Source and receiver ghosts modeling for time-varying sea surface

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Abstract

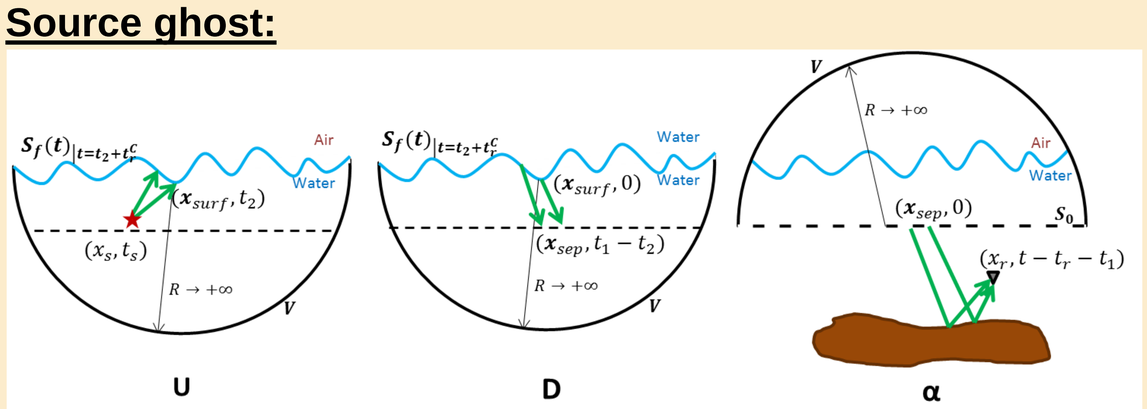
A major hindrance in fully understanding the data acquired in marine seismic exploration is the restricting assumption of flat and stationary sea surface used in modeling and processing tools. A vital first step for an accurate removal of ghost effects during data processing, is a thorough investigation of the ghost effects originating from a time-varying sea surface.

Here, we present a novel tool for modelling source and receiver ghosts in the presence of rough time-varying sea surfaces. Based on acoustic reciprocity, we derived an integral method to couple up-going subsurface reflection data with modelled time-varying sea surface reflectivity. First modeling results show the major difference on seismic data between a time varying sea surface and a stationary one.

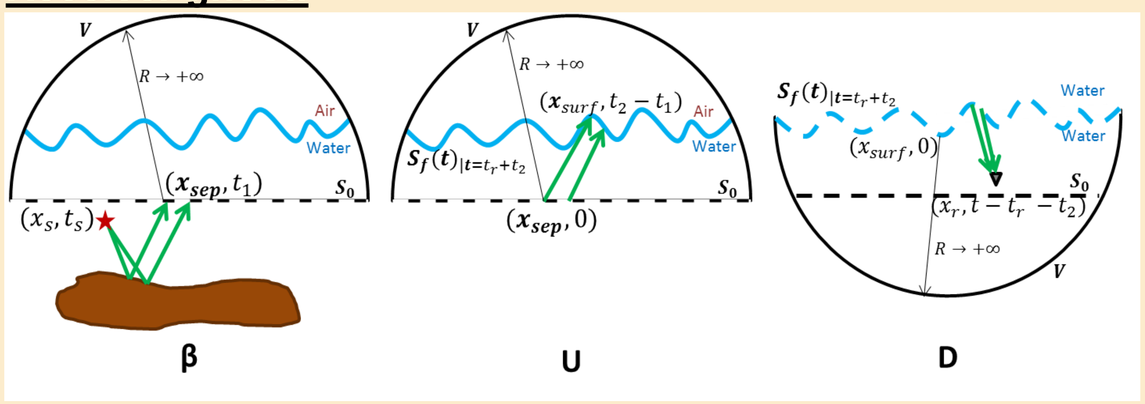
Theory

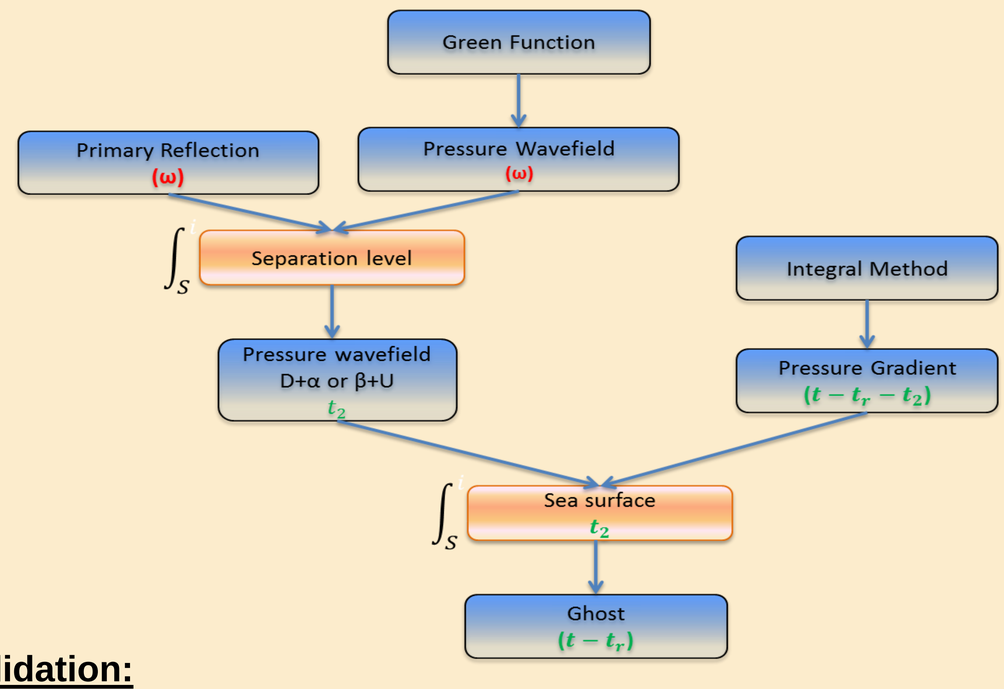
Starting from the Gauss theorem in three different states, we derive a Kirchhoff-Helmholtz equation in time domain to model the sea surface reflectivity (U and D). This can be coupled with subsurface wavefields (α or β) generated by any modelling approach using wavefield separation, and causality conditions at the separation level.

Source ghost:



Receiver ghost:



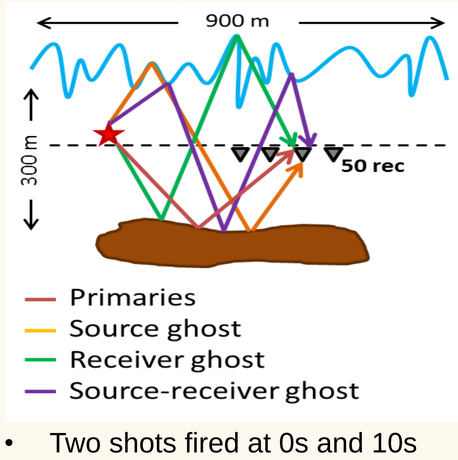


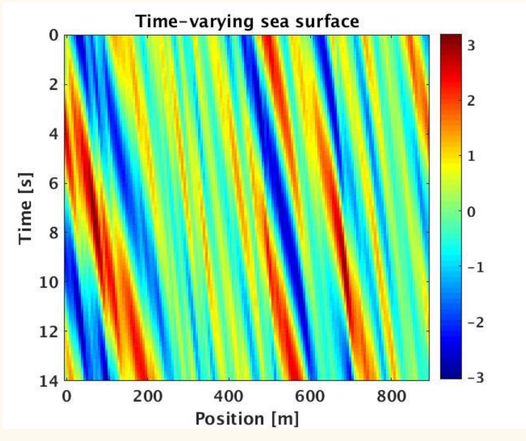
Validation:

- Both algorithms have been benchmarked using analytical solution for a frozen flat sea surface.
- Quality control of the Kirchhoff Approximation compared to the full Integral Inversion has been done using a frozen rough sea surface.
- Using a moving flat sea surface, Doppler effect have been investigated. We obtained numerical results which match the analytical predictions.

2D Synthetic data

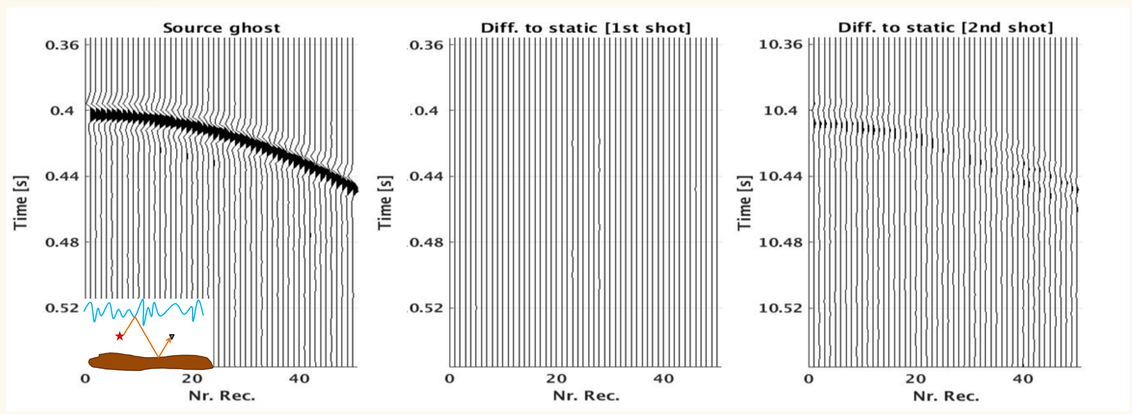
Acquisition configuration:

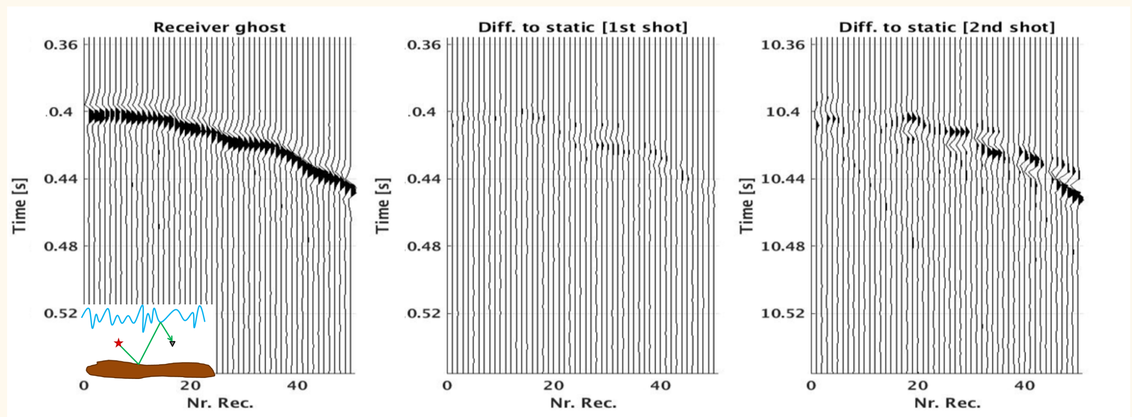


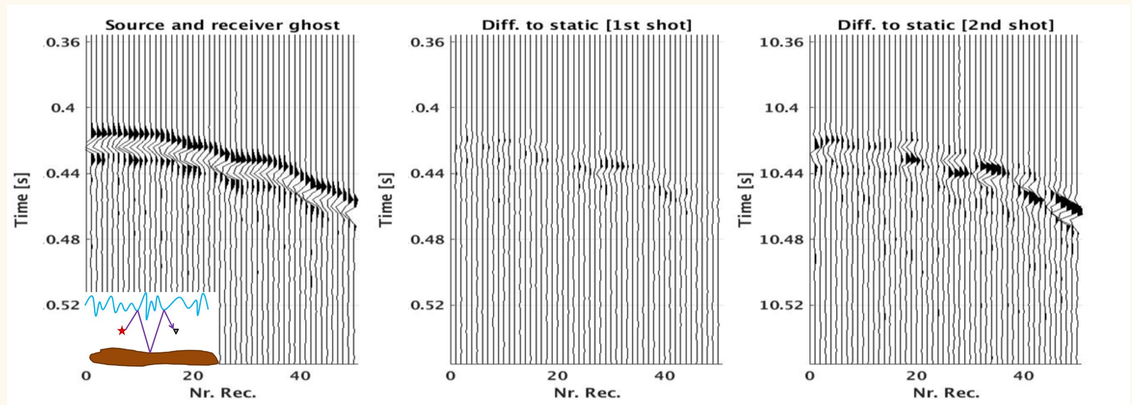


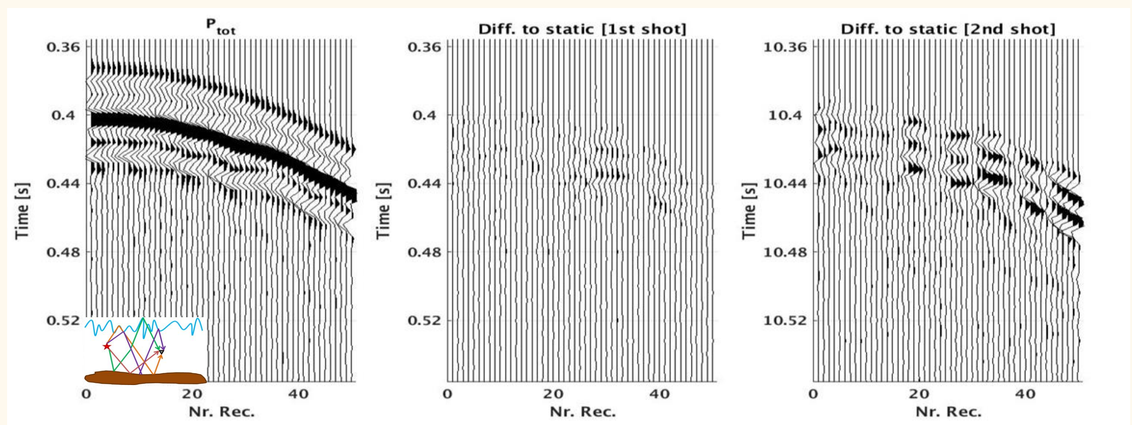
- Two shots fired at 0s and 10s
- Recording length of 1s
- Comparison with the stationary case (sea surface at 0s)

Results:









Conclusion

- An algorithm based on acoustic reciprocity has been developed to model source and receiver ghosts for time-varying rough sea surfaces.
- The results highlight the fact that interaction with time-varying sea surfaces can have a significant effects on the receiver and source ghosts.

References:

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- Fokkema J. and van den Berg P. (1993). 'Seismic applications of acoustic reciprocity.' *Elsevier, Amsterdam*
- Okwudili C. Orji , Walter Söllner and Leiv-J. Gelius. 'Effects of time-varying sea surface in marine seismic data.' *Geophysics* 77.3(2012): P33-43