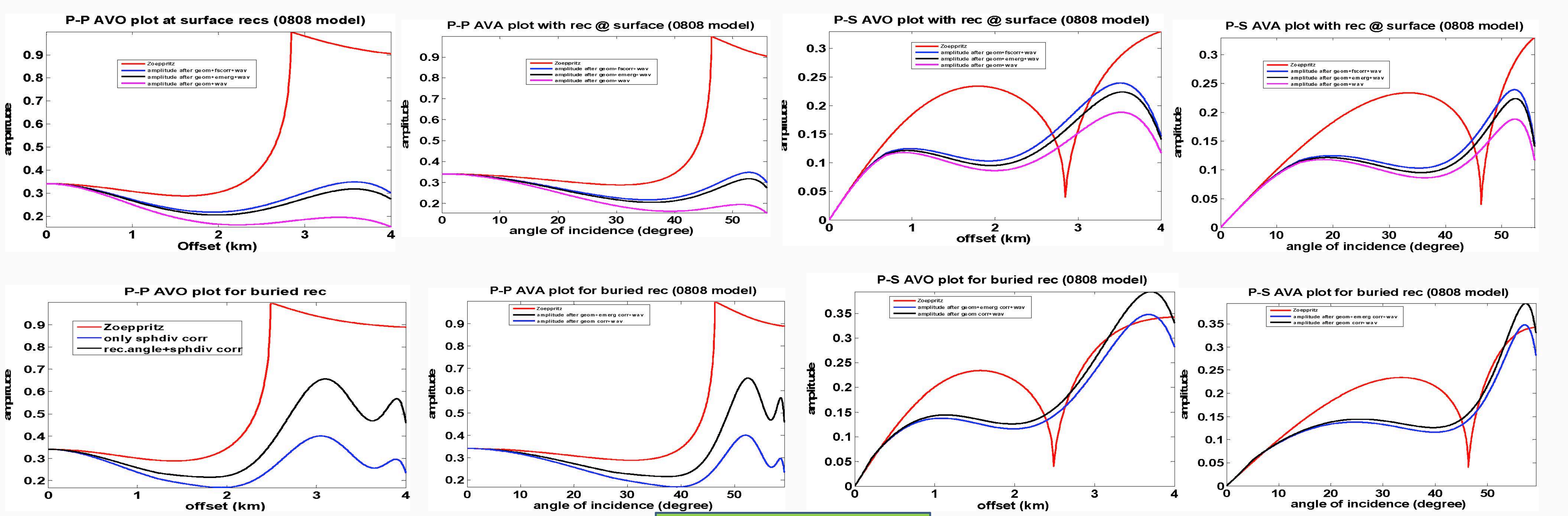
$$G_z = P_I cos\Theta_0 + R_{pp}P_I cos\Theta_0 + R_{ps}P_I sin\Phi_0$$
$$G_r = P_I sin\Theta_0 + R_{pp}P_I cos\Theta_0 + R_{ps}P_I cos\Phi_0$$

Incident S-wave

$$G_z = S_I sin\Phi_0 + R_{ss}S_I sin\Phi_0 + R_{sp}S_I cos\Theta_0$$
$$G_r = S_I cos\Phi_0 + R_{ss}S_I cos\Phi_0 + R_{sp}S_I sin\Theta_0 ,$$







ACKNOWLEDGEMENT

We thank the sponsors of CREWES for their support. We also gratefully acknowledge support from NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 379744-08.