Mid-frequency sound propagation through internal waves at short range with synoptic oceanographic observations

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Both *linear* and *non-linear* internal waves are potentially important at the SW06 site.

On August 18, mid-frequency acoustic transmission data were collected on a vertical array over a continuous 7-hour period at range 550 m.

The combination of acoustic frequency and range selected for this part of the experiment were deemed relevant to studying the effects of *both* types of internal waves.
Introduction

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- At lower mid-frequencies (~1 kHz) and range 550 m, acoustic propagation should be described by classical weak-scattering theories (e.g., Born, Rytov).

- At higher mid-frequencies (~10 kHz) and range 550 m, acoustic propagation should be described by strong-scattering theories (e.g., 2nd and 4th moment theories).
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Non-linear internal waves are often modeled as a more event-like process causing strong, localized changes in the acoustic sound speed.
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Non-linear internal waves are often modeled as a more event-like process causing strong, localized changes in the acoustic sound speed.

- Packets of non-linear internal waves are not unusual.

- 550 m acoustic path might permit individual waves in the packet to be isolated.
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Present analysis considers data collected immediately before, during, and after the passage of a non-linear internal wave.
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Results show a new acoustic path being generated as the internal wave passes above the acoustic source.
Measured sound speed profiles showed anomalous bump at ~30 m that hadn’t been observed earlier in experiment. Layer of warm, salty, neutrally buoyant water present.

Based on measurements, decision made to put source at depth 40 m. (Source depth was 30 m on data collected earlier in experiment.)
Pre Non-Linear Internal Wave

**Modeling Result:** Eigenrays to receiver at depth 50 m for assumed range-independent environment.

Indistinct direct path sensitive to details of sound speed profile.

Strong, distinct bottom-bounce path.

**Experimental Result:** Matched filter output for LFM chirp signal.

Strong, distinct bottom-bounce path.
Internal Wave “Sonny”

Non-linear internal wave named “Sonny” as observed by radar aboard the R/V Knorr.

R/V Oceanus collected oceanographic data on Sonny in close proximity to acoustic source deployed off stern of R/V Knorr.
Internal Wave “Sonny”

Measurements made from R/V Oceanus
Experiment Geometry

Positioning of Assets:

- MORAY acoustic receiver
- R/V Knorr acoustic source
- R/V Oceanus oceanographic measurements
- Internal wave "Sonny"

North

meters

-200 -400 -200 0 200 400 600

meters

400 200
Using the measured bearing and speed (0.89 m/s) of Sonny observed at R/V Oceanus, we can estimate when wave will pass acoustic assets.
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Results

Acoustic arrival pattern evolving over 32 minutes at depth 50 m.

Bulk shift in arrivals due to source and/or receiver motion.

Bottom (B), Surface-Bottom (SB) and Bottom-Surface (BS) paths noted as is position of internal wave.

**Main Result:** New acoustic path splits from bottom bounce as internal wave passes acoustic source.
Results

New acoustic arrival induced by passing internal wave arrives at steeper angle than original bottom-bounce path.

New ray path only observed on bottom part or receiving array as shown (depth 50 m) not on top part (depth 25 m).
Interpretation: Upward launched ray refracted downward by passing internal wave. Ray strikes bottom further downrange than original bottom-bounce path and so arrives at receiving array at steeper angle.
Summary

Mid-frequency acoustic transmission data were collected on a vertical array over a continuous 7-hour period at range 550 m.

Present analysis considers data collected immediately before, during, and after the passage of a non-linear internal wave.

Results show a new acoustic path being generated as the internal wave passes above the acoustic source.

Future work includes: acoustic data analysis of complete 7-hour period; range-dependent acoustic modeling that is better integrated with the collected oceanographic data; data/model comparison; data/scattering-theory comparison.