Estimating geoacoustic properties of marine sediment on the New Jersey Continental Shelf from broadband signals

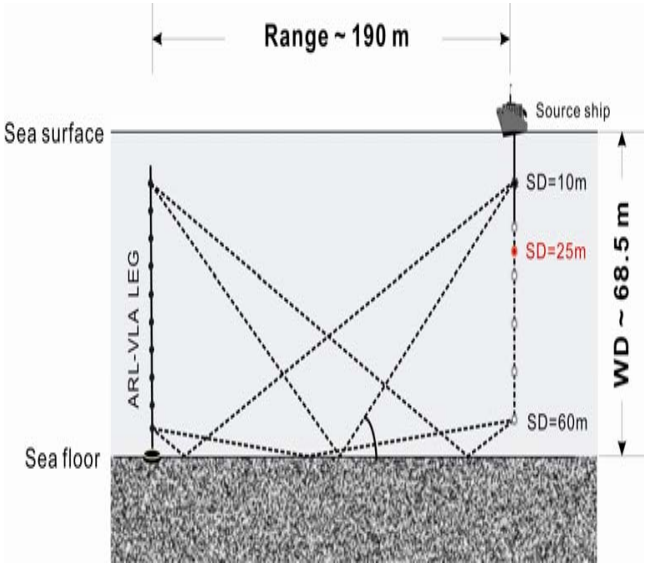
Yong-Min Jiang and N. Ross Chapman

University of Victoria, Victoria, BC, Canada

Work supported by ONR

Objective :

Geoacoustic inversion using the chirp signals collected on the vertical leg of ARL 'L'-shape array at SWAMI32 site during SW06

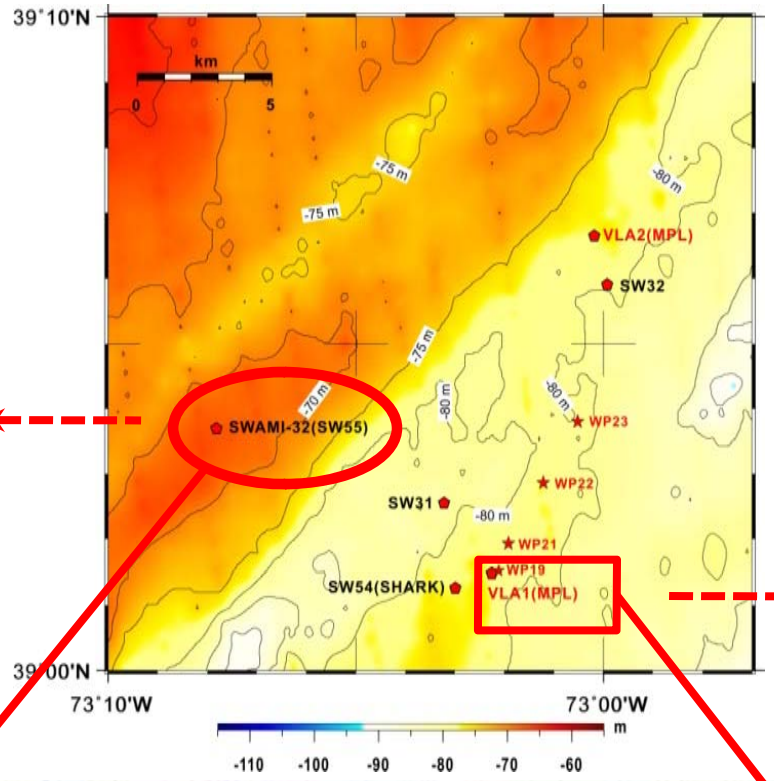


- MORAY site (*JASAEL, IEEE, ASA 157*):
- sediment sound speed and layer thickness
- sediment attenuation estimate and its uncertainty

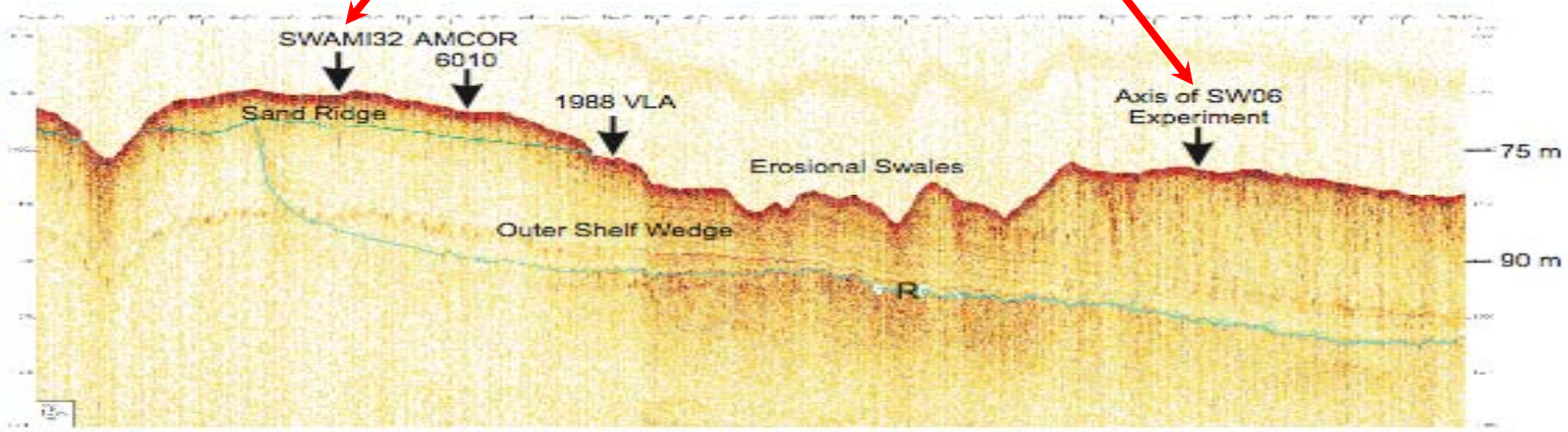
- SWAMI32 site:
- check the information contents of the signals at two frequency bands
- travel time inversion at two frequency bands

Study site :

SWAMI32 site:
ARL's L-shape array

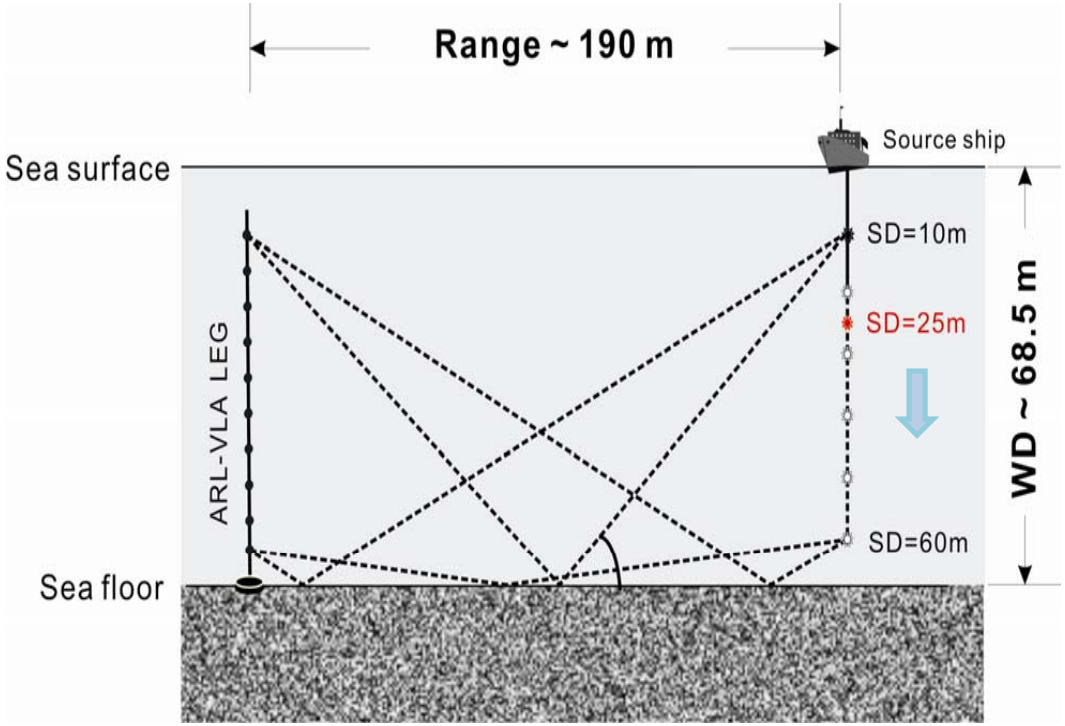


Moray site:
MPL's VLA1



Provided by Dr. John Goff

Experiment:



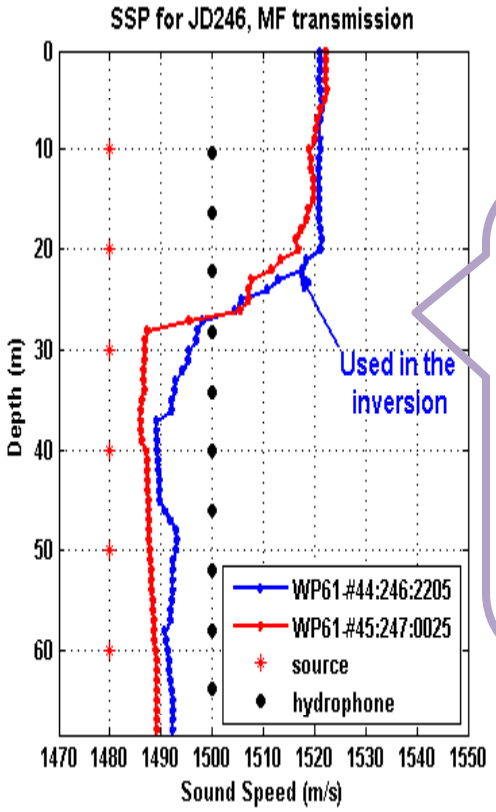
Experimental geometry:

- Water depth: 68.5m
- Range: 190 m
- Vertical leg of ARL array:
  - 10 hydrophones
  - separation: 5.95 m
  - depth: 10.3 ~ 63.85 m
- Source depth:
  - 6 depths: 10 to 60 m
  - extra depth at 25 m for low frequency transmission
- Angular coverage : 4 ~ 31.5˚

- **Mid-frequency chirp transmission:**
  - Date: Sept. 03, 2006
  - Frequency band: 1100 ~ 2900 Hz
  - Time resolution: 0.49ms (0.37~0.43m)

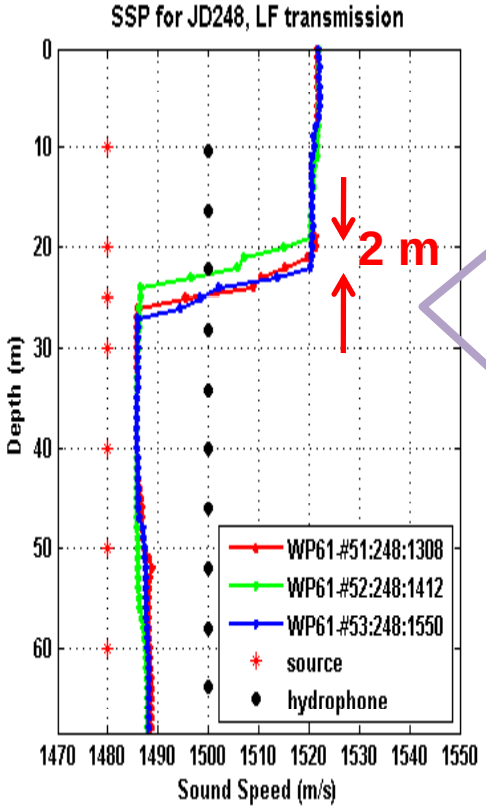
- **Low-frequency chirp transmission:**
  - Date: Sept. 05, 2006
  - Frequency band: 100 ~ 900 Hz
  - Time resolution: 1.1 ms(0.8~0.95m)

The environmental data:



Time line:

22:05, CTD
22:06, start (10 m)
……
22:43, finish (60m)
00:25, CTD(JD247)



Time line:

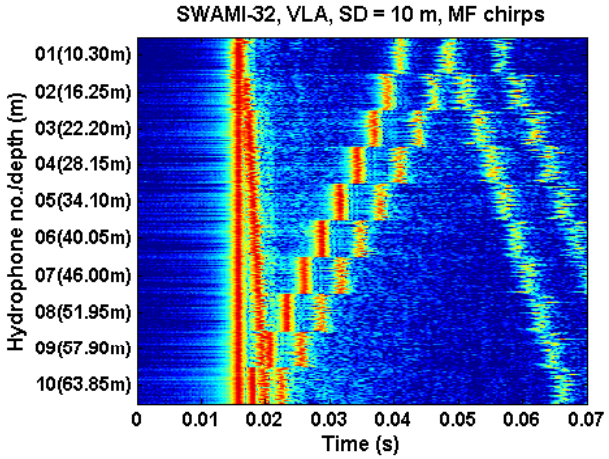
13:08, CTD
13:28, start (10 m)
……
14:10, finish (60m)
14:12, CTD
15:50, CTD

CTD cast for MF transmission

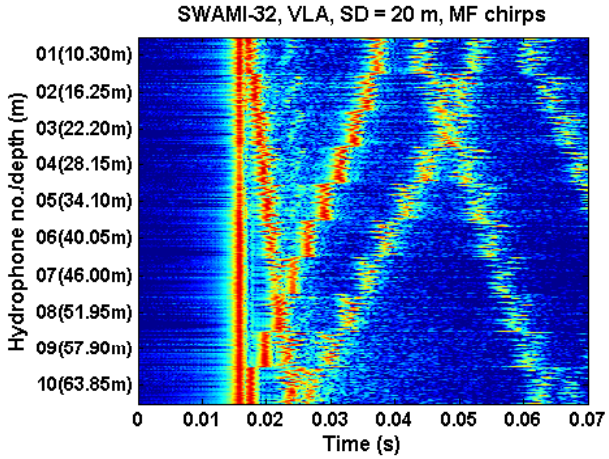
CTD casts for LF transmission

The acoustic data:

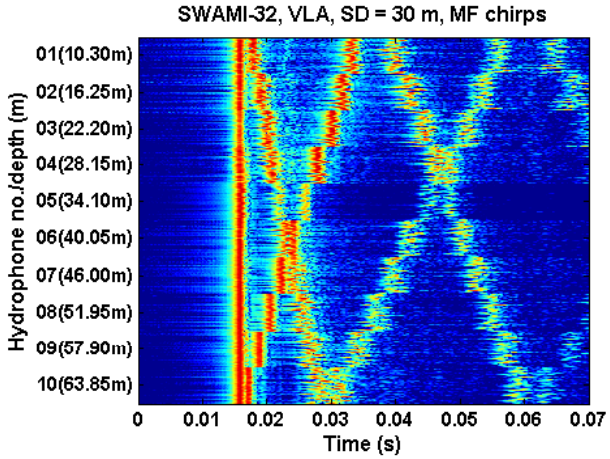
mid – frequency, 1100 ~ 2900 Hz



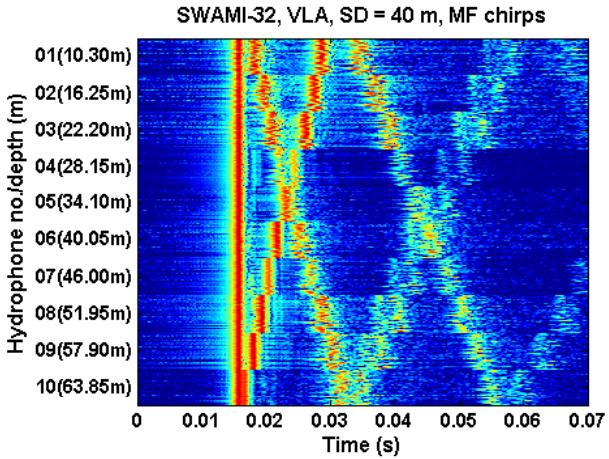
SD = 10 m



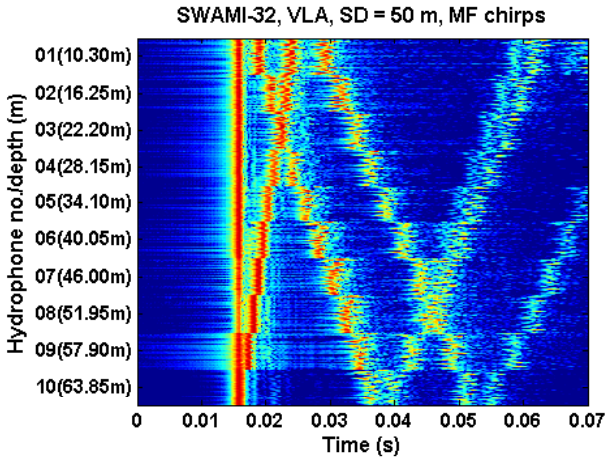
SD = 20 m



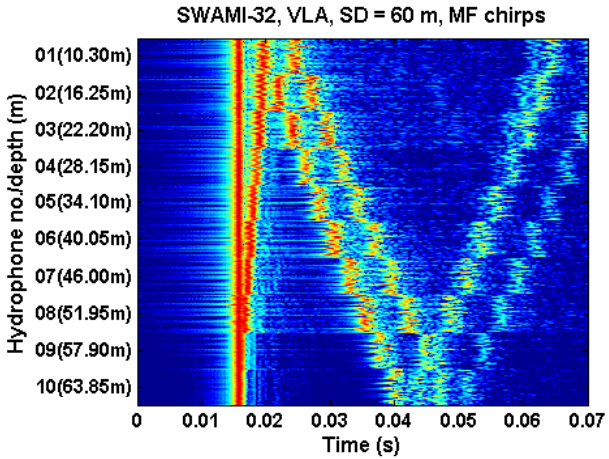
SD = 30 m



SD = 40 m



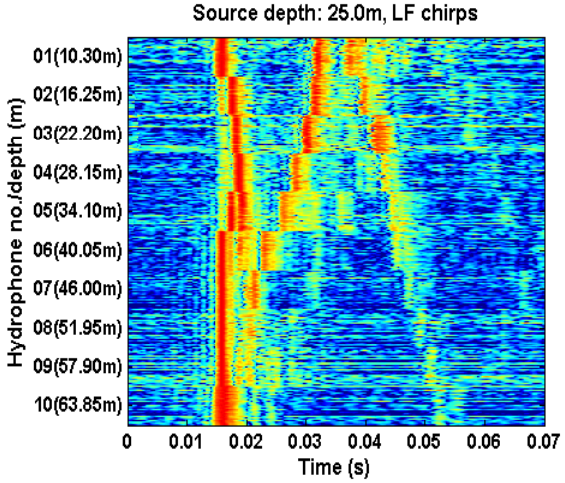
SD = 50 m



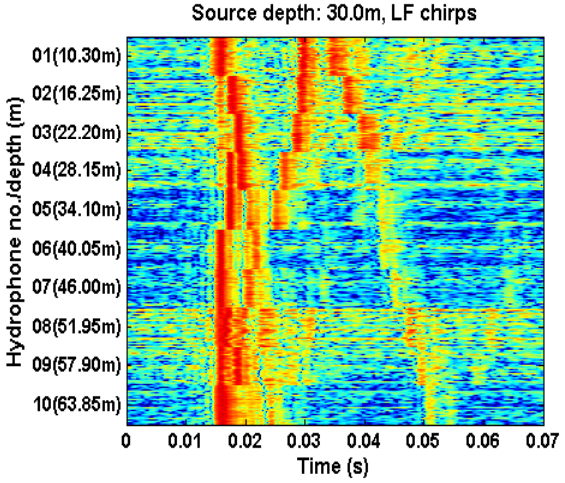
SD = 60 m

The acoustic data

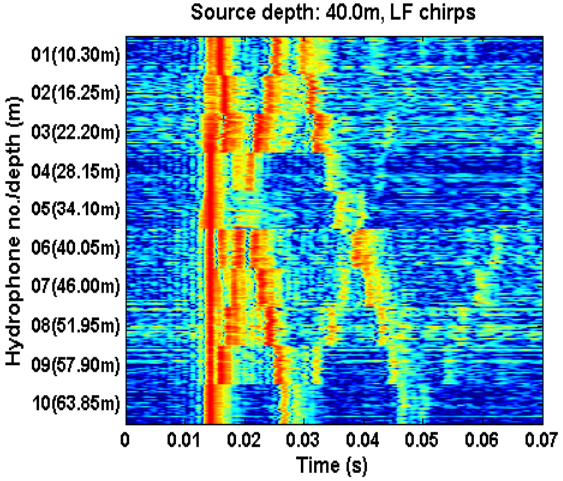
low – frequency, 100~900Hz



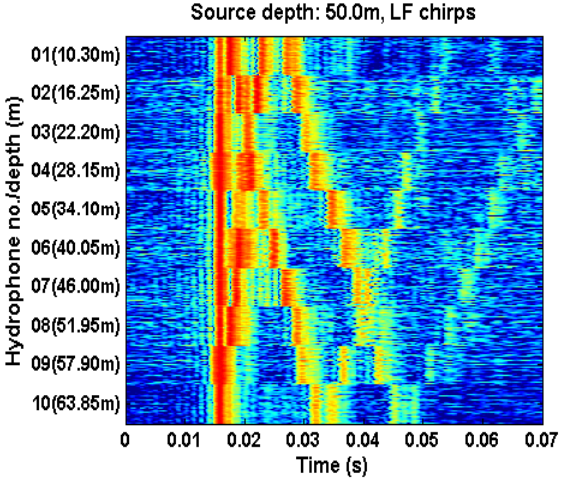
SD = 25 m



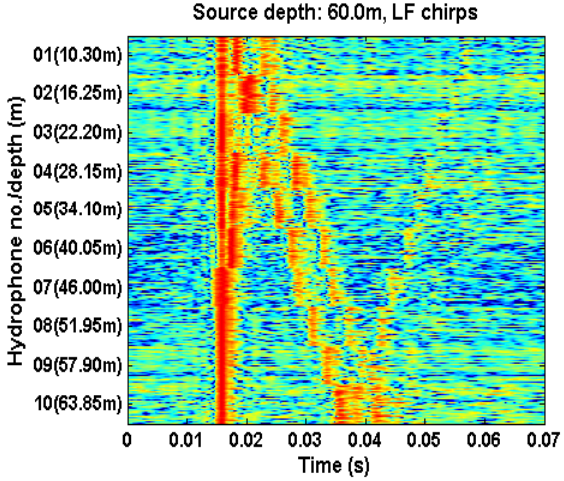
SD = 30 m



SD = 40 m

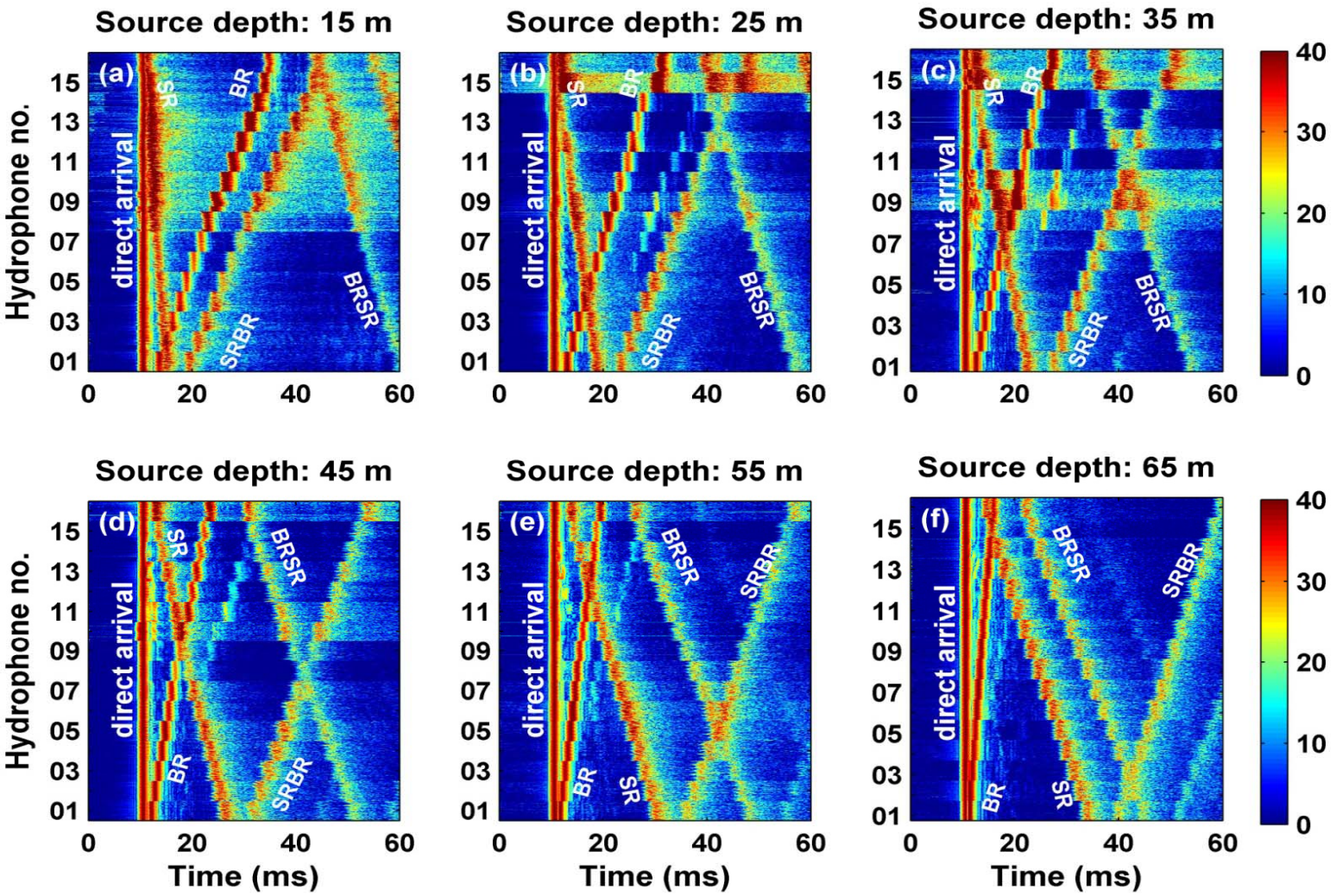


SD = 50 m

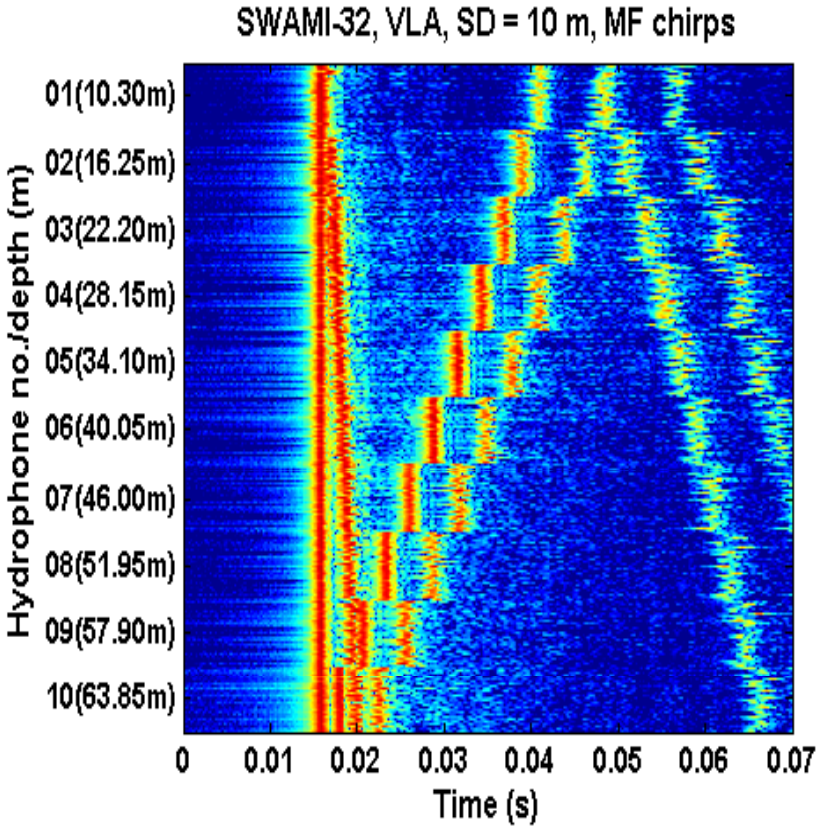


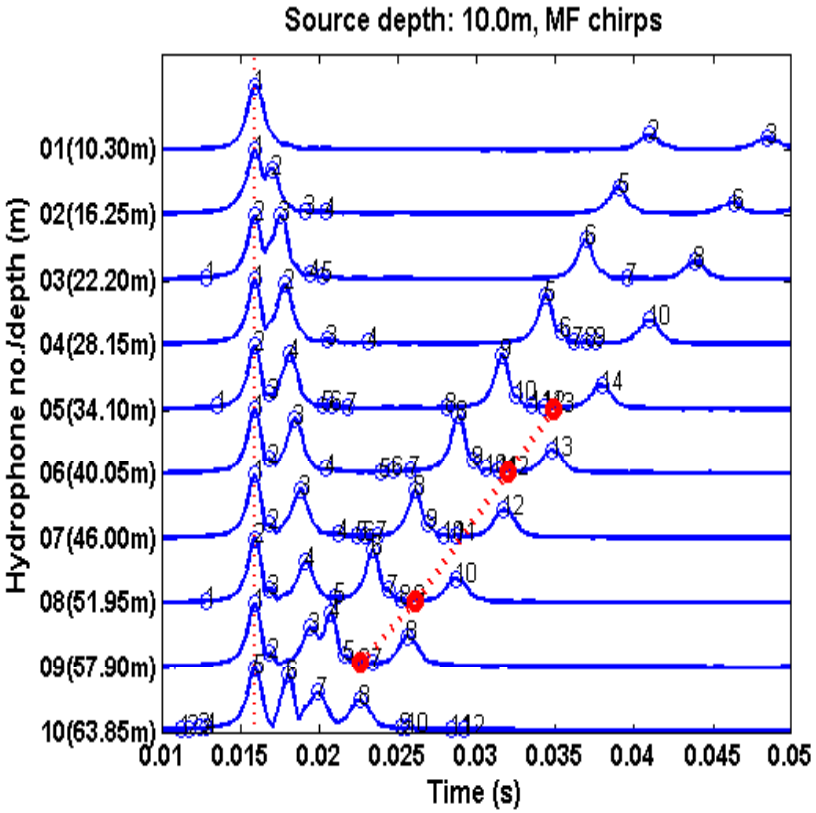
SD = 60 m

For comparison – signals from Moray site frequency band: 1500 ~ 4500 Hz



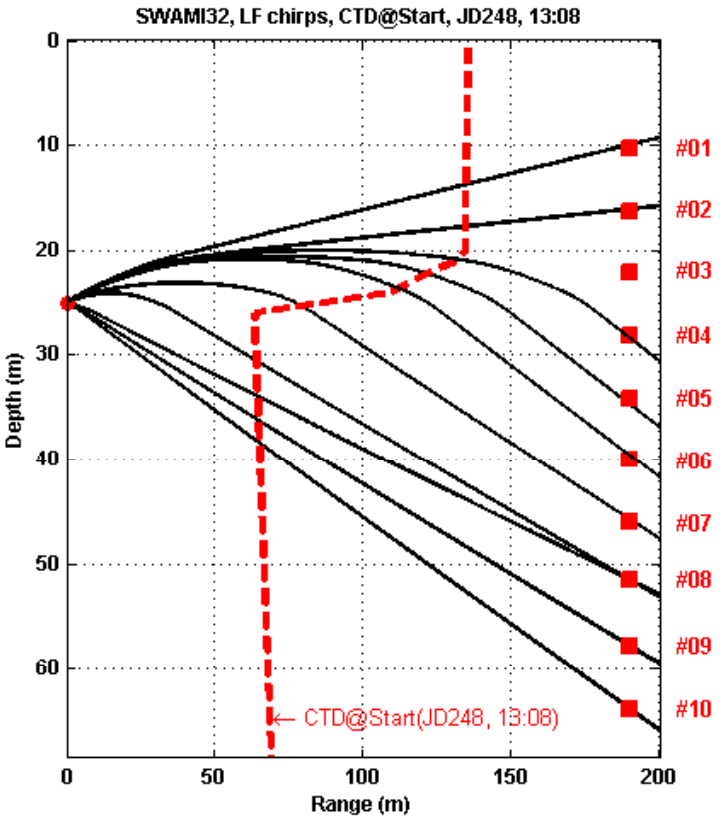
Data processing example (MF chirps, SD = 10m):



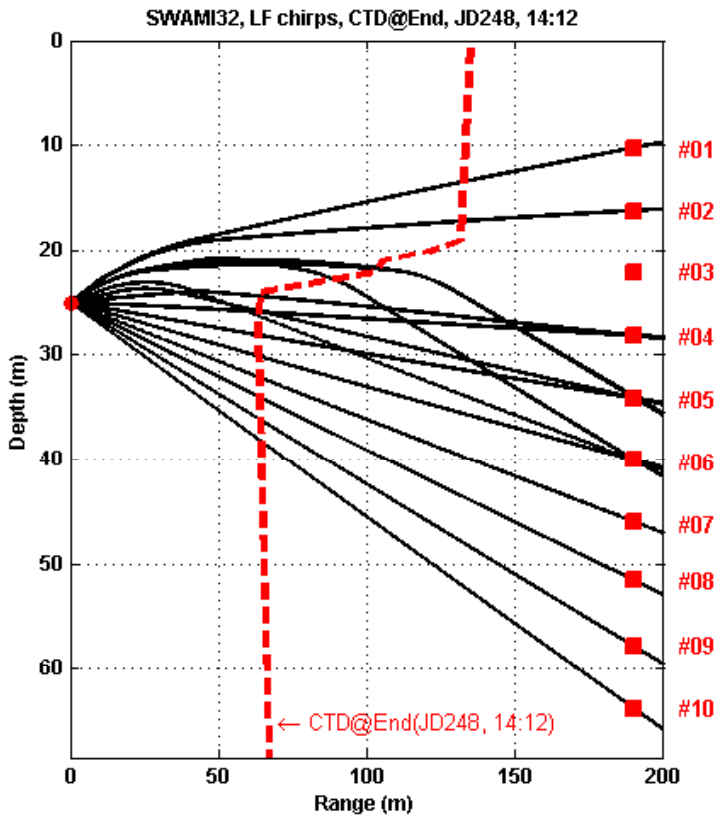


TVG

Simulation on the effect of the oceanic SSP for the 100 ~ 900 Hz chirps:



CTD before the transmission



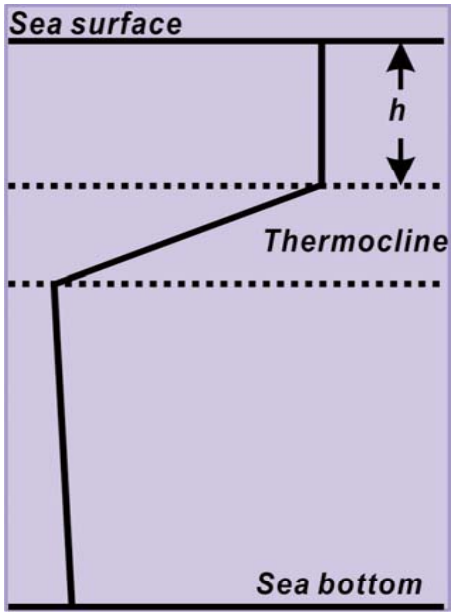
CTD after the transmission

Inversion strategy:

- Geoacoustic model: based on the resolvable layers in data
- Forward acoustic model: ray tracing
- Inversion method: adaptive simplex differential evolution
- Energy function:

$$E(m) = \sum_{i=1}^{N_L} \sum_{j=1}^{N_H} (\Delta t_{i,j} - \Delta T_{i,j}(m))^2$$

- Water column SSP parameterization:
  model the depth of the thermocline
  (for 100 ~ 900 Hz chirps only)



Inversion scheme:

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	For 1100 ~ 2900 Hz chirps	For 100 ~ 900 Hz chirps
once	• Use the SSP measured at the beginning of the 10 m source transmission and water column only arrivals to determine: WD, Rng, RD and SD • Fix WD, Rng and RD	• Use the SSP measured at the end of the 60 m source transmission and water column only arrivals to determine: WD, Rng, RD and SD • Fix WD, Rng and RD
each depth	• Water column only arrivals for SD (and array tilt) • Bottom and sub-bottom arrivals to determine: sediment sound speed and layer thickness	• Water column only arrivals for SD and oceanic SSP • Bottom and sub-bottom arrivals to determine: sediment sound speed and layer thickness

Preliminary inversion results:

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100 ~ 900 Hz chirps, WD = 70.11m, Rng = 182.13m

SD (m)	Bounds	40	50
Inverted SD (m)	[SD-5, SD+5]	40.84	51.03
Water SSP (top layer depth) (m)	[17, 26]	Close to CTD@14:12	
Sediment sound speed (m/s)	[1550, 1750]	1680.1	1610.7
Layer thickness (m)	[1, 30]	4.1	7.3

1100 ~ 2900 Hz chirps, WD = 69.67m, Rng = 184.96m

SD (m)	Bounds	10	20	30	40	50	60
Inverted SD (m)	[SD-5, SD+5]	9.95	20.07	29.71	38.88	49.30	59.89
Array tilt (˚)	[-5 5]	-1.26	-2.47	-2.78	-3.82	<-5	<-5
Sediment sound speed (m/s)	[1550, 1750]	1592.1	1632.1	1623.3	1647.8	-	-
Layer thickness (m)	[1, 30]	7.1	6.8	5.6	5.3	-	-

Summary:

- No observation of the reflections from ‘R’ reflector in both frequency bands – implications?
- Not so consistent inversion results from the low and mid frequency data – low SNR and lack of spatial constrains
- compare with the inversion results with David Knobles *et al.* (JASAEL 124, No.3 Pt.2, EL155)

Depth (m)	Sound speed (m/s)
0	1650
3.2	1653
3.2	1580
23	1600

Acknowledgements:

- ONR for sponsoring the work
- Dr. David Knobles for providing the data