Modeling the Effect of Oceanic Internal Waves on the Accuracy of Multibeam Echosounders

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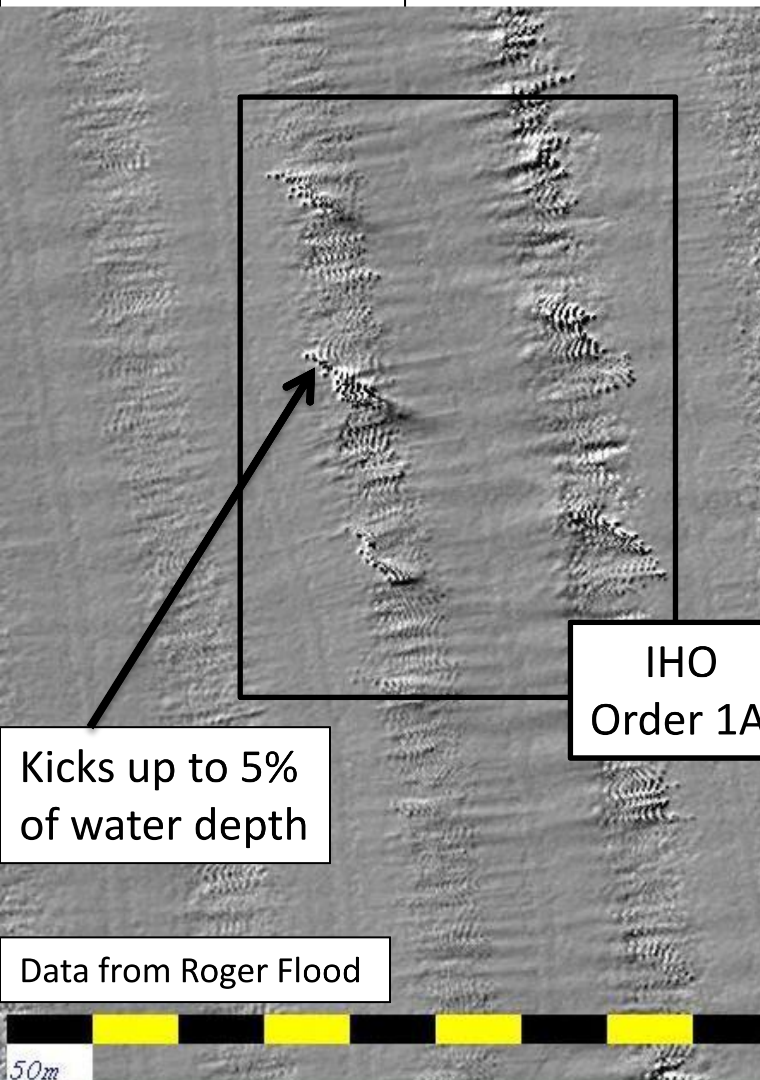
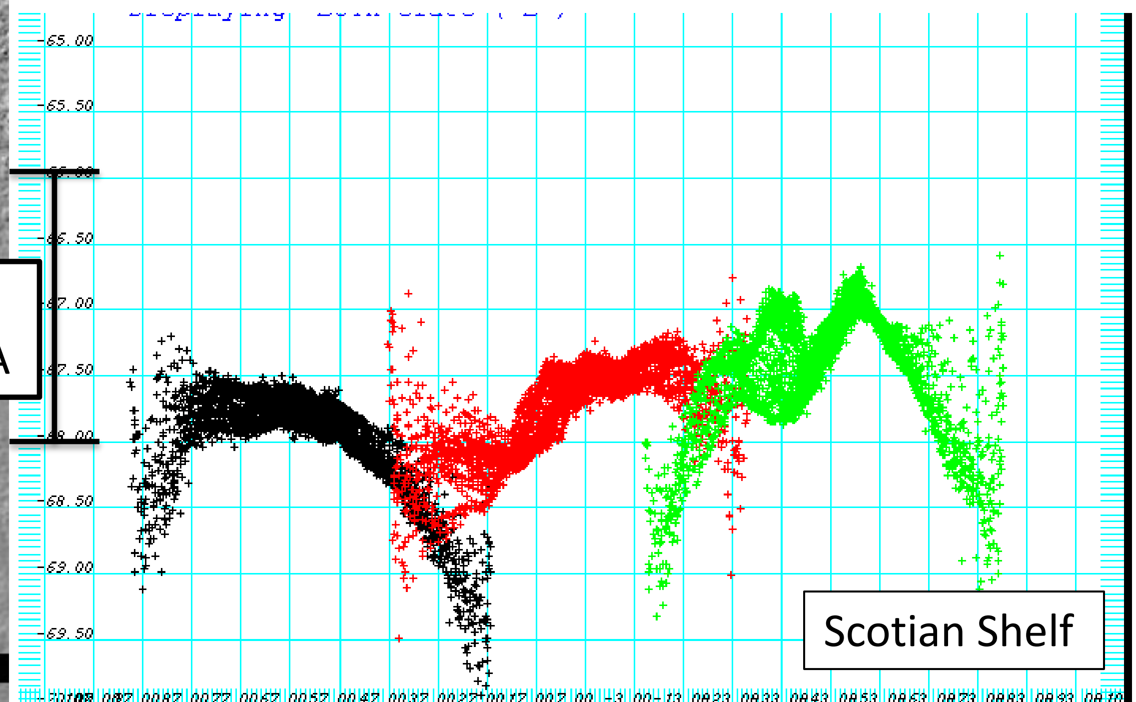
Introduction

Off Southwest Washington State



Both data sets collected with the presence of internal waves in the water column.

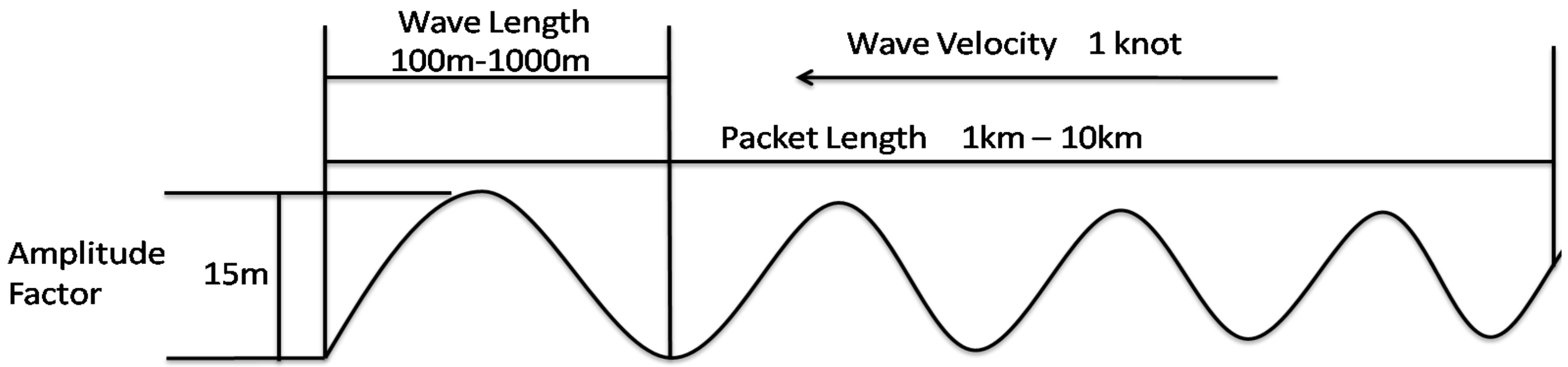
Jonathan Beaudoin, FEMME 2009 presentation

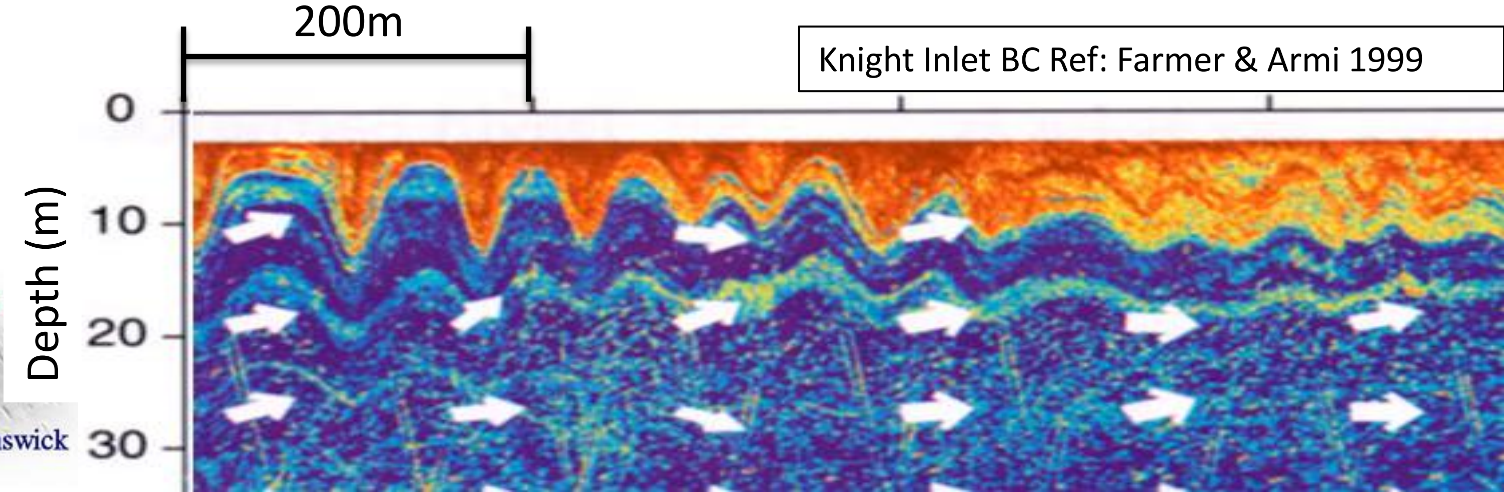


Internal Waves

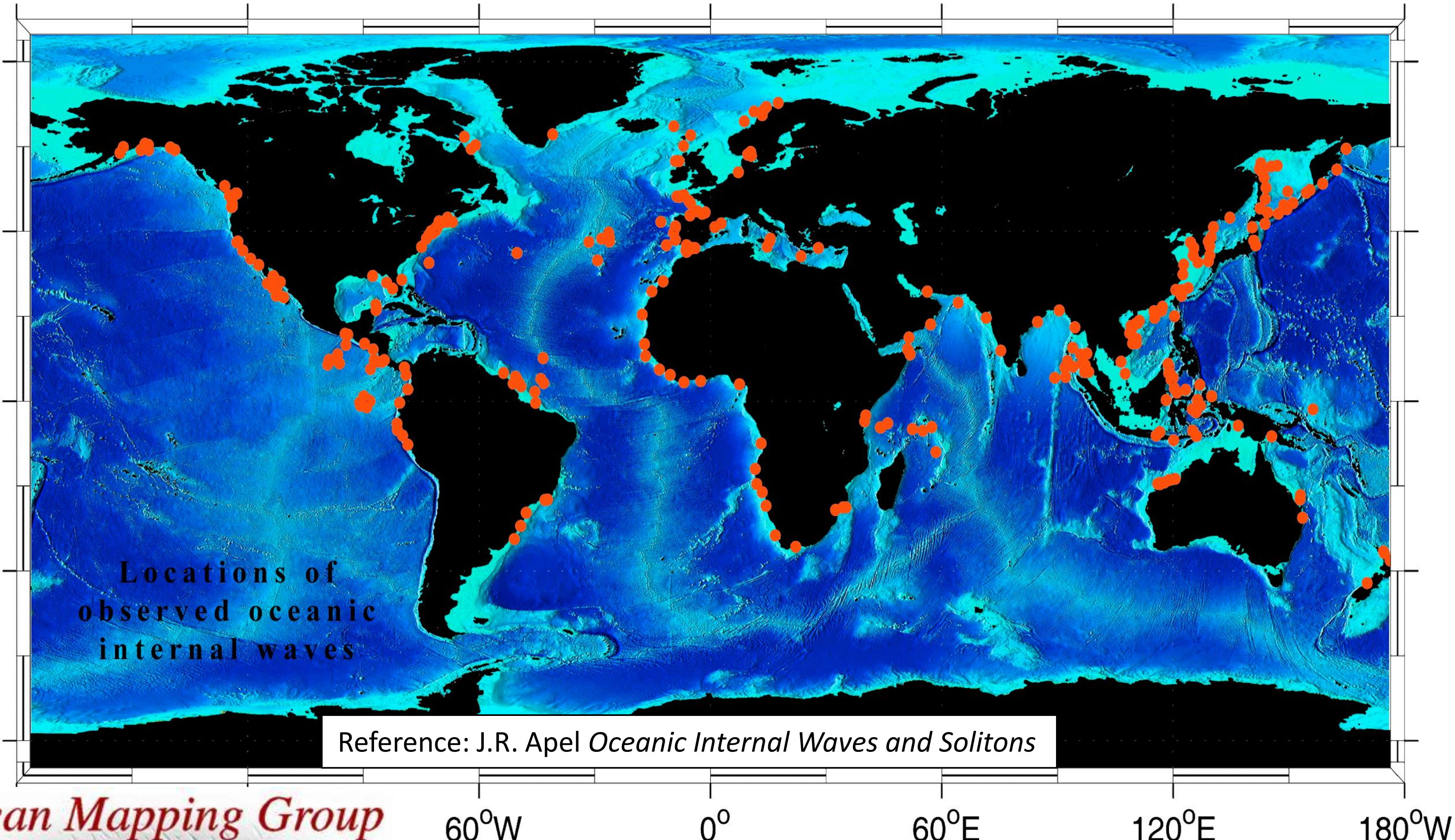
- Internal waves develop along layers of strong density gradient (pycnocline).
- Pycnocline oscillates when perturbed.

Typical scales on continental shelves





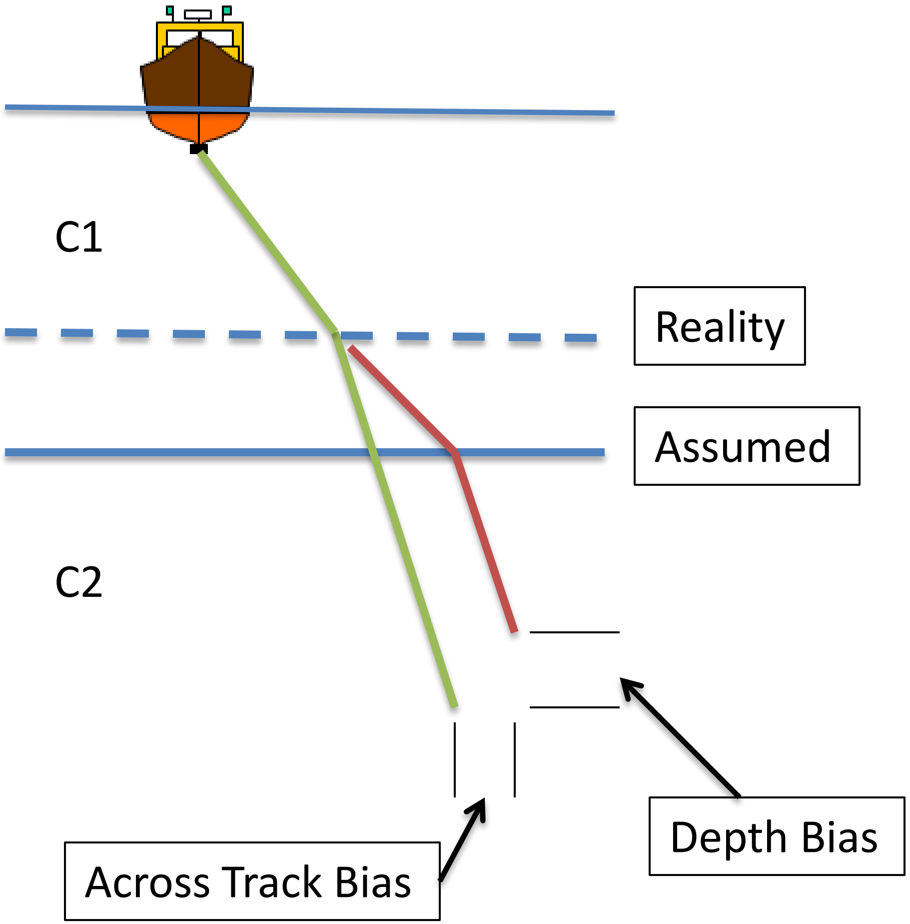
Internal Waves



Reference: J.R. Apel *Oceanic Internal Waves and Solitons*

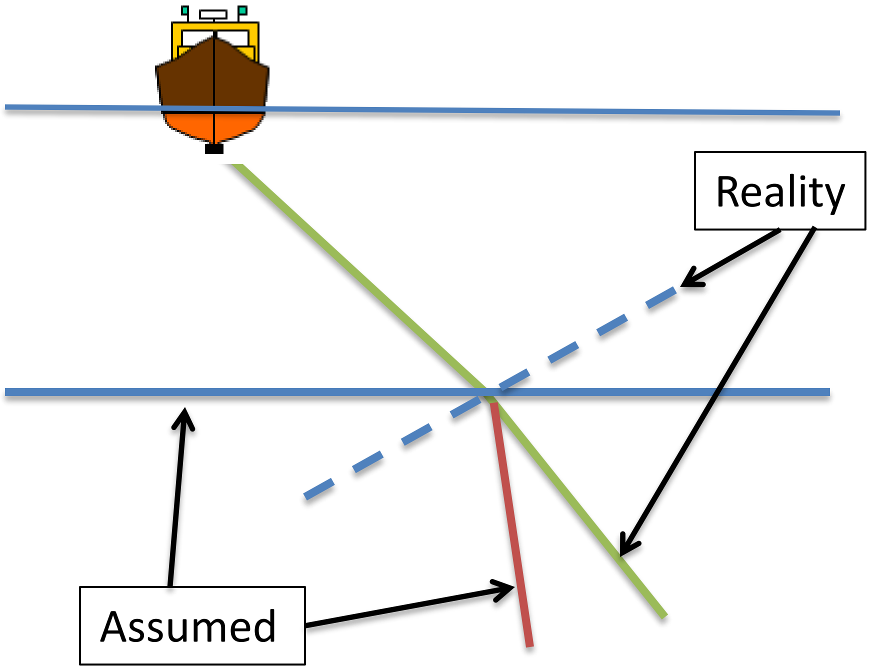
Vertical Oscillation of Velocline

- Strong gradient in density (pycnocline) is associated with a strong gradient in sound speed (velocline).
- Vertical offset of the velocline causes the refracted ray path to have:
  - Different Path
  - Different Length

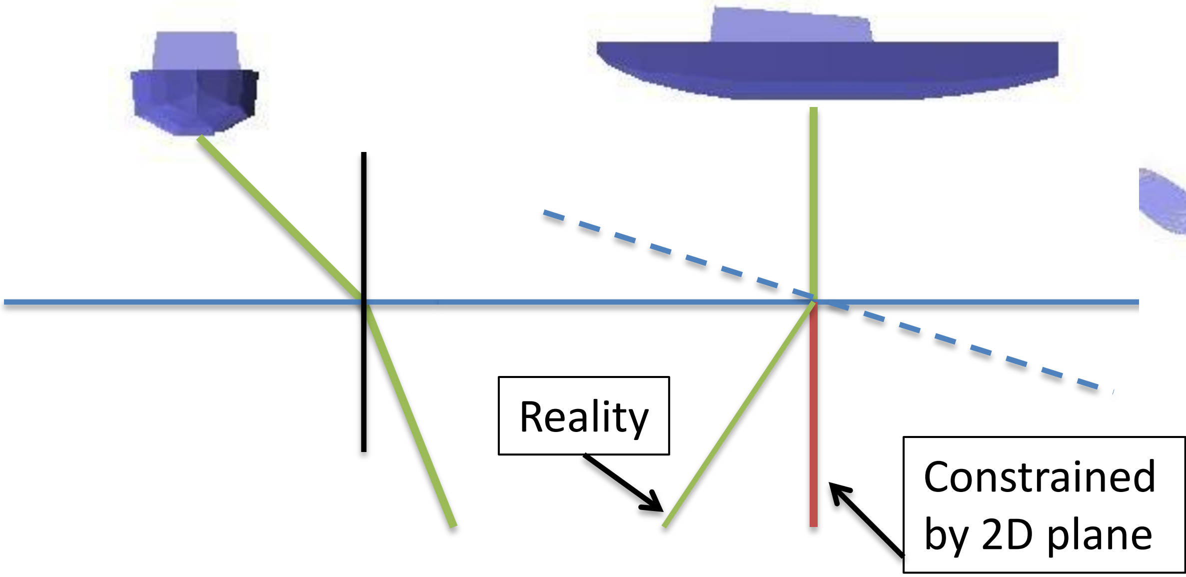


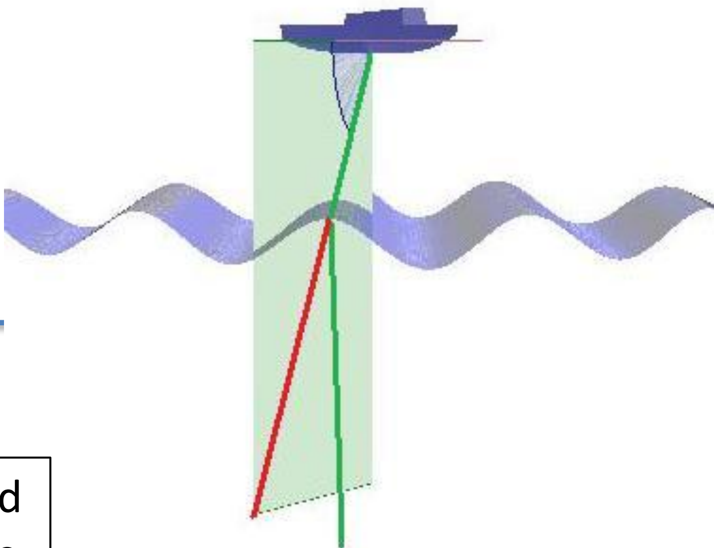
Across Track Tilt

- Internal wave violates the assumption that sound speed layers are horizontally stratified.
- Every degree of tilt causes a 1° bias in the incidence angle.
- Tilt can be greater then 24°.



Along Track Tilt





Assumption that sound speed layers are horizontally stratified means that the ray is constrained by a 2D plane.

An internal wave causes tilt in the along track and across track direction causing the ray to exit the 2D plane.

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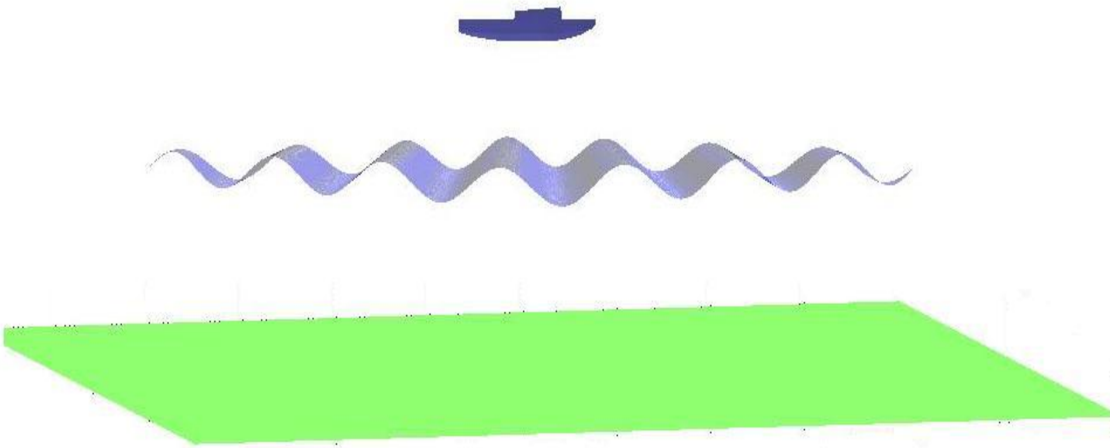
Objective

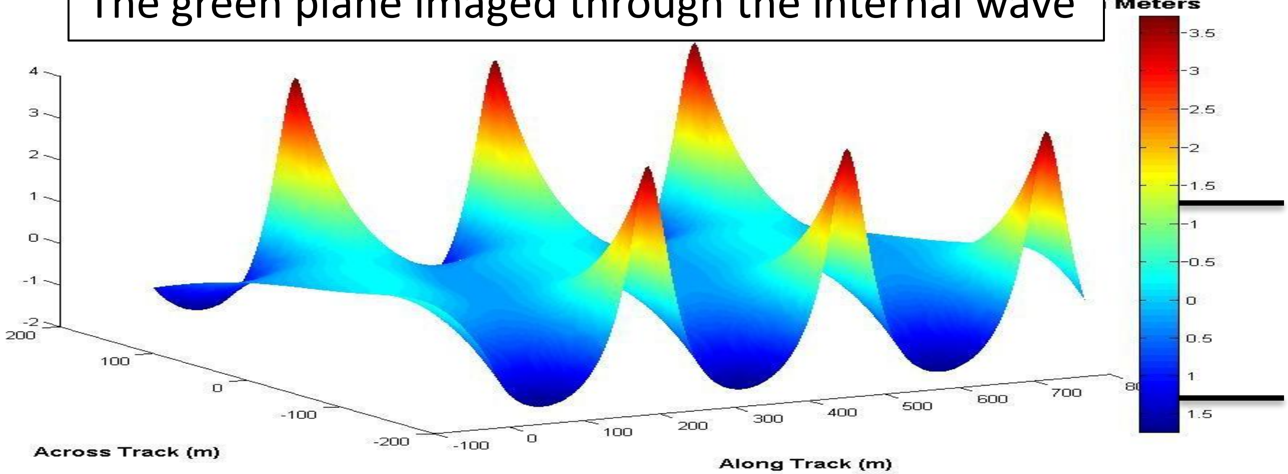
- Create a 3D model of the bias introduced by internal waves



Internal Wave:
- 230 m wave length
- 16.5 m amplitude

Water depth = 90m
Angular Sector = 130°

The green plane imaged through the internal wave



IHO Order 1A

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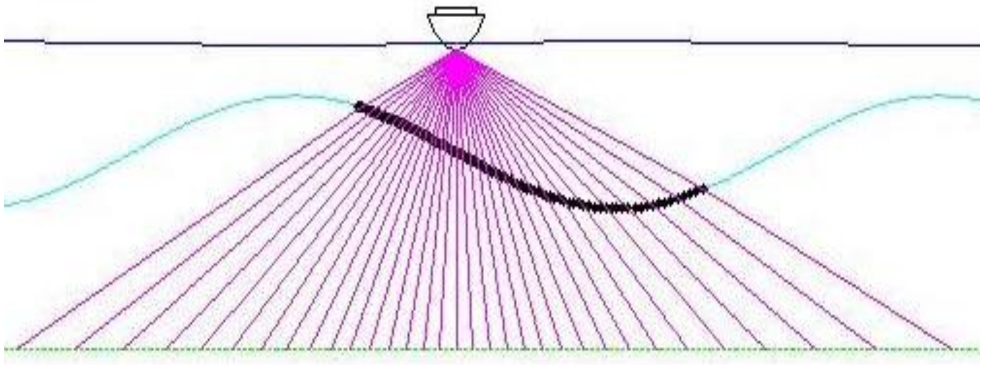
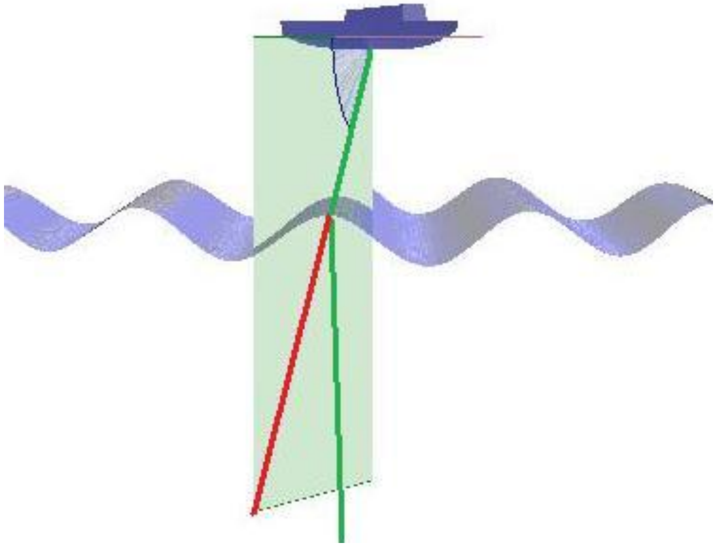
Calculations

- Simulate soundings using 3D ray tracing based on the angle of incidence with the velocline, and sound speed in each layer.
- Simulated TWTT is assumed to be the true TWTT.





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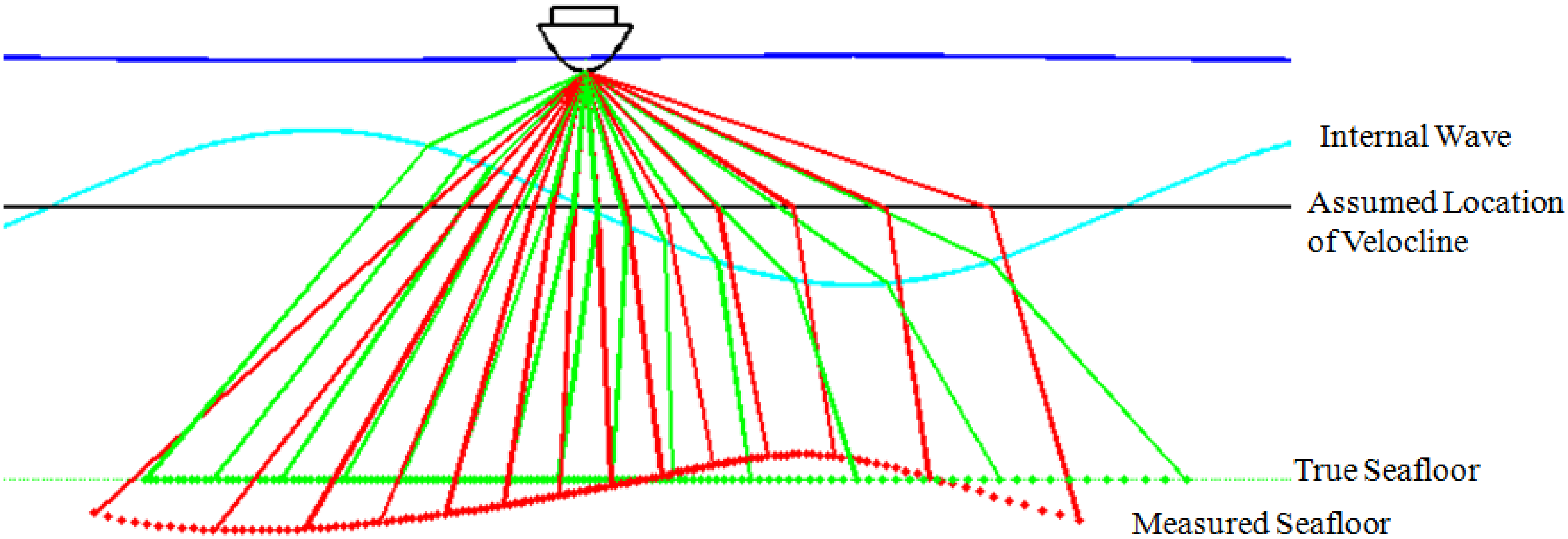
Calculations

- Use simulated TWTTs with a traditional ray trace which assumes the velocline is horizontally stratified.



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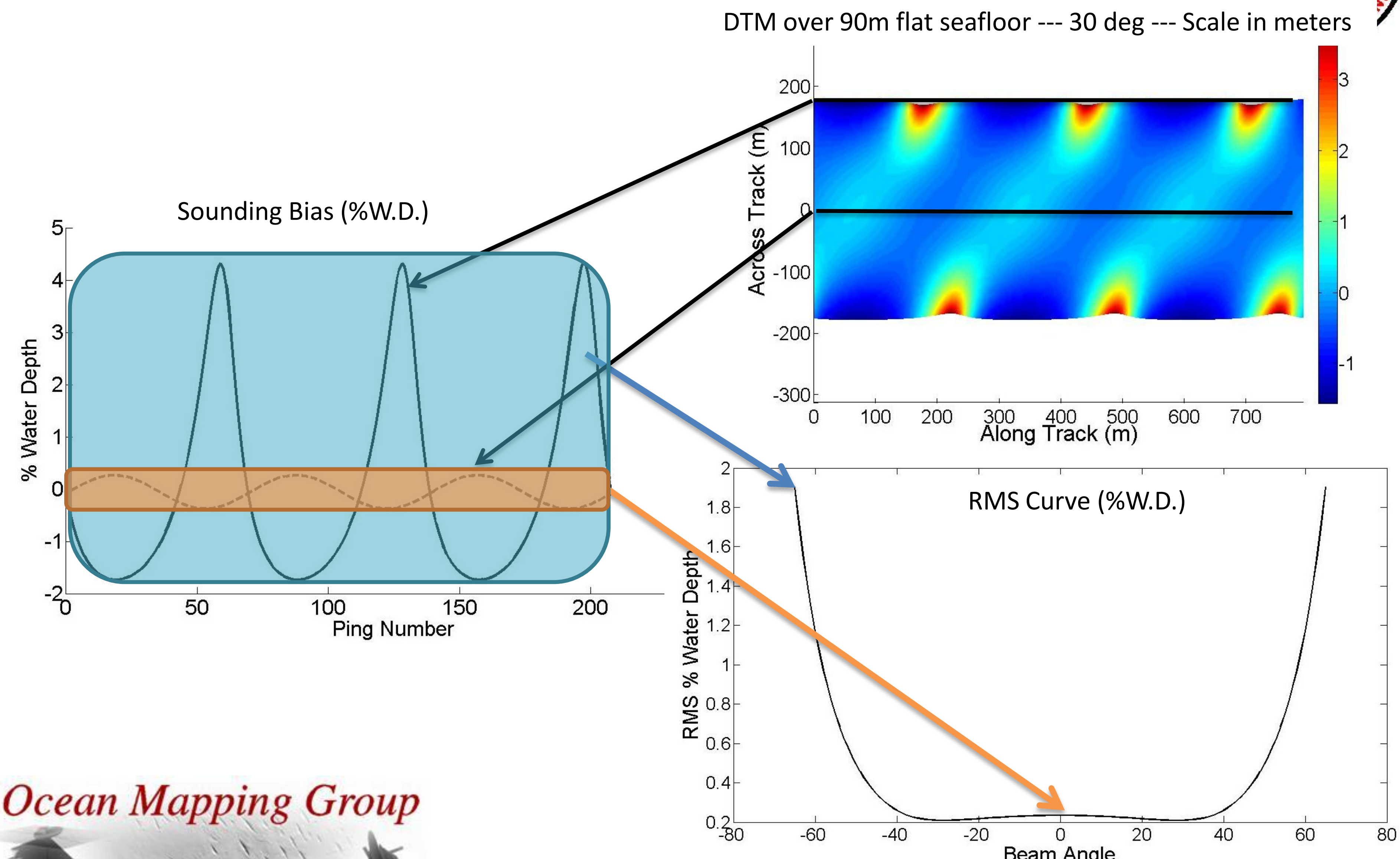
Calculations



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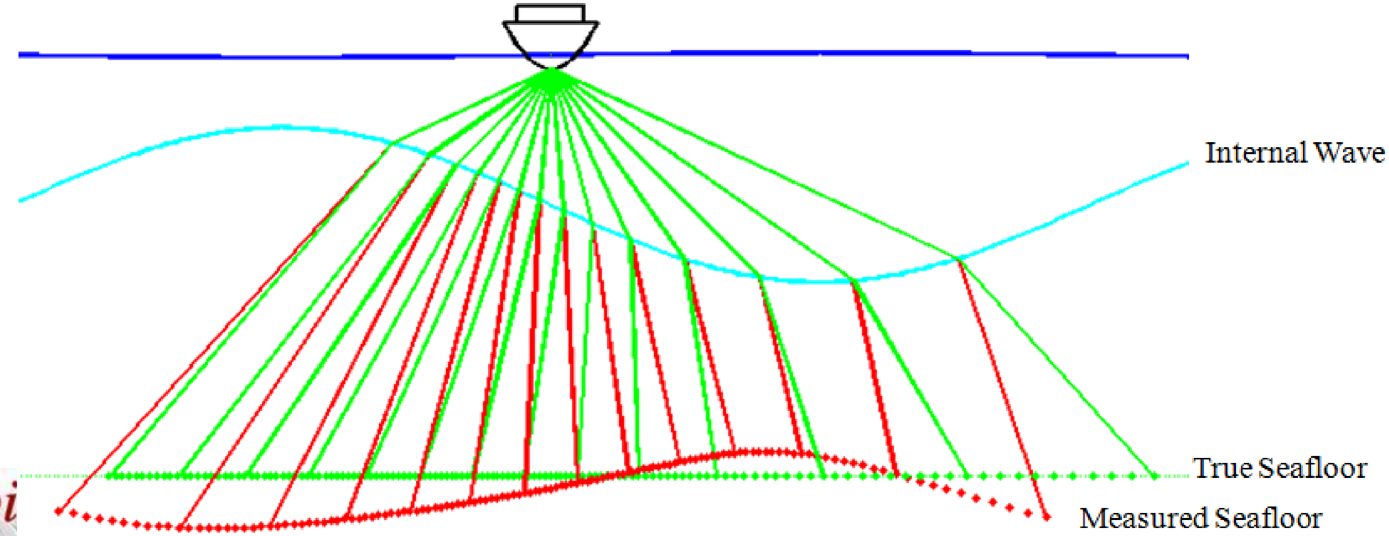
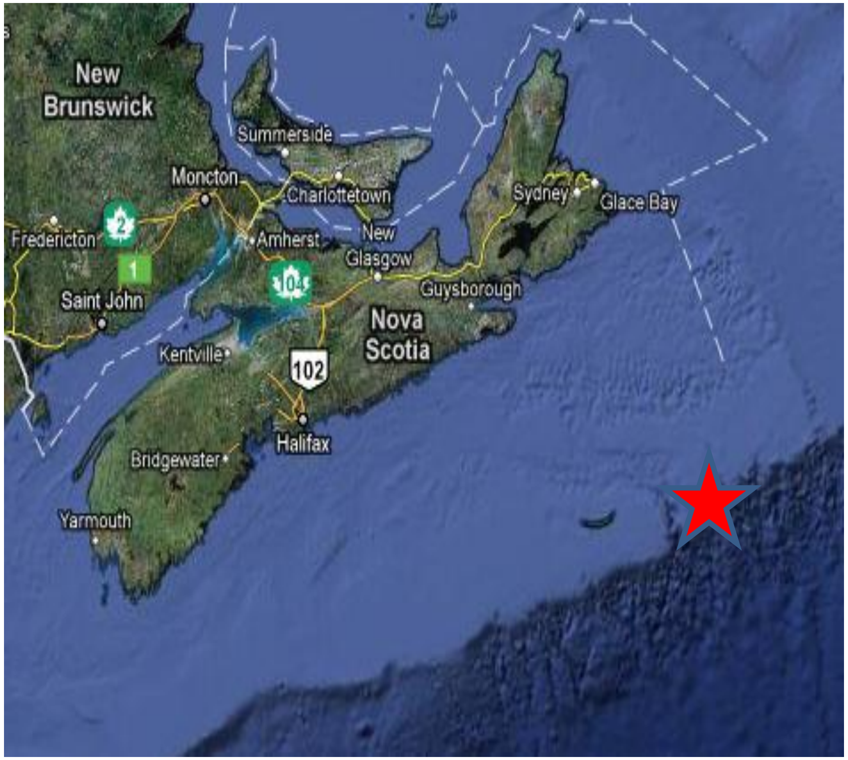
Calculations

- Use simulated TWTTs with Augmented Ray Trace.
- Accounts for vertical displacement of the velocline under the assumption that the velocline's depth for every receiver beam ray path is identified with water column imaging.
- Does NOT account for tilting.



Case Study - Location

Banquereau Bank

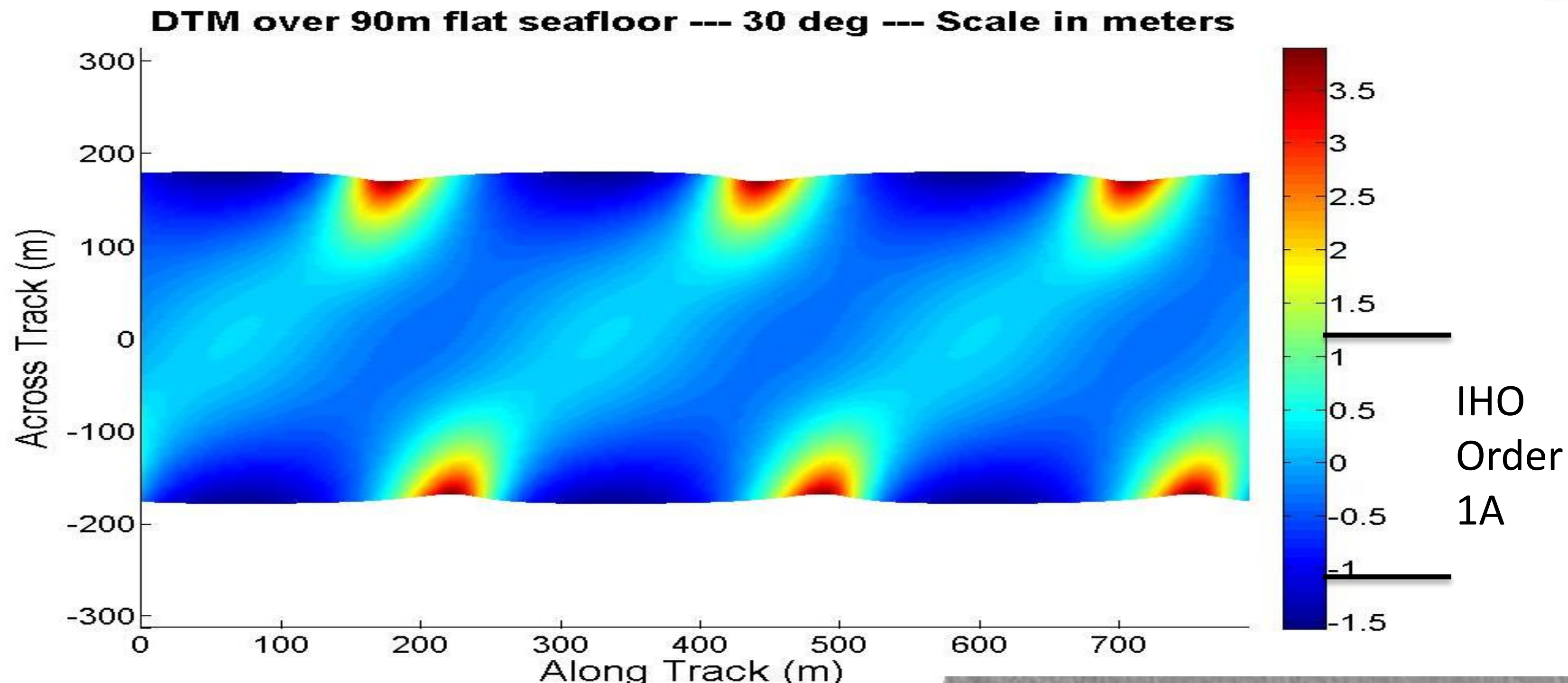


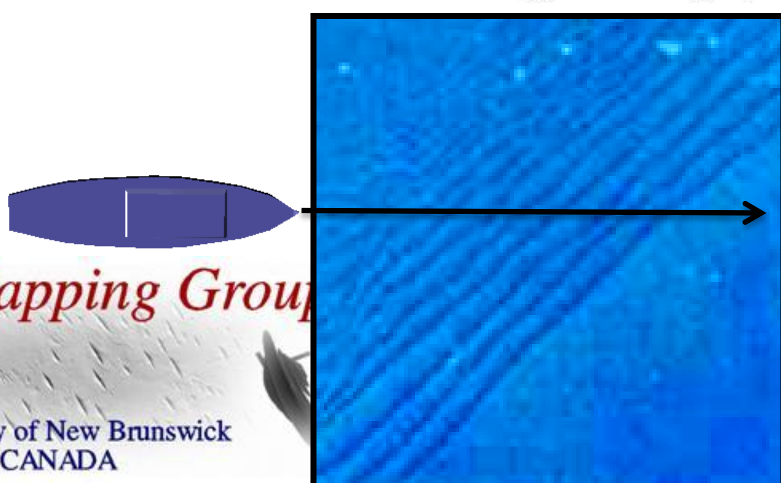
Parameters

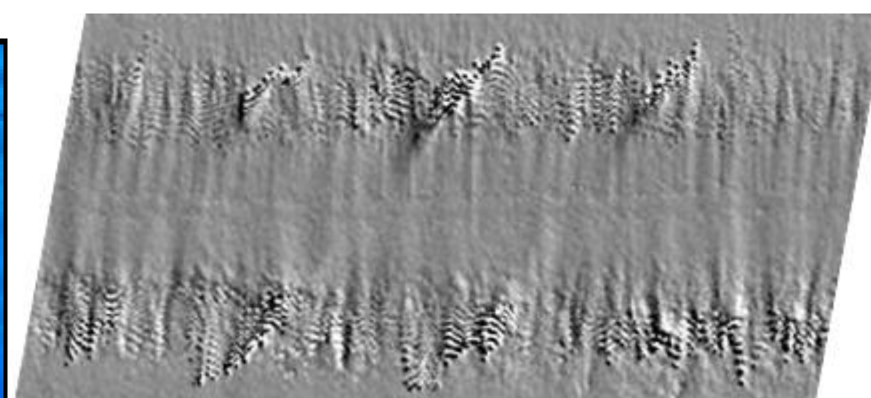
- 230m Wavelength
- 16.5m Amplitude
- 90m Water Depth
- Upper layer 1485 m/s
- Lower layer 1459 m/s

From H.Sandtrom et.al. 1988

Case Study – Bias DTM







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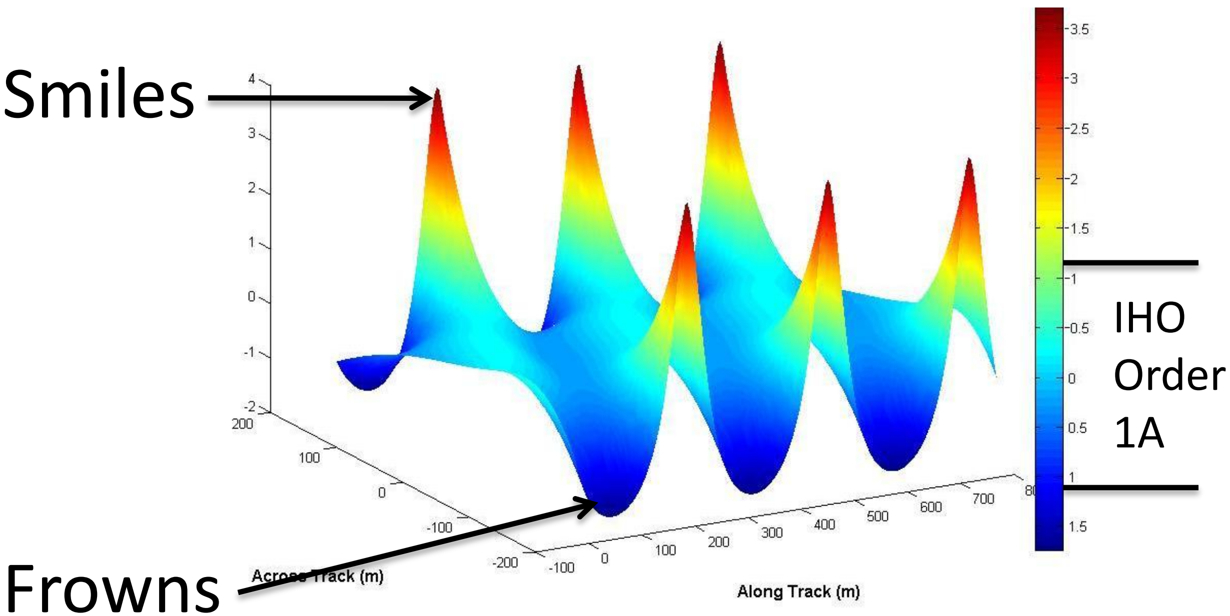
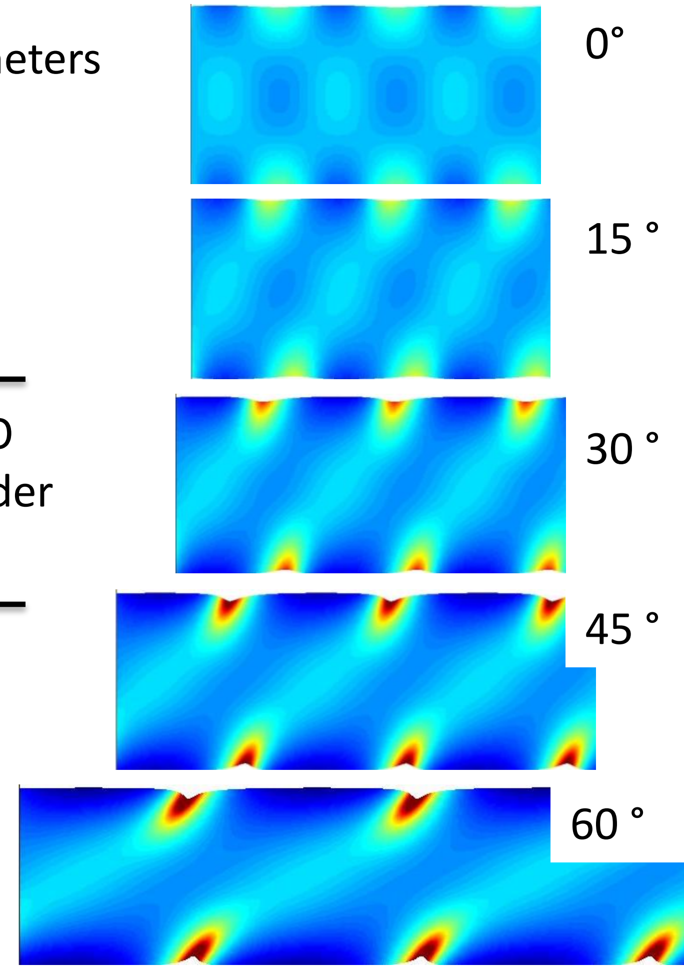
Data from Roger Flood

Case Study – Bias DTM

DTM over 90m flat seafloor --- 30 deg --- Scale in meters





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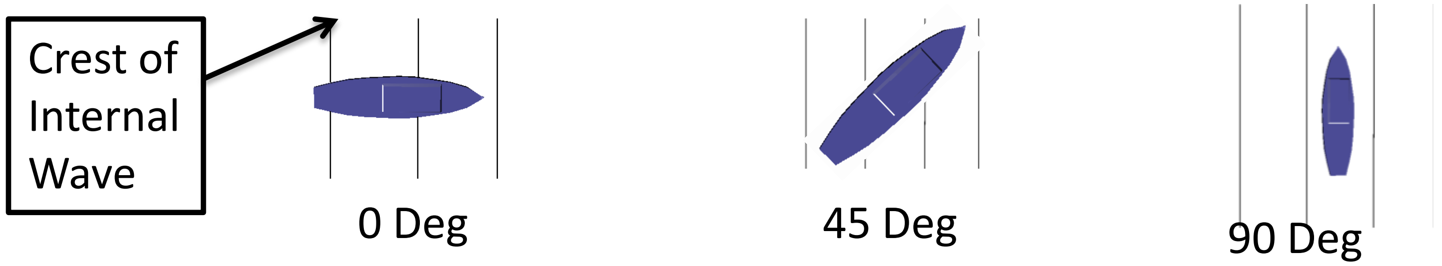
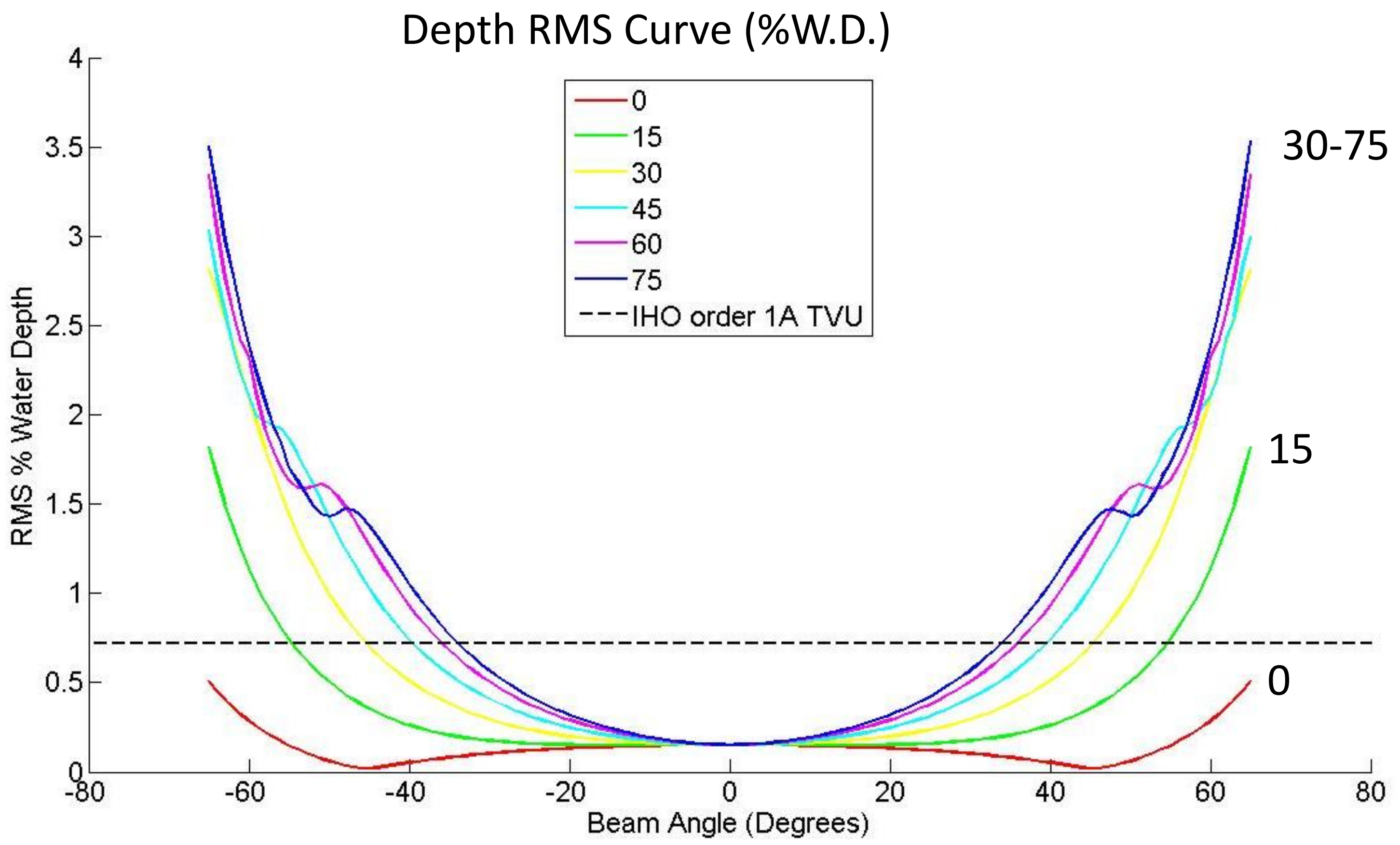
Case Study – Direction of Travel





Uncertainty minimized while travelling perpendicular to the crests of the internal waves.

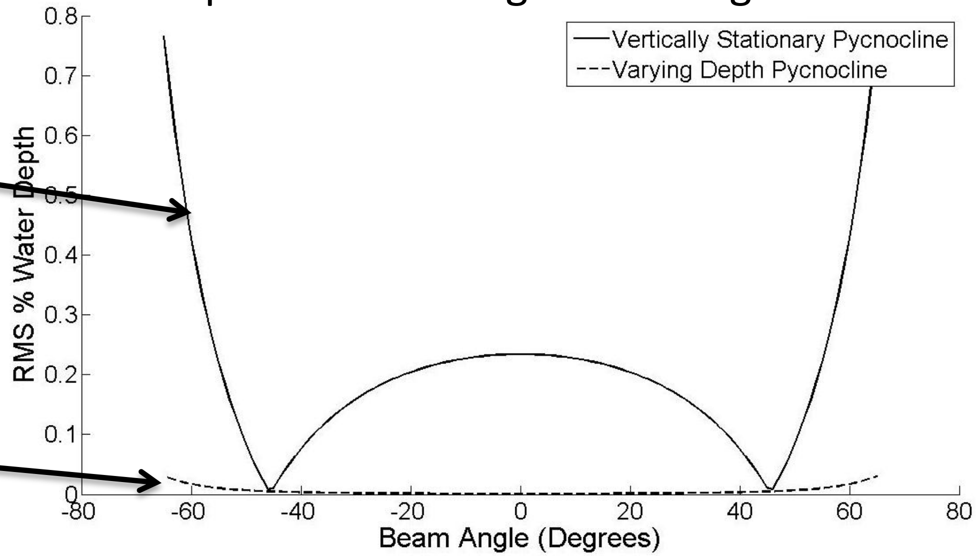
Case Study – Augmented Ray Trace

- Traditional Ray Trace

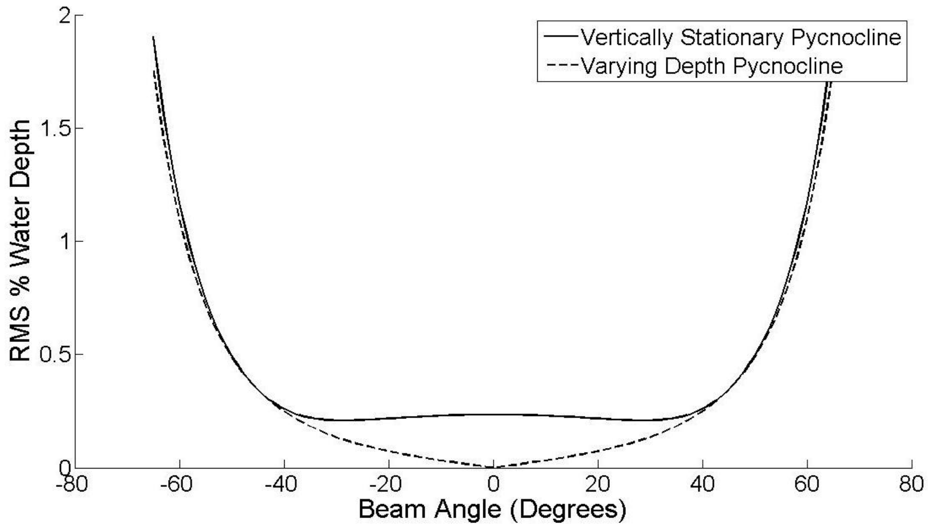
  vs.

  Augmented Ray Trace.

Depth RMS – 0 Degree Bearing



Depth RMS – 30 Degree Bearing

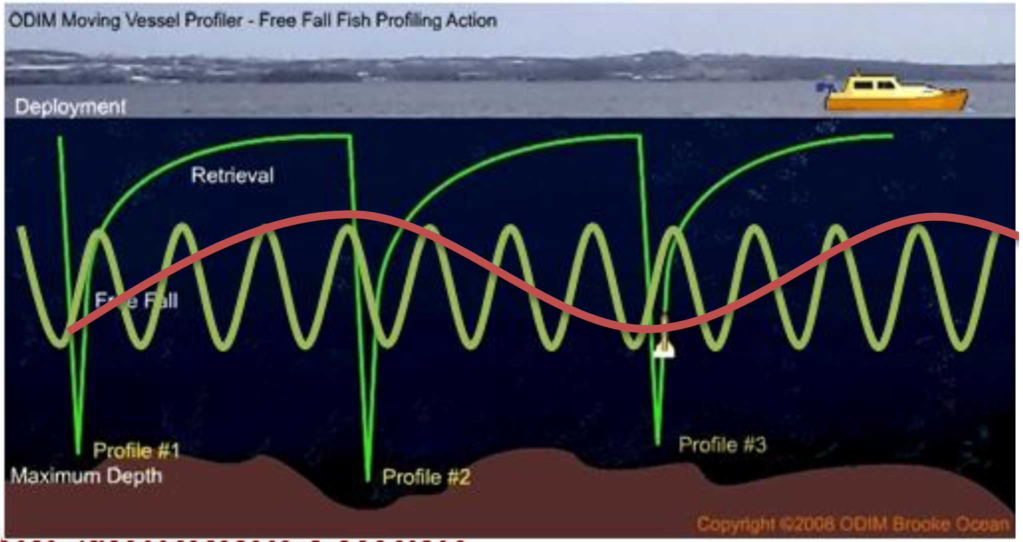


Case Study –Water Column Sampling

- Near Continuous Sampling
  - Aliasing
  - Does not account for tilt

True Internal Wave

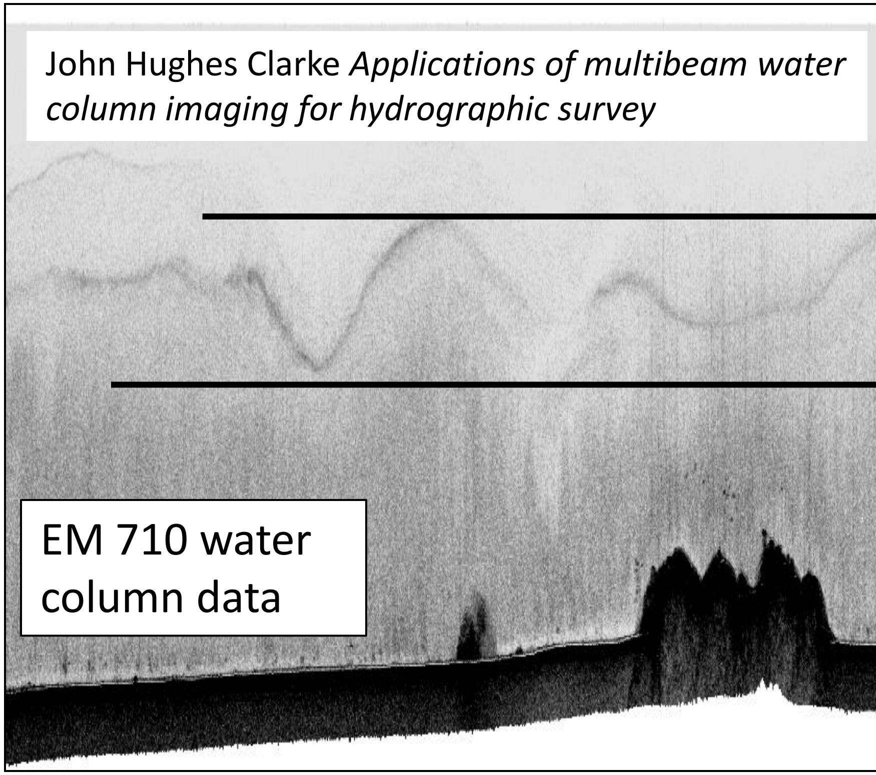
Result of Aliasing

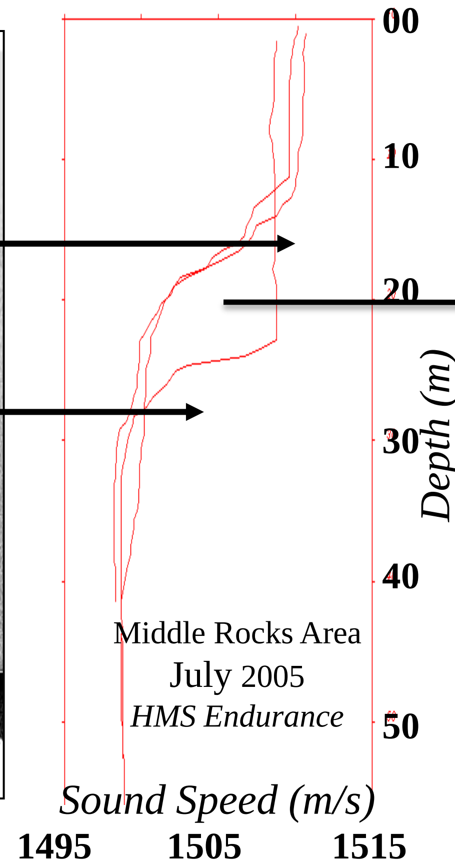


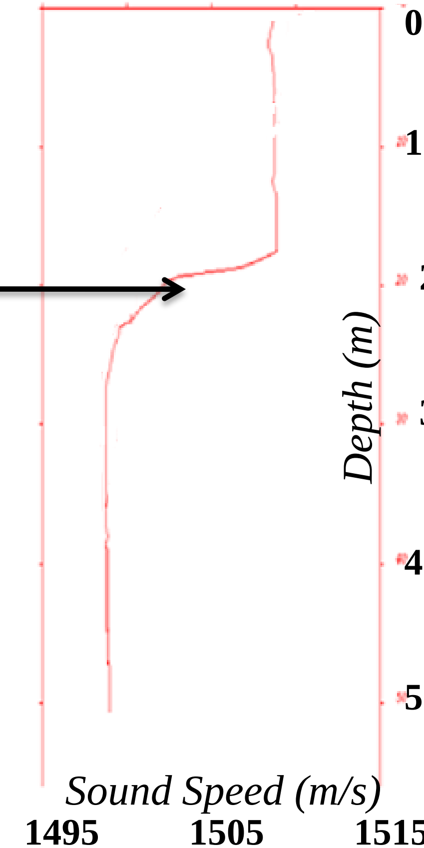
Sampling interval = 3 minutes
Vessel speed = 8 knots ....
1 profile every 740m

Wave length of internal wave 230m

Average Cast







Using an average cast limits the maximum potential vertical offset, between the assumed depth and true depth of the velocline, to the internal wave`s amplitude.

Recommendations

- Uncertainty can exceed allowable TVU according to IHO.
- Oceanographic background research may identify internal wave characteristics allowing:
  - More reliable estimate of total propagated uncertainty,
  - Ideal survey design parameters (i.e. Line spacing & direction).
- Research may reveal periods of low internal wave activity (e.g. After storms, neap tides).

Knight Inlet BC Ref: Farmer & Armi 1999

Acknowledgements

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- Route Survey – Canadian Navy

Thanks to

- John Hughes Clarke
- Doug Cartwright