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Very high-resolution deep towed multi-channel seismic imaging: Solving the impact of variable array shape on data processing

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Deep-towed multi-channel very high-resolution (VHR) seismic profiles acquired in deep-sea environments provide data of unrivaled metric resolutions compared to conventional surface-towed seismic acquisitions. Yet, the main challenge in the processing of such data arises from the positioning uncertainties associated with inherent variable receiver array structure.

SYSIF (Systeme Sismique de Fond) is a deep-towed seismic acquisition system developed by Ifremer that brings VHR capabilities down to deep-sea environments. The deep-towed system is the result of the development of both an acoustic source (220-1050 Hz) (Ker et al., 2010) and a multi-channel streamer (52 traces at 2 m interval), tailored for working under high hydrostatic pressure environments (Marsset et al., 2014). SYSIF was deployed in the Romanian sector of the Black Sea during the GHASS cruise in 2015 (DOI 10.17600/15000500) where 370 km of multi-channel VHR seismic profiles were successfully acquired. During an acquisition, the source is towed at a constant altitude (50 or 100 m above the sea floor depending on the submarine relief), which in turn causes immersion variations. The vertical motions of the source propagate along the neutrally buoyant, towed streamer as a mechanical wave, causing variations in the source-receiver offsets. These mechanically induced variations introduce errors that affect the quality of the seismic profile outputs. Thus to retrieve the most information from the seismic data, we need more accurate receiver locations, which we require to have a location error of less than 30 cm.

We present an additional processing step for retrieving more accurate receiver offsets. We first reconstruct the shape of the streamer by inversing the tangential data along the array. Next, we interpolate the curvilinear positions of the receivers along the streamer to recover their offsets. We then relocate the absolute, i.e. geographic, position of the system based on dedicated acoustic measurements. Finally, we crosscheck the relocation step, taking advantage of multi-beam bathymetry. This procedure was successfully applied on seismic profiles of the GHASS cruise to help identify small-scale sub-surface structures.

Our proposed approach results in a better fit between theoretical and measured travel times and an overall sharpness gain in seismic profile outputs. This approach also allows for further analysis of the data, such as determining velocity profiles and their sensitivities as a semi-automated process. These preliminary results pave the way for more accurate geophysical characterization of small-scale sub-surface processes from deep-towed multi-channel VHR seismic data.