Estimating the Elastic Properties of the Near Seabed Using Post-critical Energy

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Abstract

Introduction

In ocean-bottom sensor data, the combination of pressure (P), horizontal (Vx or/and Vy), and vertical (Vz) components allows characterizing the seabed elastic properties. These properties are important to marine seismic data processing (Schalkwijk et al., 2003) and to identify geohazards and constraints for seabed infrastructure design. In this work, we propose solutions to improve their estimation by using post-critical energy.

Theory

With post-critical energy, we mean the energy generated by multiple reflections at post-critical angles (guided waves) and the surface waves (Scholte waves). Before analysing the meaning of this, let us recall the decomposition operators in the frequency ray-parameter (ω,p) domain that relate Vz to P (F), Vx to P (Q), and Vx to Vz (W). $F(p) = (\rho_1 \beta_1) / q_{P,1}$, $Q(p) = (\rho_1 \beta_1) / (p \gamma_1)$ and $W(p) = q_{P,1} / (p \gamma_1)$ (1) where $\beta_1 (p,\omega) = c_{S,1}^4 [4p2\ q_{P,1}\ q_{S,1} + (c_{S,1}^{-2} - 2p2)2]$, (2) $\gamma_1 (p,\omega) = c_{S,1}^2 [2q_{P,1}\ q_{S,1} - (c_{S,1}^{-2} - 2p2)]$, (3) $q_{P,1} (p) = \sqrt{}(c_{P,1}^{-2} - p2)$, $q_{S,1} (p) = \sqrt{}(c_{S,1}^{-2} - p2)$, (4) and $c_{P,1}$, $c_{S,1}$, and ρ_1 are the P- and S-wave velocities and density of the sea floor. In the post-critical region, where $q_{P,1}$ or/and $q_{S,1}$ become complex numbers, the operators apply an amplitude scaling as well as a phase rotation that is p-dependent. The largest phase rotation occurs in at the critical slowness where the amplitude scaling shows a singularity. To exploit the relationships between P, Vx, and Vz, we satisfy the condition that no downgoing energy must be present in upgoing normal-stress fields and in upgoing shear-stress fields after applying the decomposition operators. To do this, we use the energy function EAP (Sen and Stoffa, 1991) that, for Vz and P in the frequency domain, is $EAP(c_{P,1},c_{S,1}) = -(1/N_P) \sum_p [(2\sum_\omega P (F\ Vz)^*)/(\sum_\omega P P^* + \sum_\omega (F\ Vz) (F\ Vz)^*)]$ (5) where N_P is the number of slownesses in the summation and * means complex conjugate. A similar expression can be written for Vx - P and Vz - Vx. Equation 5 gives a perfect correlation only in the case of matching between the amplitude and the phase of the two components mitigating the effect of singularities and reducing the uncertainty in estimating near-seabed elastic parameters/

Conclusions

For a substantial improvement in estimating $c_{P,1}$ and $c_{S,1}$ of the seabed, we propose full-waveform matching in the frequency domain of the direct arrivals for the three different components. In this way, we do not have to deal with the singularities of F(p) and we can include post-critical energy in the elastic parameter estimation. Acknowledgments We thank Schlumberger for permission to publish this work.

References

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