Submission code: 6574Z9LDGZ

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Improved Seismic Data Regularization in OBN Environments Using a CRP-Informed Traveltime Operator

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Introduction

Oil and gas exploration increasingly targets challenging environments, such as complex geology and ultra-deep waters, driving demand for technologies that minimize risk and reduce costs. In Brazil, pre-salt reservoirs exemplify these difficulties and require advanced seismic acquisition and processing for precise subsurface imaging. Ocean Bottom Node (OBN) acquisition has emerged as a key technology, offering pressure and shear wave recordings, enhanced azimuthal coverage, improved data quality, and superior repeatability for 4D seismic monitoring. This research leverages these advantages to propose a multiparametric traveltime operator designed to regularize irregular OBN geometries. The method improves data consistency and enables more reliable inversion and imaging, contributing to more efficient seismic workflows in complex offshore exploration scenarios.

Method

We present the implementation of a multiparametric traveltime operator, based on the common reflection point (CRP) trajectory, designed to accurately align reflection events in seismic data acquired using OBN geometries. This operator relies on four kinematic parameters: two describe the slopes of reflection events in the midpoint direction (inline and crossline), one represents the subsurface propagation velocity, and the fourth accounts for water column characteristics and node elevation. Together, these parameters enable precise modeling of seismic event kinematics in complex marine settings.

Parameter estimation is performed through a global search across all samples of the target output geometry, which can be regular or irregular. This approach ensures identification of the parameter set that best matches recorded events, even under challenging acquisition conditions or in the presence of noise. Once estimated, local stacking operators are applied at each output position to enhance and reconstruct events at new locations.

The proposed methodology offers flexibility for various processing goals. It can be used for amplitude enhancement while preserving the original acquisition geometry or for regularization by increasing midpoint resolution and generating regularly spaced offsets within defined azimuth ranges. This regularization capability is particularly valuable in preprocessing for seismic inversion or migration, where uniform and denser spatial coverage improves the fidelity of final results.

Results and Conclusions

The proposed CRP multiparametric traveltime operator shows strong potential for enhancing seismic data processing in OBN acquisitions. Its effectiveness in accurately fitting events and reconstructing data under complex and sparse acquisition scenarios underscores its robustness and flexibility. The method supports improved imaging and inversion quality by preserving azimuthal content and enabling geometry regularization. These capabilities make it a valuable tool for lowering acquisition costs while maintaining data integrity, offering practical benefits in challenging offshore exploration environments. Future work may investigate its integration into complete processing workflows and evaluate performance with field data.