Modelling of acoustic wave propagation in realistic ocean environment

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BAYESIAN LOCALISATION IN THE UNDERWATER ENVIRONMENT (BLUE)

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Objectives

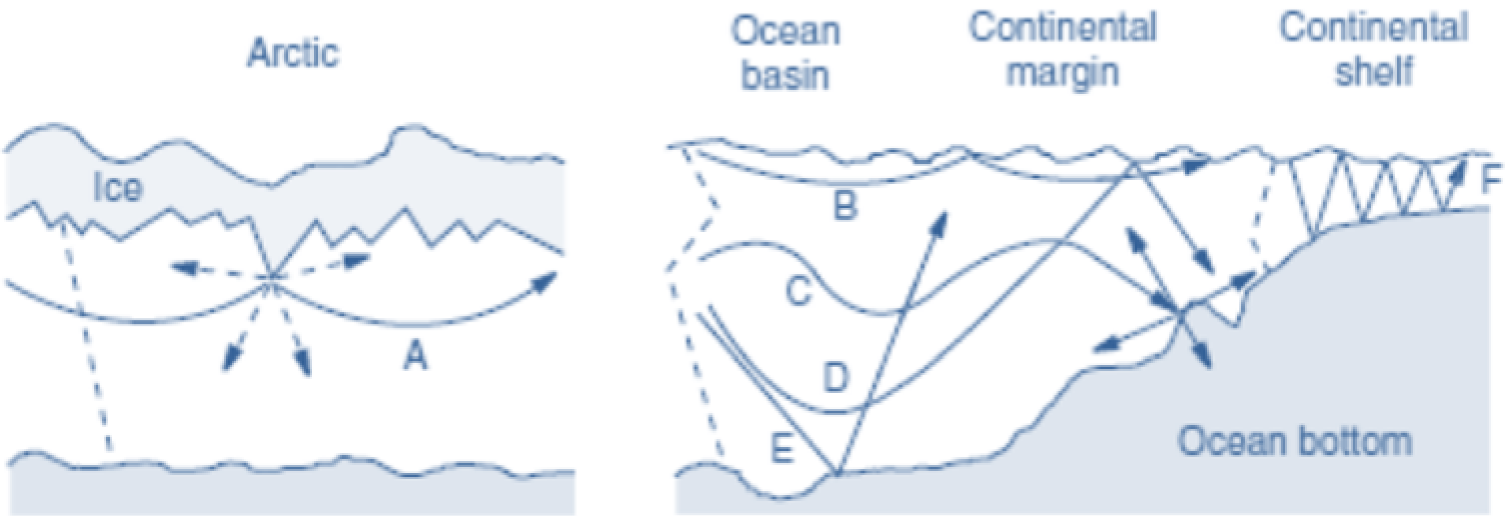
- Study the effects of realistic water column date on underwater acoustic wave propagation

• Heterogeneous vs Layered
• Layered vs Gradient
• 2D vs 3D
• Water column data

- Compare different wave propagation models.

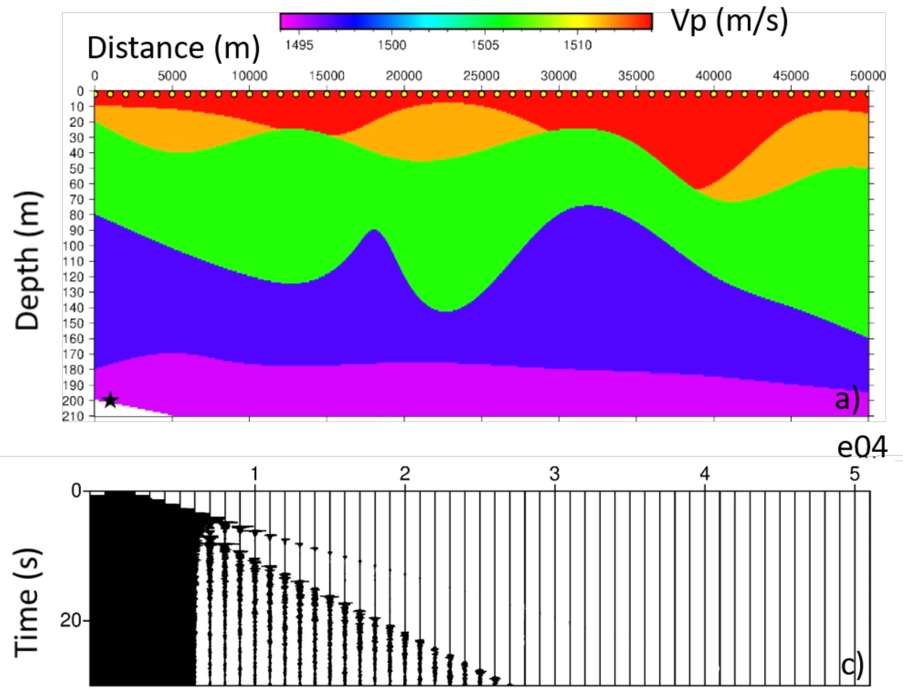
• **Ray tracing - BELLHOP**
• Normal mode
• Parabolic equation
• Wavenumber integration - OASIS
• Energy flux
• **Finite Difference- OpenSource** (Thorbecke & Draganov, 2011)

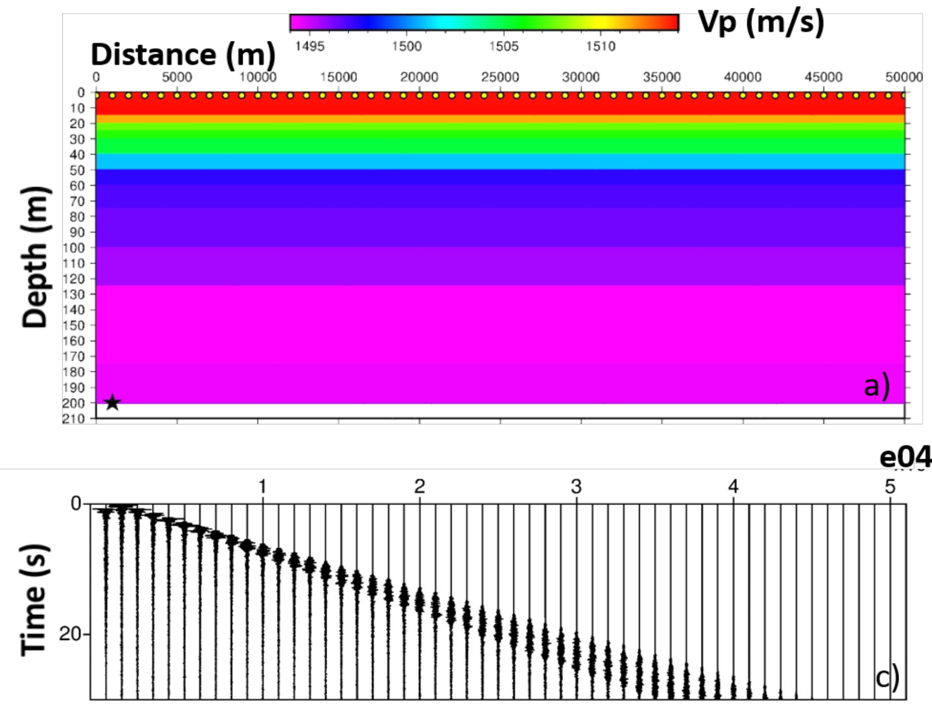
Underwater wave propagation



A. Arctic
B. Surface duct
C. Deep sound channel
D. Convergence zone
E. Bottom bounce
F. Shallow water

Heterogeneous vs Layered water



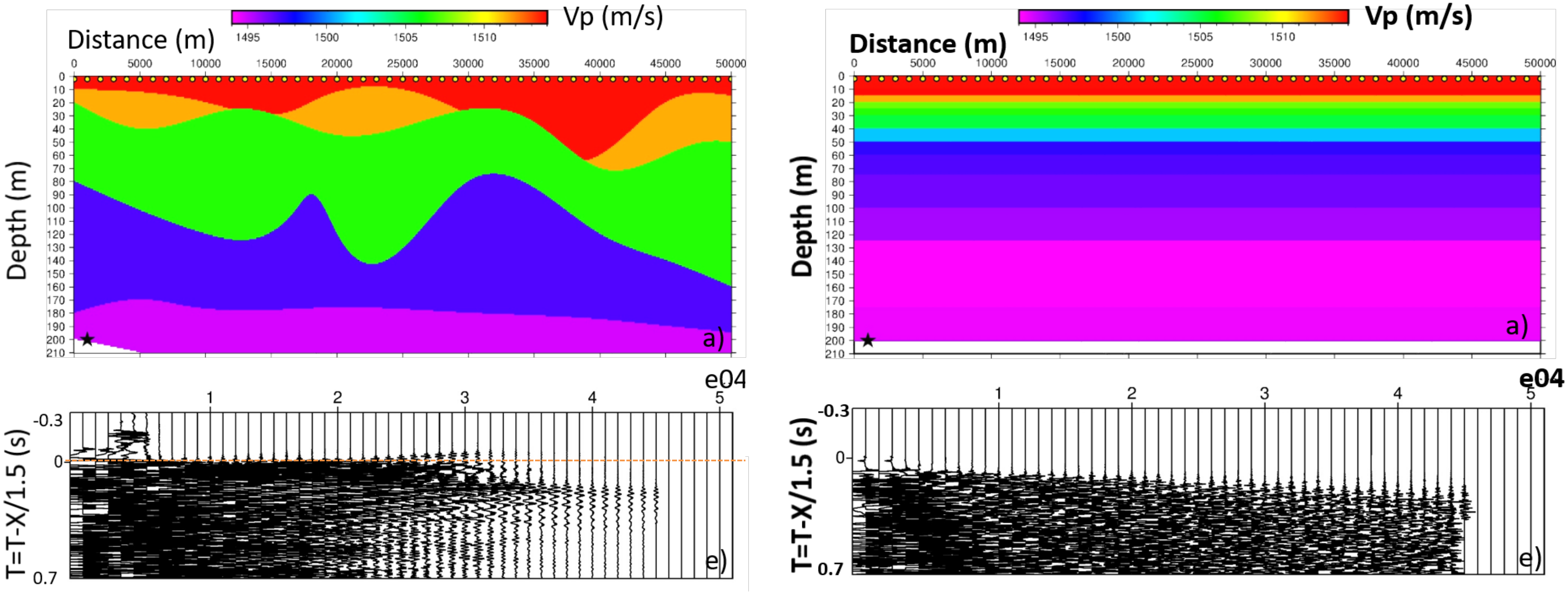


- Gaussian wavelet, Seabed sound speed- 2 km/s
- Heterogeneous model has higher amplitudes for the near source-receiver offsets

(< 5 km, receiver are saturated due to very high amplitudes),

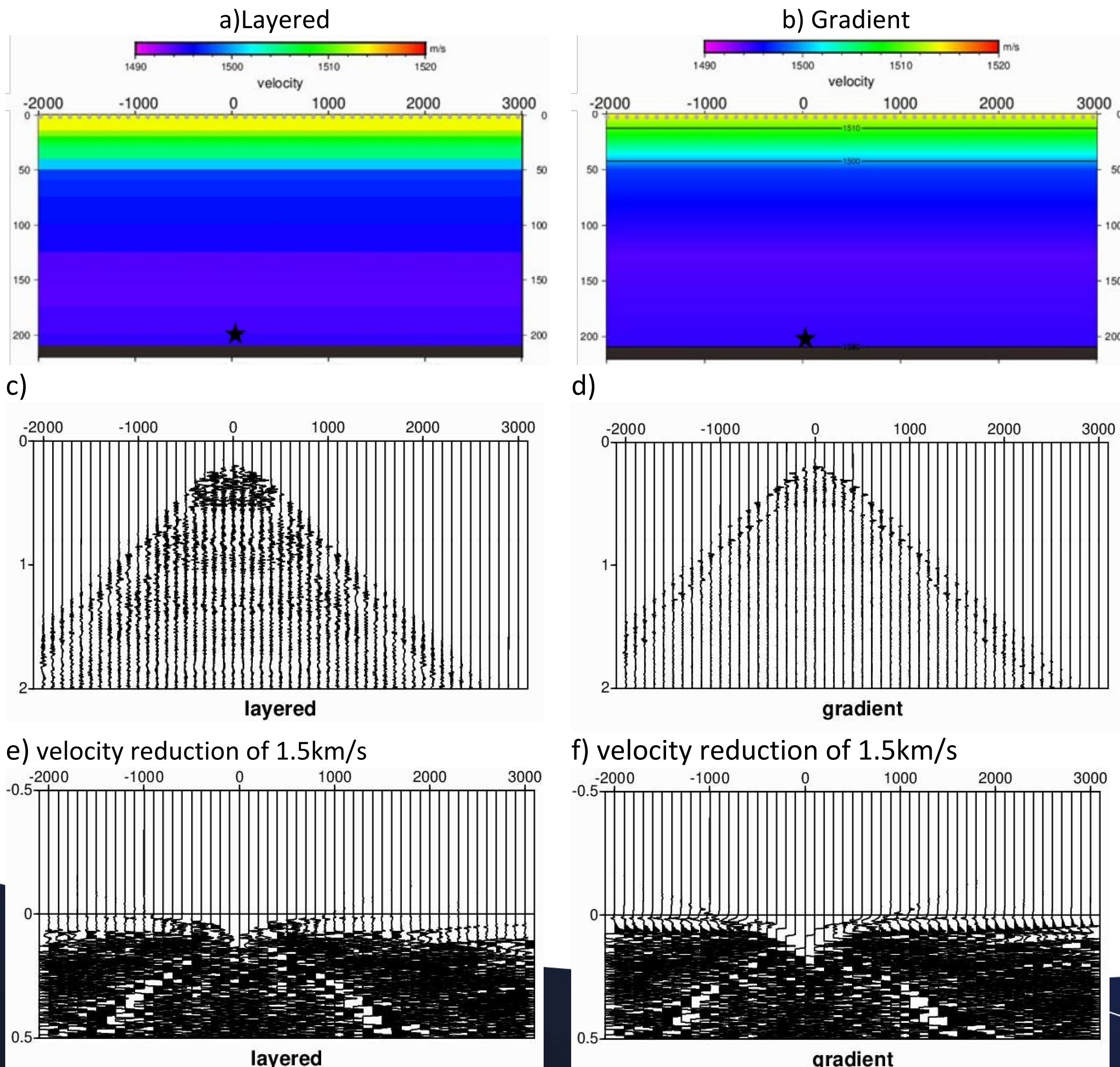
- Amplitudes decrease for far offsets

Heterogeneous vs Layered water



- Velocity reduction has the effect of flattening all arrivals with an average velocity of 1500 m/s, making visualisation easier; jittering of arrival times illustrate that heterogeneous water velocity causes ray path bending (refracted and reflected).
- First arrival signal can be followed only up to 35 km at least 10 km less than in the layered model
- 20 km of first arrival signals over 35 km correspond to the direct water wave arrival. Signals between 21 and 35 km offsets are propagating within the seabed of 2 km/s
- Near offset traces (< 5 km) arrive earlier than 0 s in the reduced hydrophone data – so travelled faster that 1.5 km/s i.e seabed with 2 km/s

Layered vs Gradient



- The first arrival (zero offset) around 0.4 s appears continuous and easily identifiable in gradient model, whereas it is masked by amplitude variations caused by the velocity structure of the layered model.
- With the gradient model (f), the waves traveling within the seafloor of 2000 m/s are visible whereas their amplitudes are smaller with the layered model (e).
- The water column arrivals are easily distinguishable in (f) around 0 s (with a velocity reduction of 1.5 km/s) at all offsets, whereas they can only be followed up to an offset of 1500 m in (e); this suggests that the offsets at which we can track objects decreases in the presence of higher impedance contrast within the water column.

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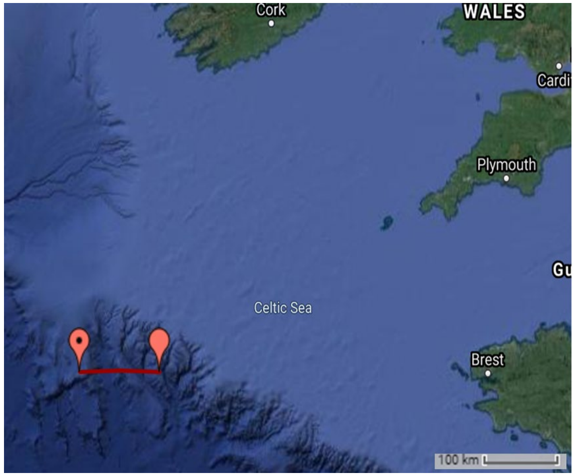
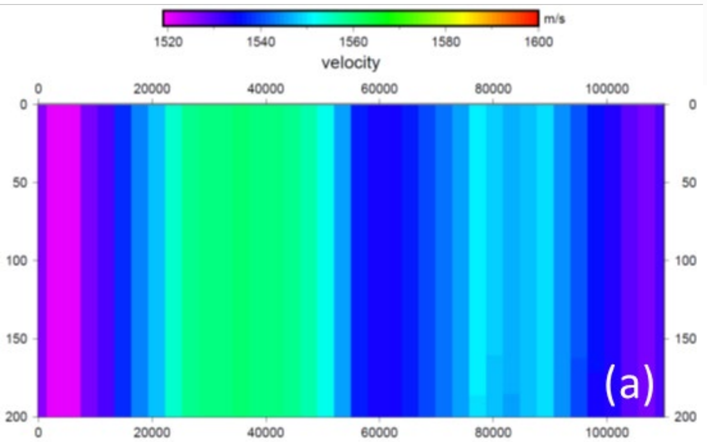
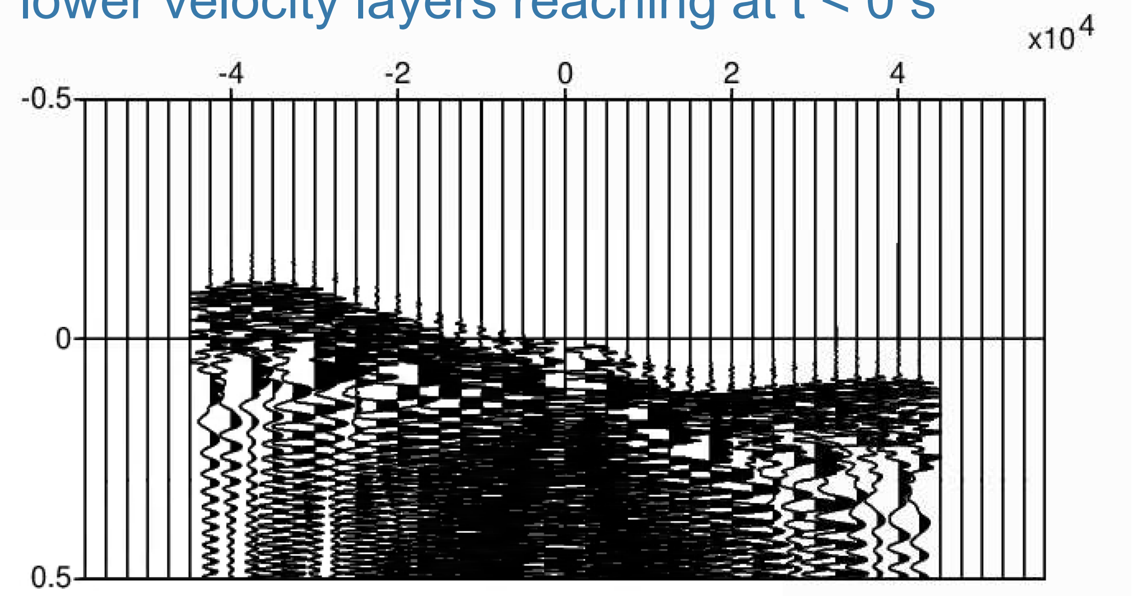
Water column data



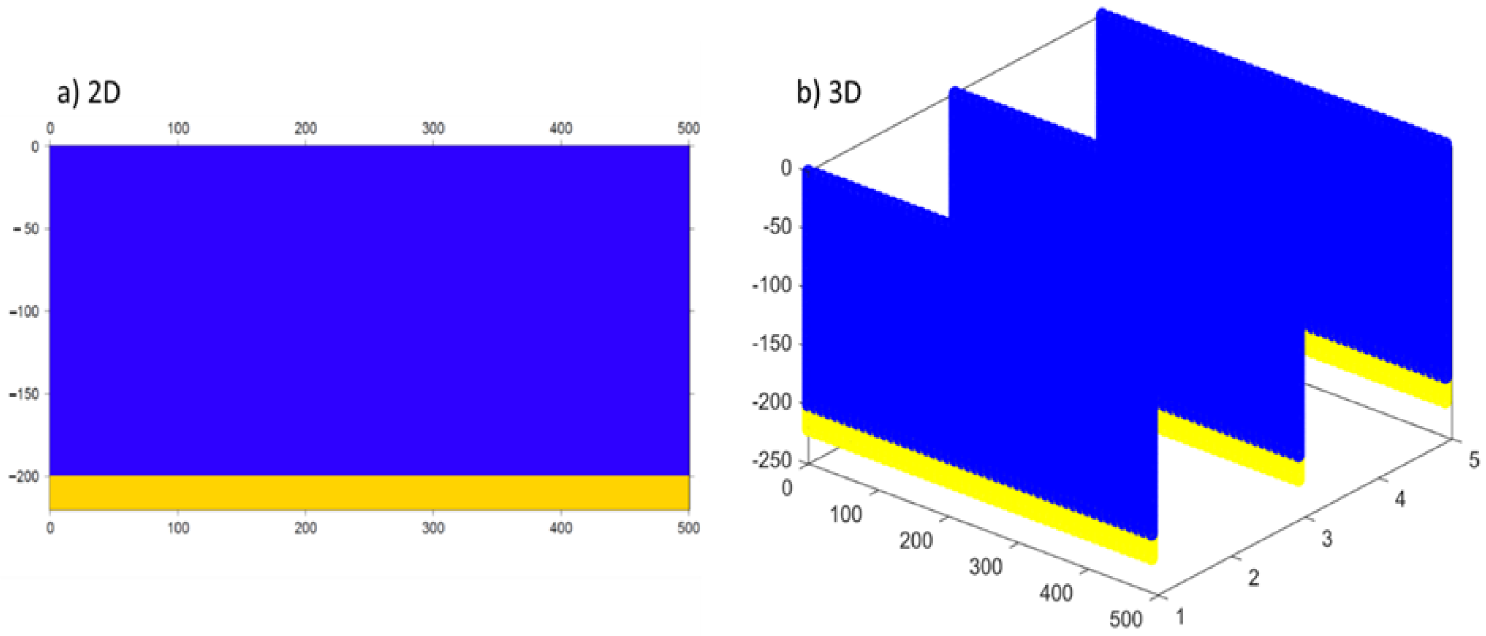
- Velocity varies horizontally – shelf areas
- Data from top 200m
- No seafloor in modelling
- A velocity reduction of 1.55 km/s makes traces in lower velocity layers reaching at t < 0 s





Velocity reduction : 1.55 km/s

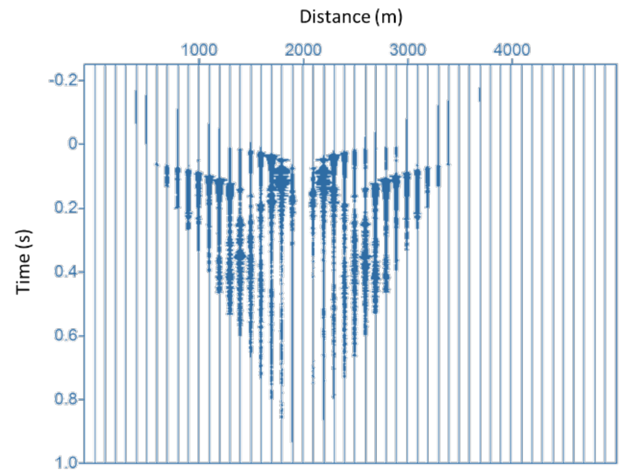
3d vs 2d


a) 2D
0
100
200
300
400
500
-50
-100
-150
-200
b) 3D
0
-50
-100
-150
-200
-250
0
100
200
300
400
500
1
2
3
4
5

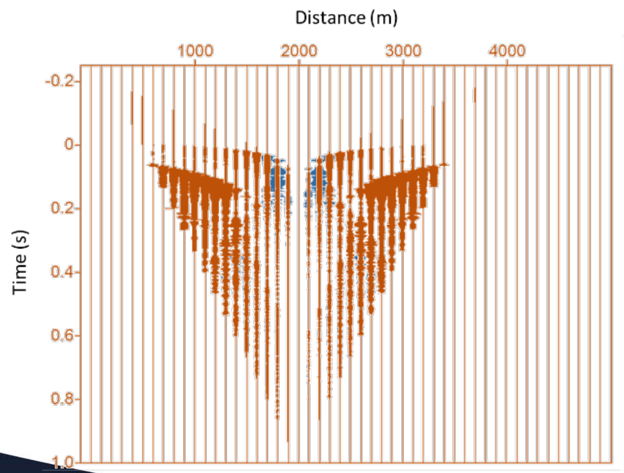
3D vs 2D

a) Seismogram for 2D model

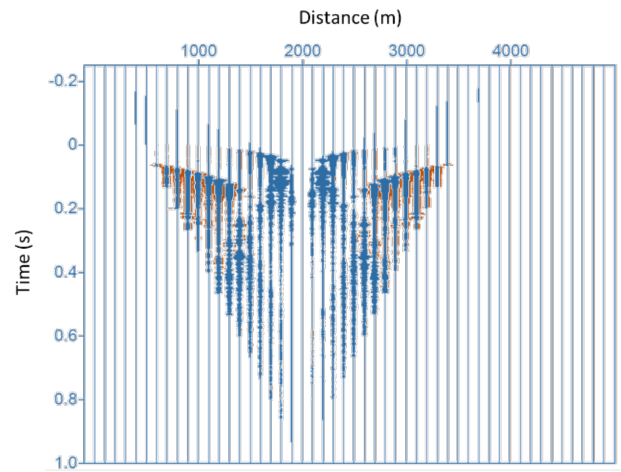
b) Inline of 3D data at y=1m



c) 2D overlapped on inline of 3D data at y=1m



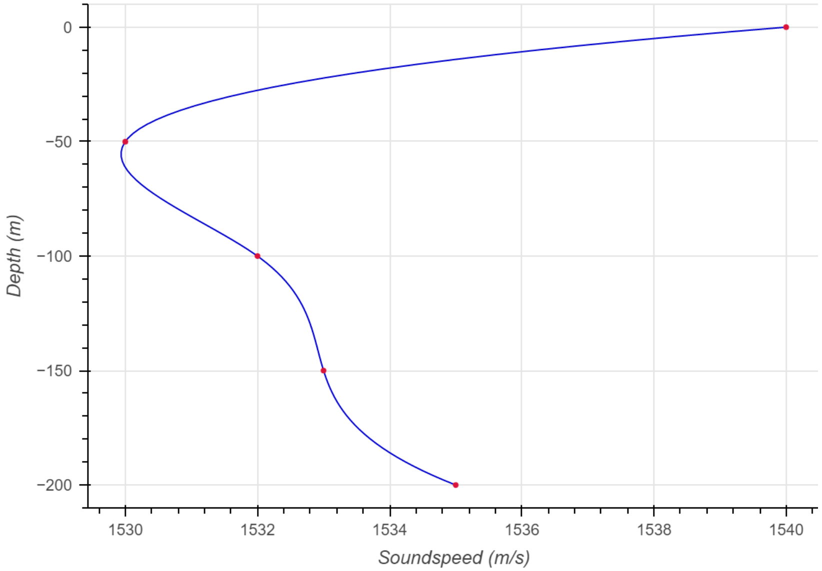
d) Inline of 3D data at y=1m overlapped on 2D



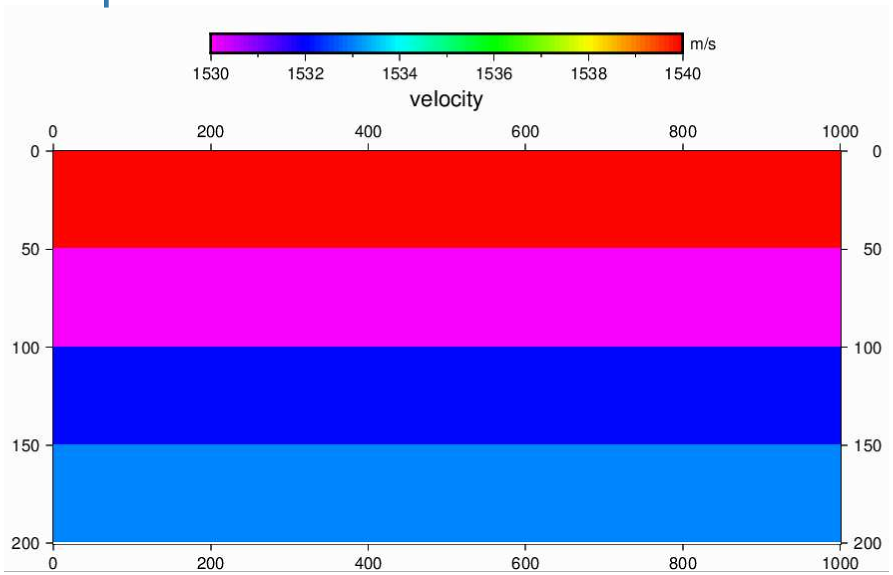
- Same configuration
- No travel time differences
- 2D model shows higher amplitudes for near offset traces, but lower for the far offsets.
- If a source is to be detected from signal amplitude, then 2D modelling may give over-optimistic results compared to reality, as it gives higher amplitudes compare to the 3D case.

Ray tracing vs finite difference

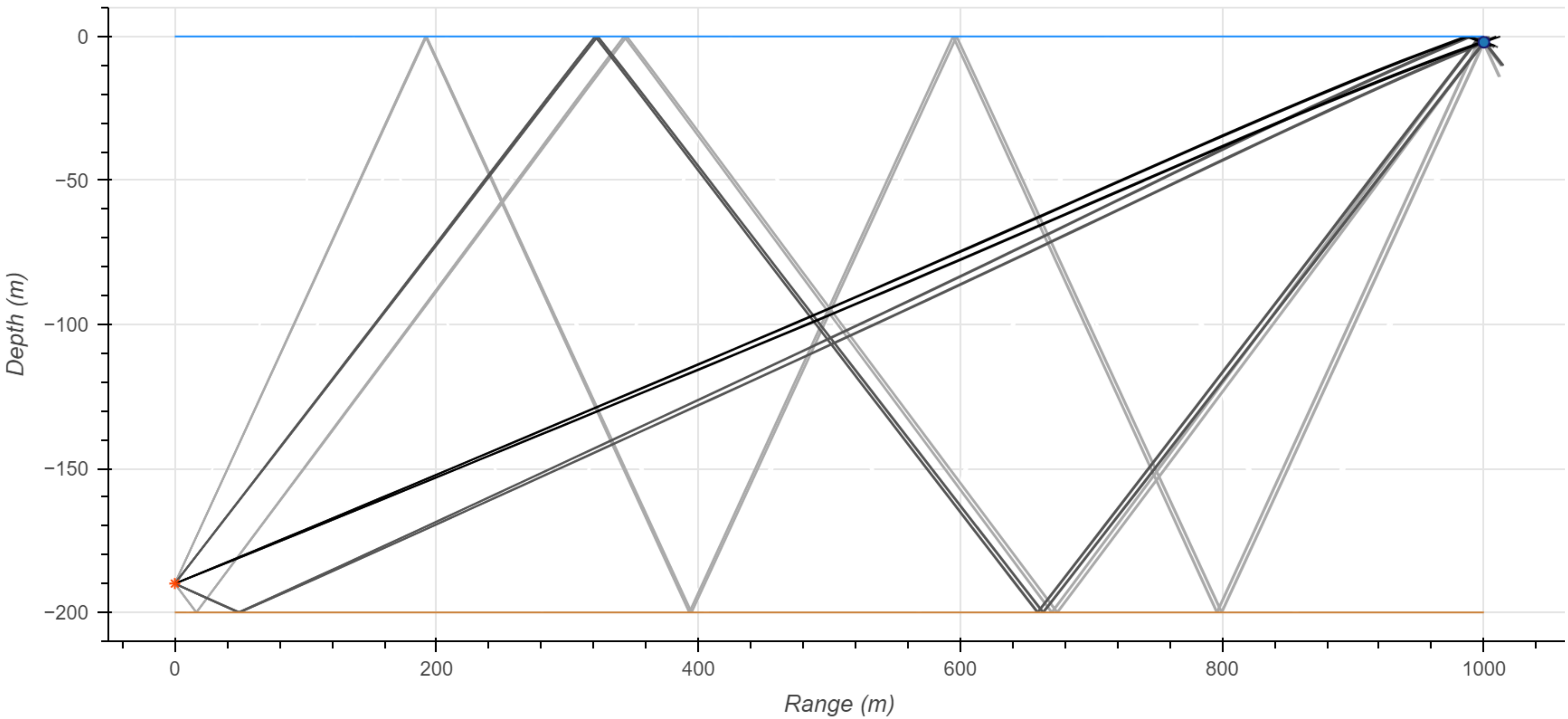
Bellhop



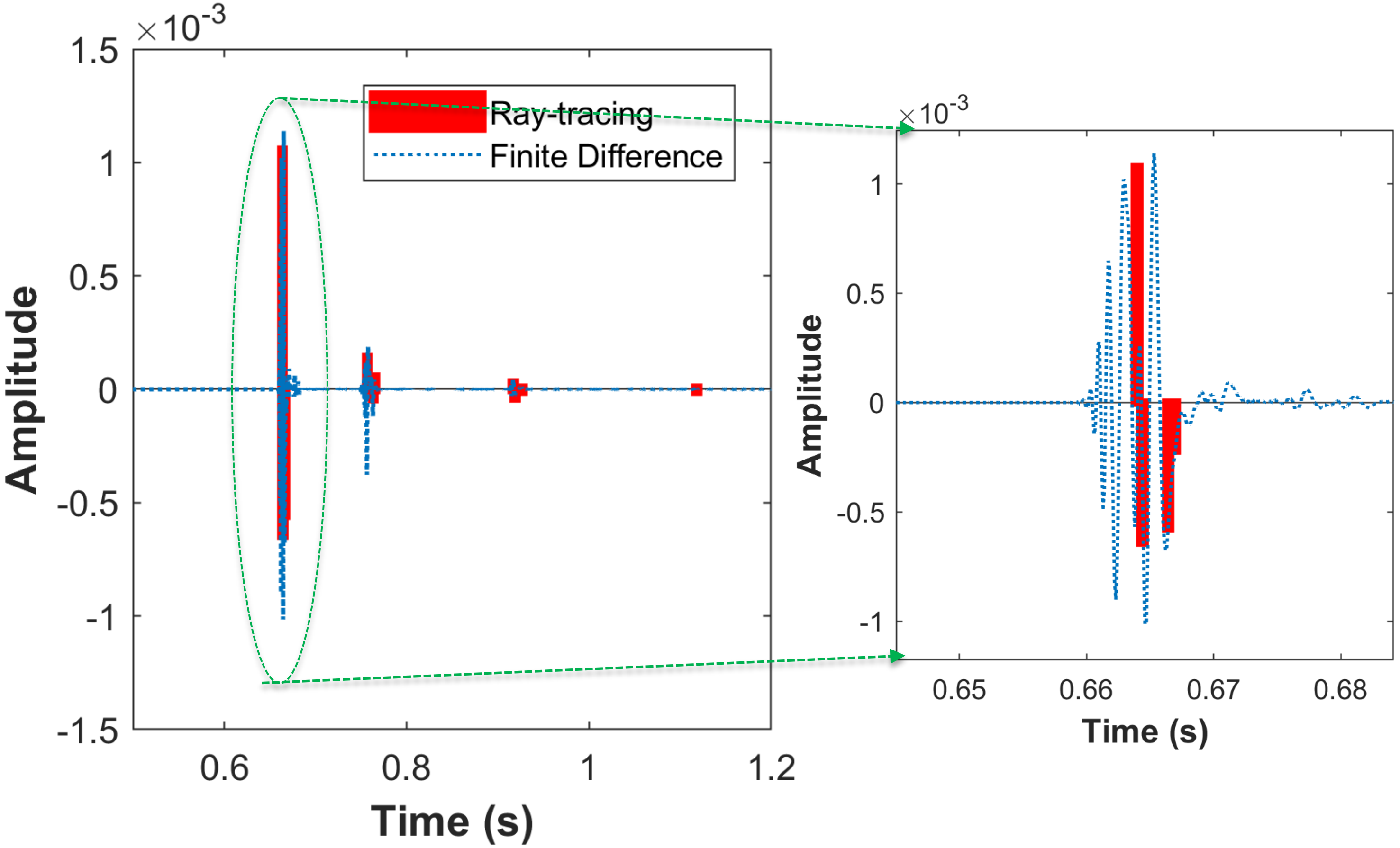
OpenSource



Bellhop ray tracing



Ray tracing vs finite difference

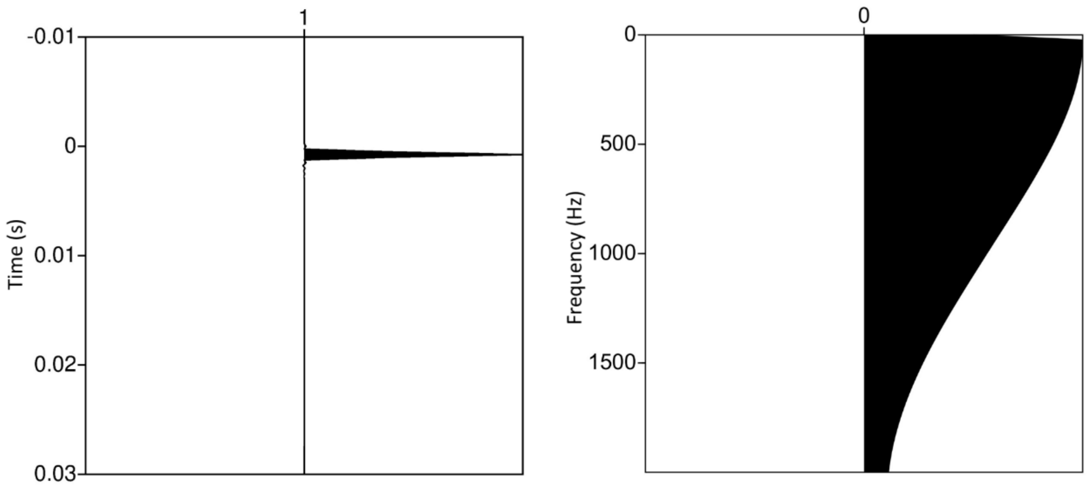


- Arrival time differ by milli seconds in ~1 km.
- Higher amplitude finite difference method.

Summary of key findings so far

- We can successfully generate acoustic ray paths through realistic ocean velocity structures giving accurate signal arrival time and amplitude predictions for any arbitrary combination of source-receiver configurations.
- The current acoustic model is limited to impulsive sources, such as Gaussian wavelets. However, we can vary frequency content and pulse duration, subject to computational time restraints, to mimic military scenarios for active or passive sonar configurations.
- We can generate acoustic wave propagation results for both 2D and 3D velocity structures, and can mimic time variations in a step-wise fashion.
- Initial results suggest there are significant differences between simple linear ray path models and more realistic ray-bending models in terms of the amplitudes and arrival times of signals.
- Significant differences in signal amplitudes vs receiver offset are also seen for gradient vs layered model and 2D vs 3D models.
- Overall, these initial results suggest a considerable military tactical advantage could be obtained by accurately simulating the realistic oceanographic conditions and their impact on acoustic detection range and spatial variations.

Thank you


1
-0.01
0
0.01
0.02
0.03
Time (s)
0
0
500
1000
1500
Frequency (Hz)