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Ocean acoustic interferometry

DOCTORAL THESIS

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This thesis is dedicated to Ruth Myra Kinsman

Ab Ovo Usque Ad Mala

Abstract

Information from accurate ocean acoustic Green's function estimations can potentially be used to determine environmental characteristics such as water column and seafloor properties, knowledge of which is beneficial in numerous fields including sedimentology, oil exploration, and defence. Good estimates of acoustic Green's functions between two locations have previously been determined from cross-correlation of sound and vibration in other research fields. There is, however, limited literature that addresses Green's function approximation from cross-correlation of sound in the ocean. The work in this thesis therefore aims to further the understanding of Green's function approximation from cross-correlation of sound recorded at two locations in a shallow water oceanic waveguide, an approach referred to as ocean acoustic interferometry. Both active source and ship dominated ambient noise ocean acoustic interferometry are considered.

A stationary phase argument is used to relate cross-correlations from active sources to the Green's function between hydrophones. A vertical line source, a horizontal line source, and a horizontal hyperbolic source are considered. The theory and simulations are in agreement with related theory presented by others. The advantages and disadvantages of each source configuration are discussed.

Empirical Green's function approximations (EGFAs) were determined from ship dominated ocean noise cross-correlation. Direct and secondary path travel times between hydrophones were determined, and agree well with simulated data. Averaging the cross-correlations between equi-spaced horizontal line array hydrophone pairs is shown to increase the signal-to-noise ratio. Analysis of temporal variations in the cross-correlations confirms that at any one time the signal is generally dominated by one or two sources. Cross-correlations obtained from data recorded during a tropical storm are shown to be clearer than those obtained at other times. This is due to both a reduction in nearby shipping, and an increase in overall sound levels caused by the increased wave action associated with the storm.

Ocean experiments were performed on the New Jersey Shelf. The direct acoustic path of the given ocean environment is shown to be highly sensitive to changes in sound speed profile, making reflection coefficient inversion difficult.

Cross-correlations of experimental data from a source lowered vertically and a source towed horizontally are compared and contrasted with the ship dominated noise cross-correlations, and also with cross-correlations of noise from a stationary ship. The EGFAs and their relationship to simulated Green's functions are explained using theory and simulations.

Two practical applications of ocean noise cross-correlation are also detailed: diagnosis of a multichannel hydrophone array, and array hydrophone self-localisation. Results obtained from active source measurements reveal that signals from several hydrophones, which were recorded on certain channels before a storm, were subsequently recorded on different channels after the storm. Noise cross-correlation of data recorded during the storm show when, and in what manner, these changes took place. Differences in travel times from any given source to hydrophone pairs were consistently less than expected for the assumed geometry. Travel times extracted from day long noise cross-correlations were used in an inversion to estimate array geometry. The resulting curved array geometry provided more consistent acoustic travel times from active noise sources than the assumed straight line geometry.

In summary, the findings documented in this thesis increase the understanding of Green's function approximation from cross-correlation of sound

in the ocean by providing: a theoretical and practical understanding of Green's function estimations for both active sources and passive ship dominated ambient noise; and examples of how the extracted travel times can be applied to practical situations.

Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University of Adelaide Library, being available for both loan and photocopying.

Laura Anne Brooks

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