Repeatability analysis of a permanent seabed receiver array

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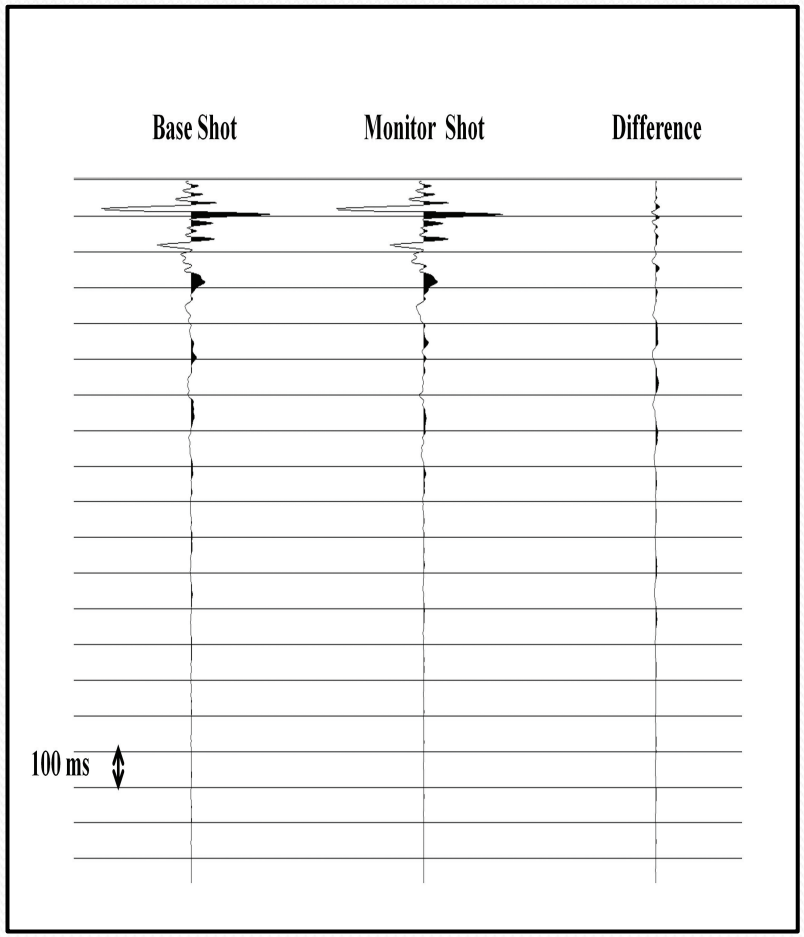
Outline

- Objective
- Repeatability benchmark for seismic data
- Repeatability Analysis
  - various seismic events, using hydrophone component
  - comparison of repeatability among X,Y and Z- geophone and Hydrophone components
  - several receiver locations along a cross line
- Improvement of repeatability by stacking for refraction event
- Discussion and conclusions

Objective

- To compare the pre-stack repeatability of the hydrophone component for various seismic events, such as refraction, reflection, sea-bottom reflection and water column noise.
- To test the repeatability of various components (X, Y, Z and hydrophone) for refracted and reflected events.

Repeatability benchmark for seismic data



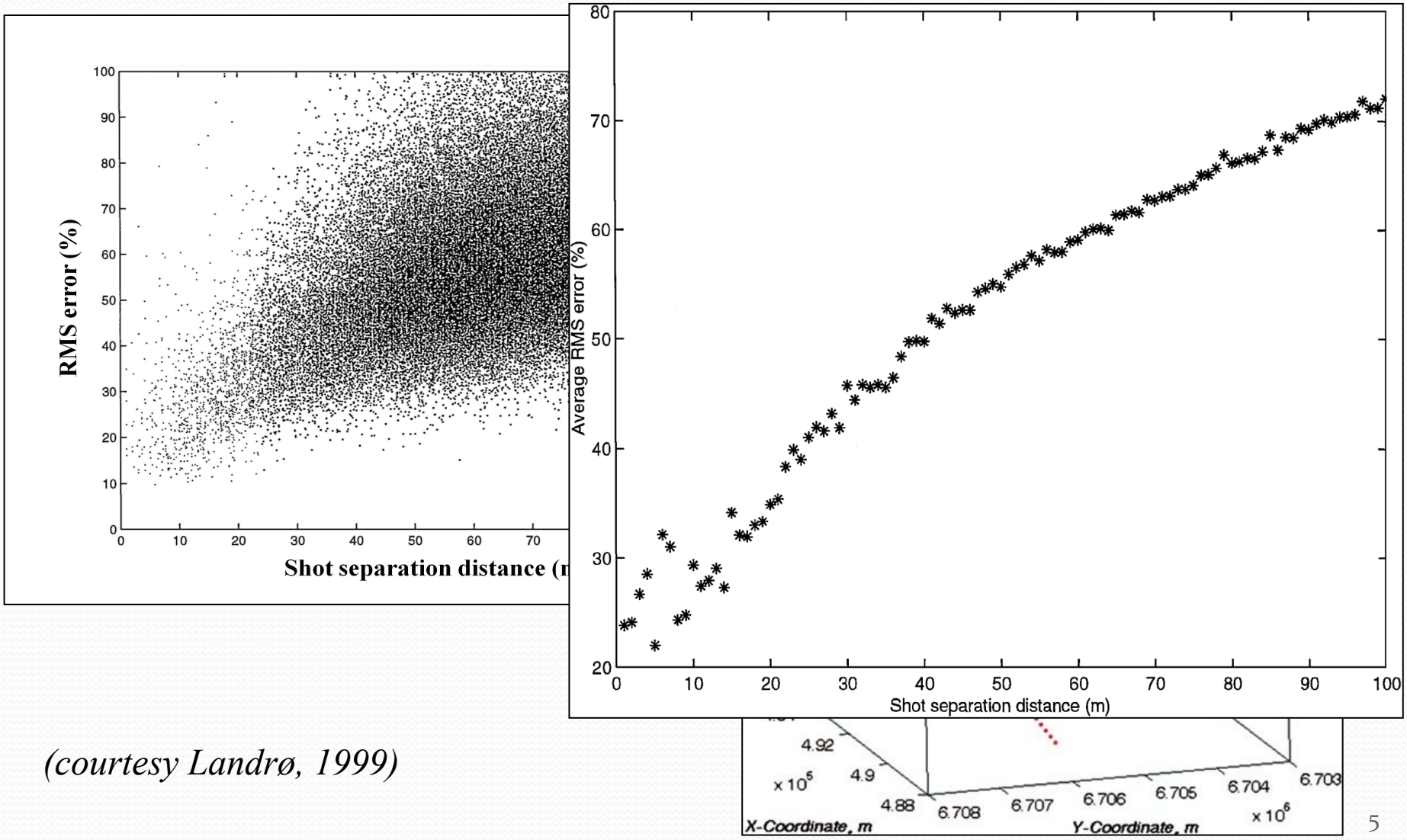
NRMS for two traces, a and b, can be given as

$$NRMS = \frac{200 * \sqrt{\sum_{i=1}^{N} (a_i - b_i)^2}}{\sqrt{\sum_{i=1}^{N} a_i^2} + \sqrt{\sum_{i=1}^{N} b_i^2}} \%$$

where i denotes time samples, i=1,…,Nt.

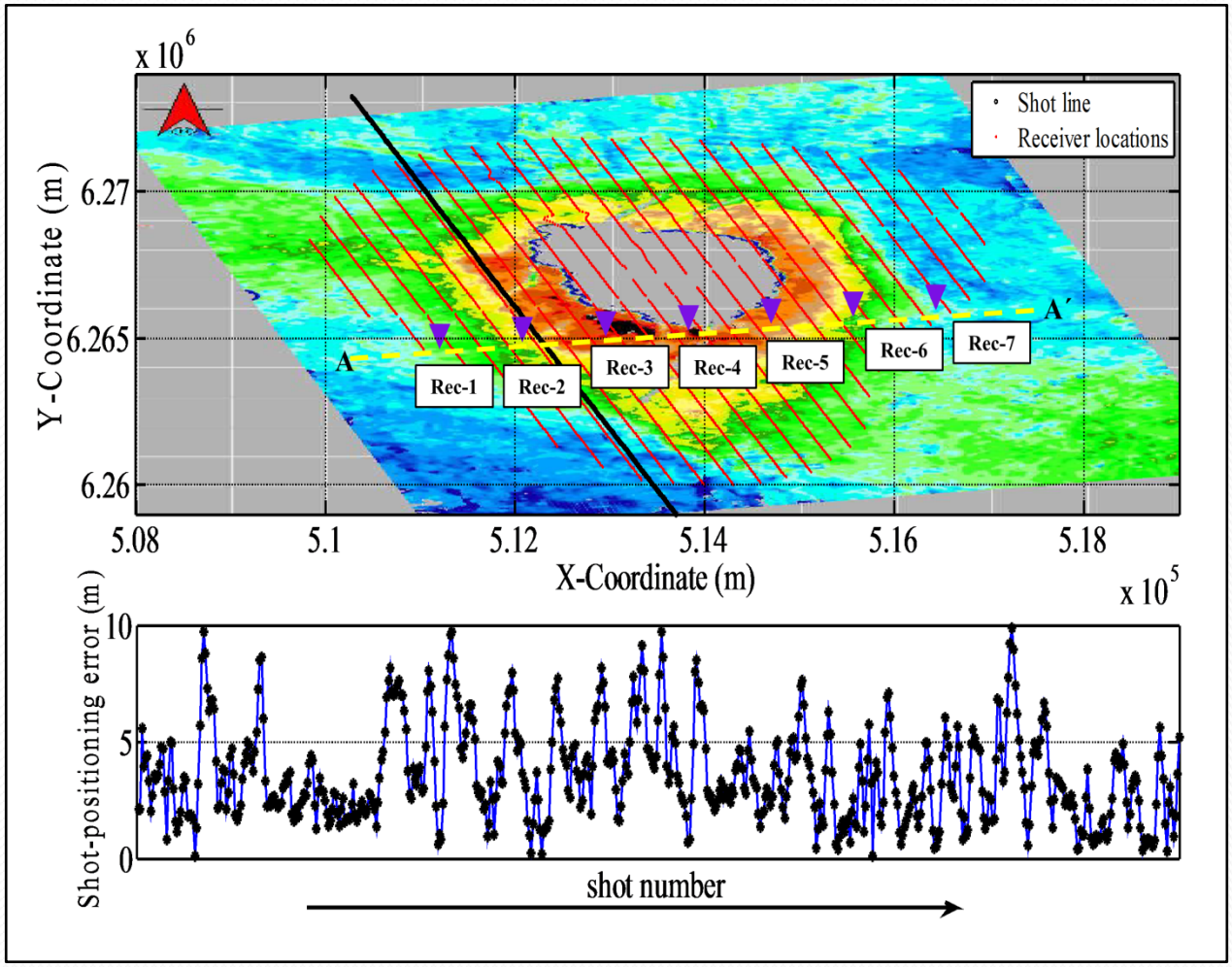
(Kragh and Christie, 2002)

Example:- Repeatability of VSP data, Oseberg field



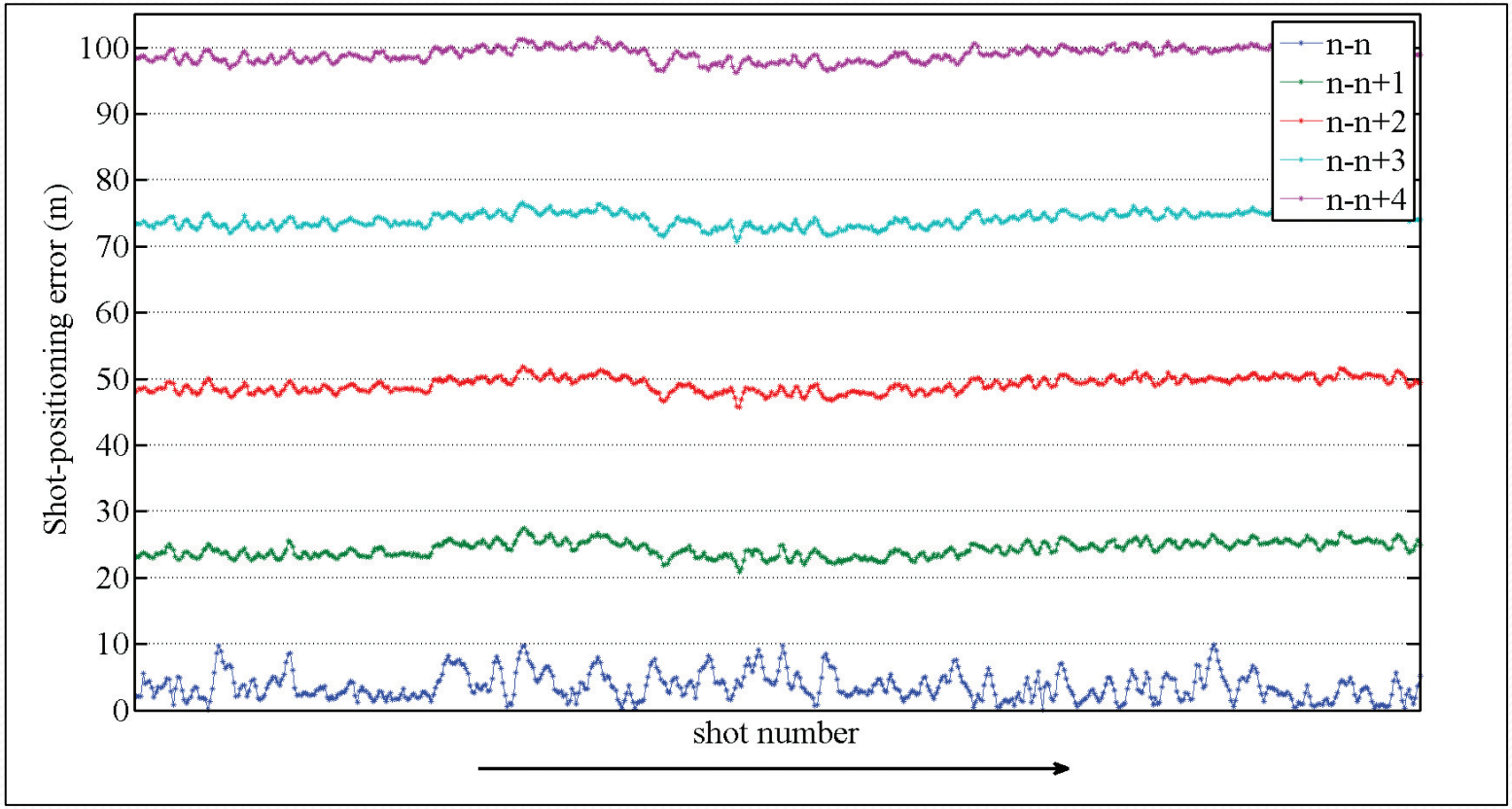
(courtesy Landrø, 1999)

Permanent reservoir monitoring system (PRM) at Ekofisk field



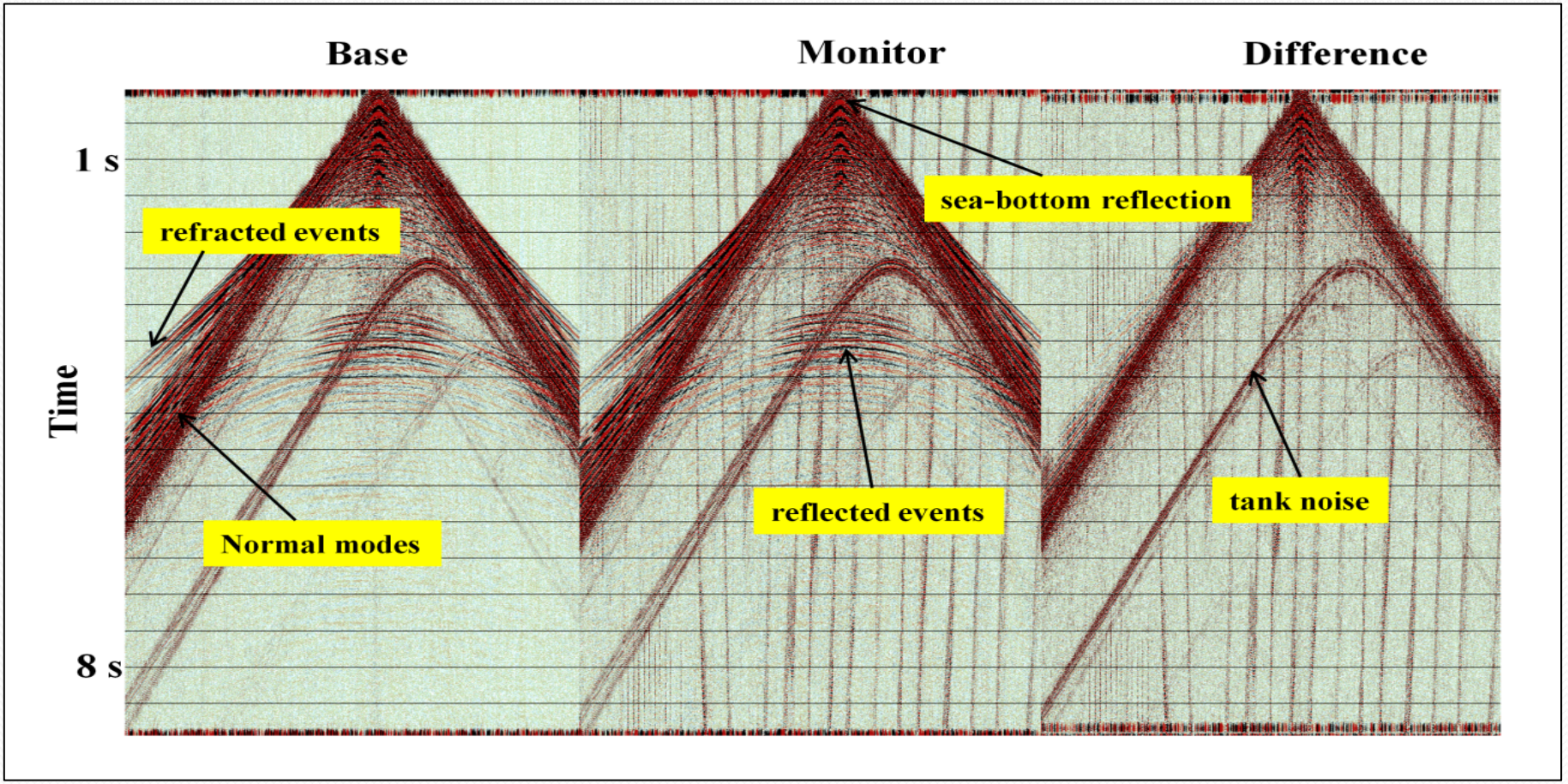
- 200 km of trenched fibre optic seismic cables
- Total 24 receiver lines are deployed covering about 60 km^2
- The total ocean bottom cable (OBC) array has 3996 4C receivers
- Shot interval is 25 m and receiver interval is 50 m
- Receiver line interval is 300 m
- Receivers are buried 1-1.5 m into the sea-floor.

Shot positioning errors for various shot pair combinations

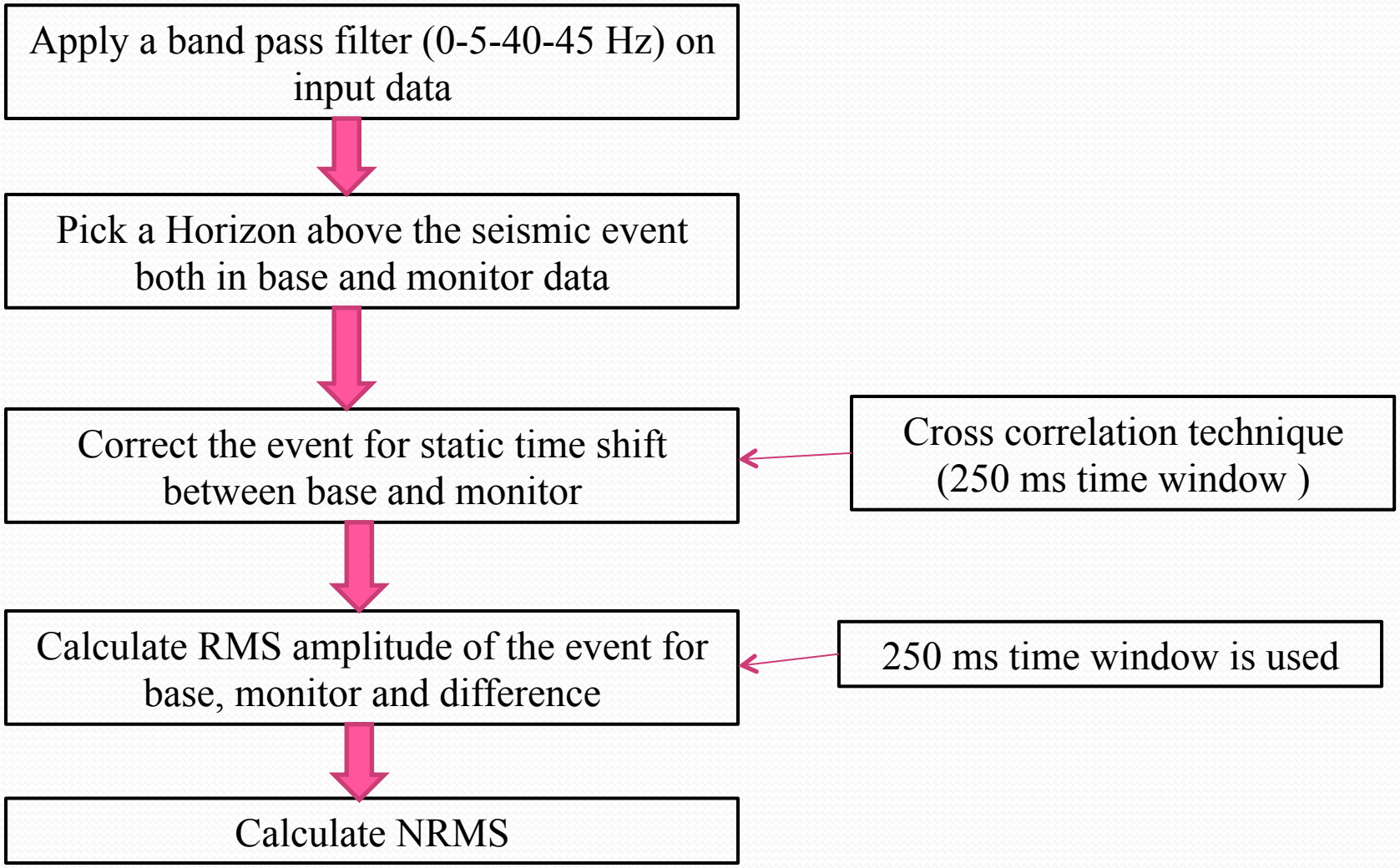


Shot positioning errors for different shot pairs (two shots but from base and monitor shot lines). 'n' indicates the shot number in shot pair. We make shot pairs/combinations with different shot separation distance errors by varying the shot numbers. For an example, we make pairs of all shots, where the shots numbers are n and n+1 for the base and monitor shot lines, respectively. Observe that the shot separation distances are not continuous like in the case of Landrø's work and so there is multiplicity of data around 5 m, 25 m, 50 m, 75 m and 100 m shot separation distances.

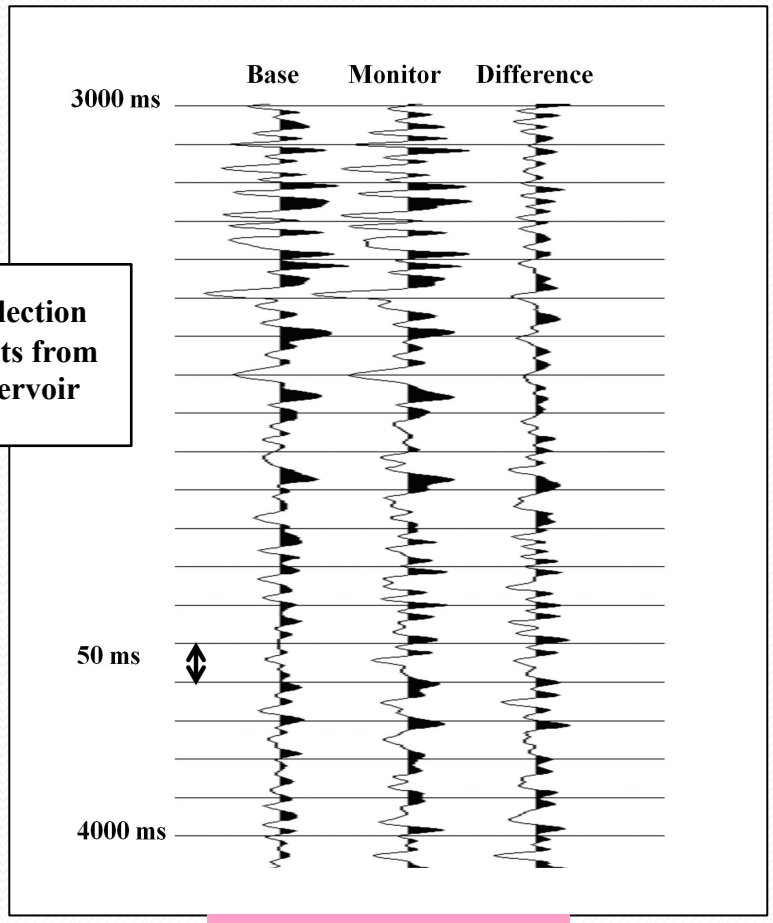
Common receiver gathers of Rec-2



Procedures for repeatability analysis



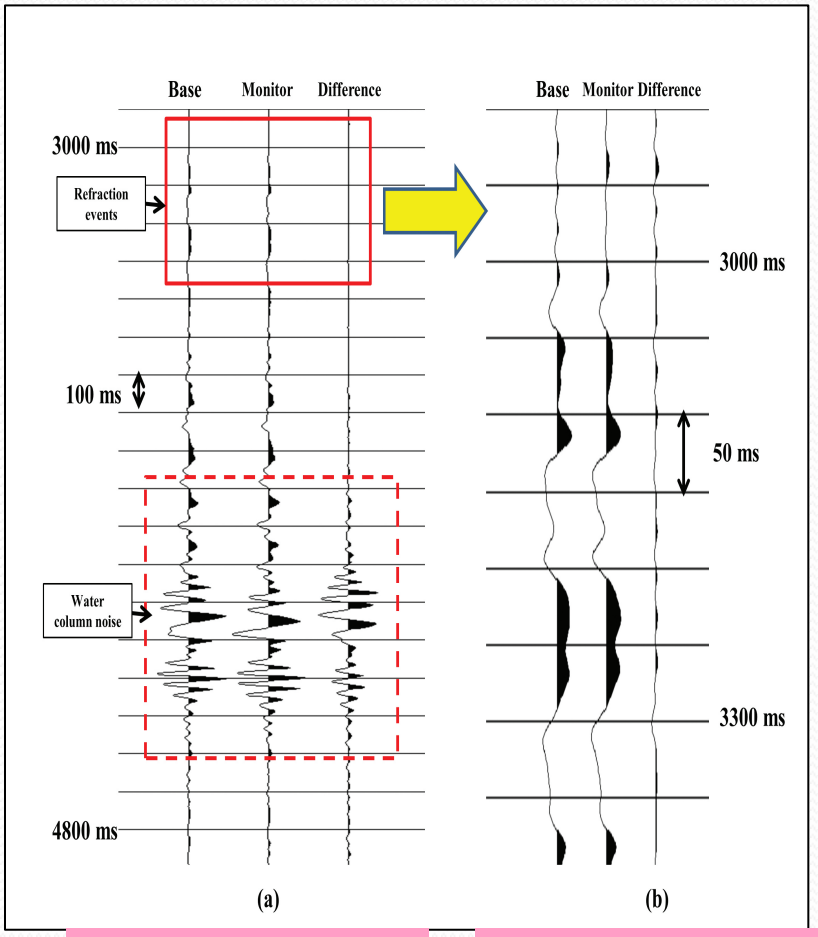
Near offset traces (~ 96 m)



Reflection events from reservoir

NRMS= 38%

Far offset traces (~ 6000 m)

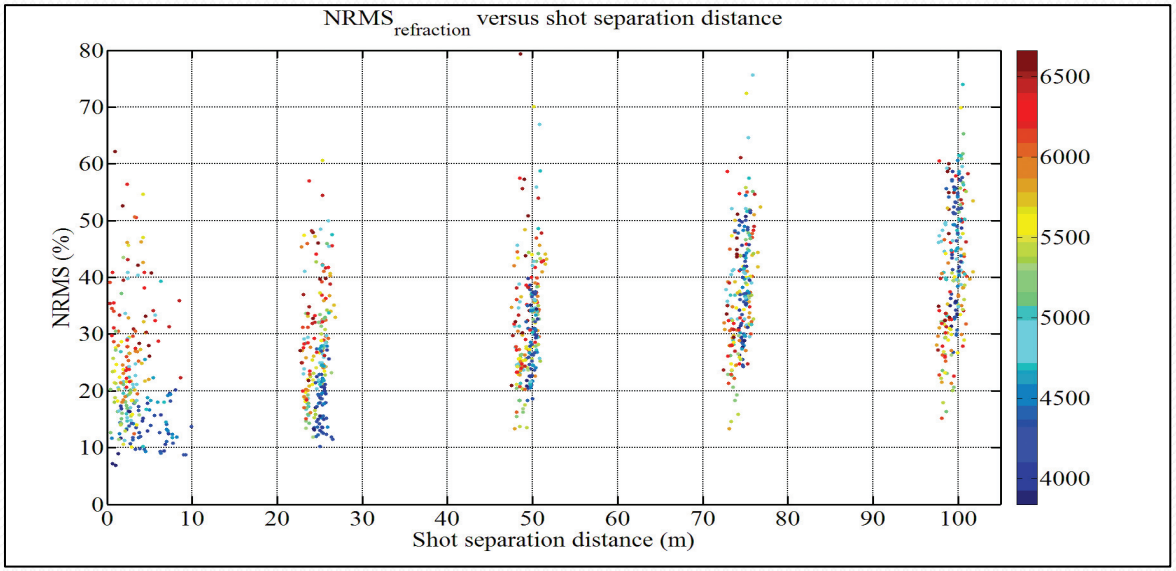


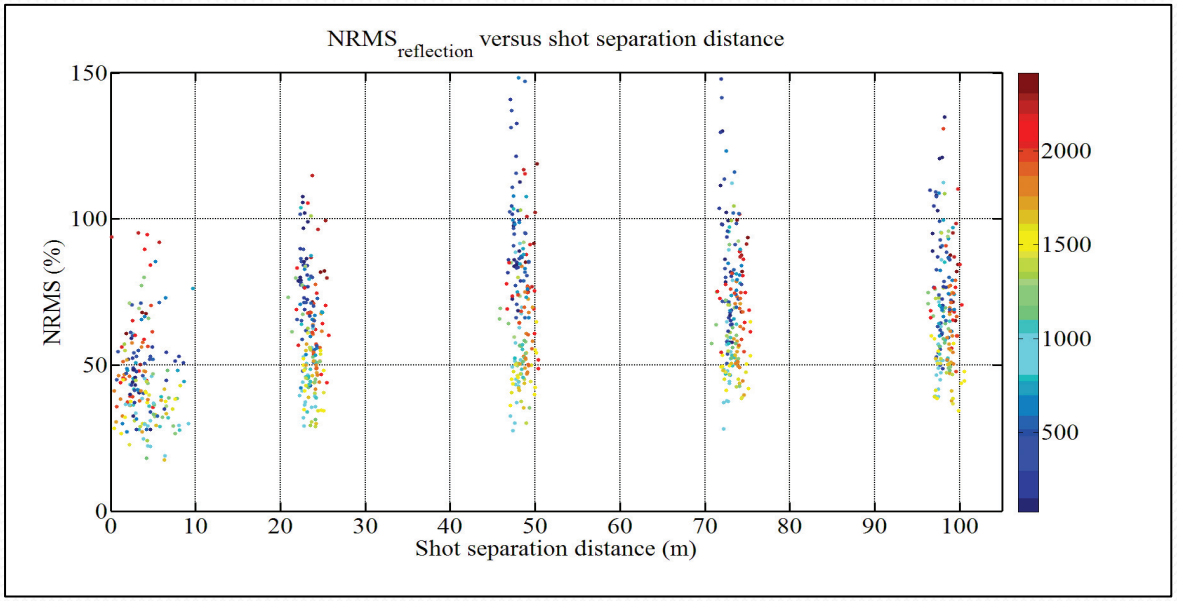
NRMS= 60 %

NRMS= 15 %

Here, only an Orsmby band pass filter (0-5-40-45 Hz) is applied.

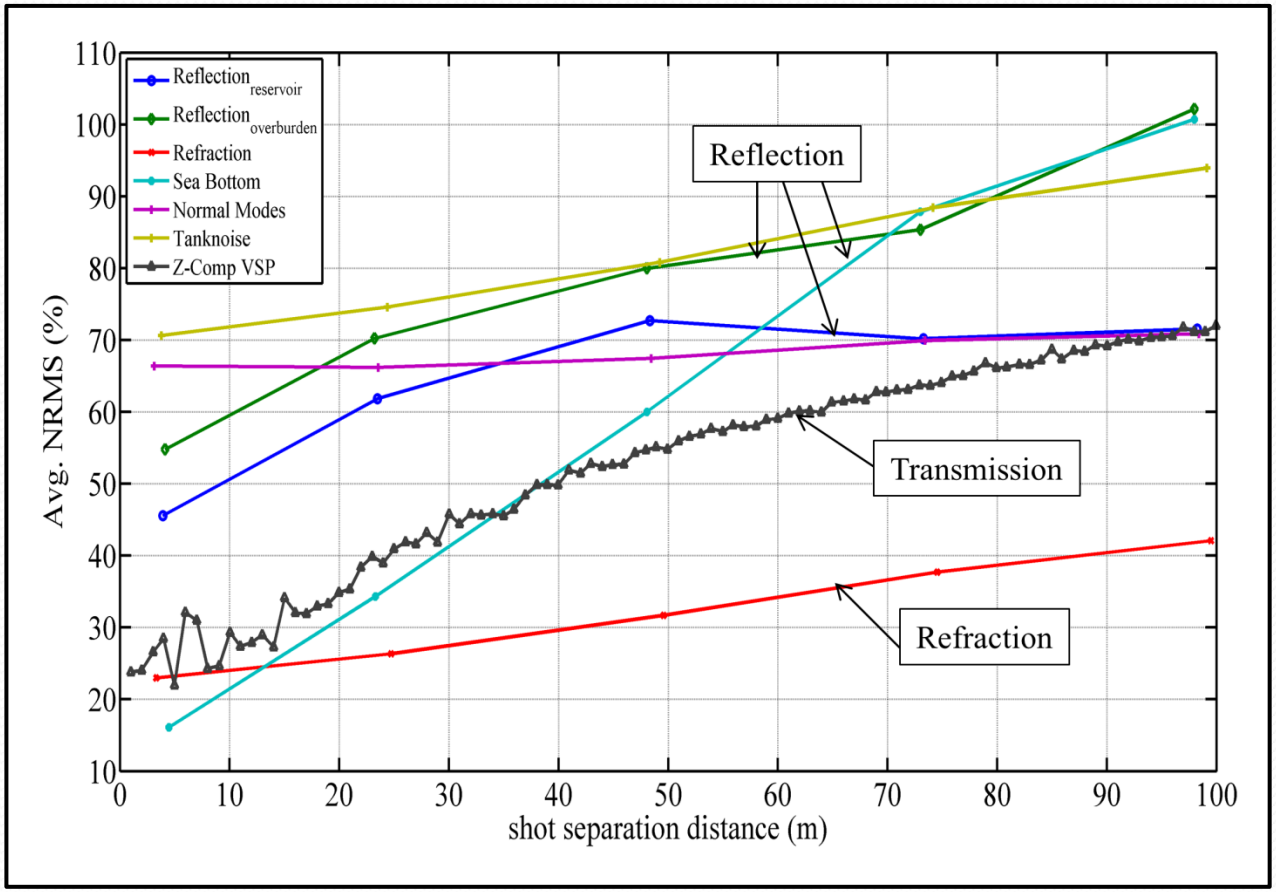
Repeatability analysis of various seismic events





- Multiplicity of data around 5 m, 25 m, 50 m, 75 m and 100 m shot separation distances
- NRMS values are highly scattered, even at least shot separation distance
- Overall trend of increased NRMS values with increased separation distance
- Reflected event is less repeatable and scattered than the refracted event.

Average NRMS values for various seismic events

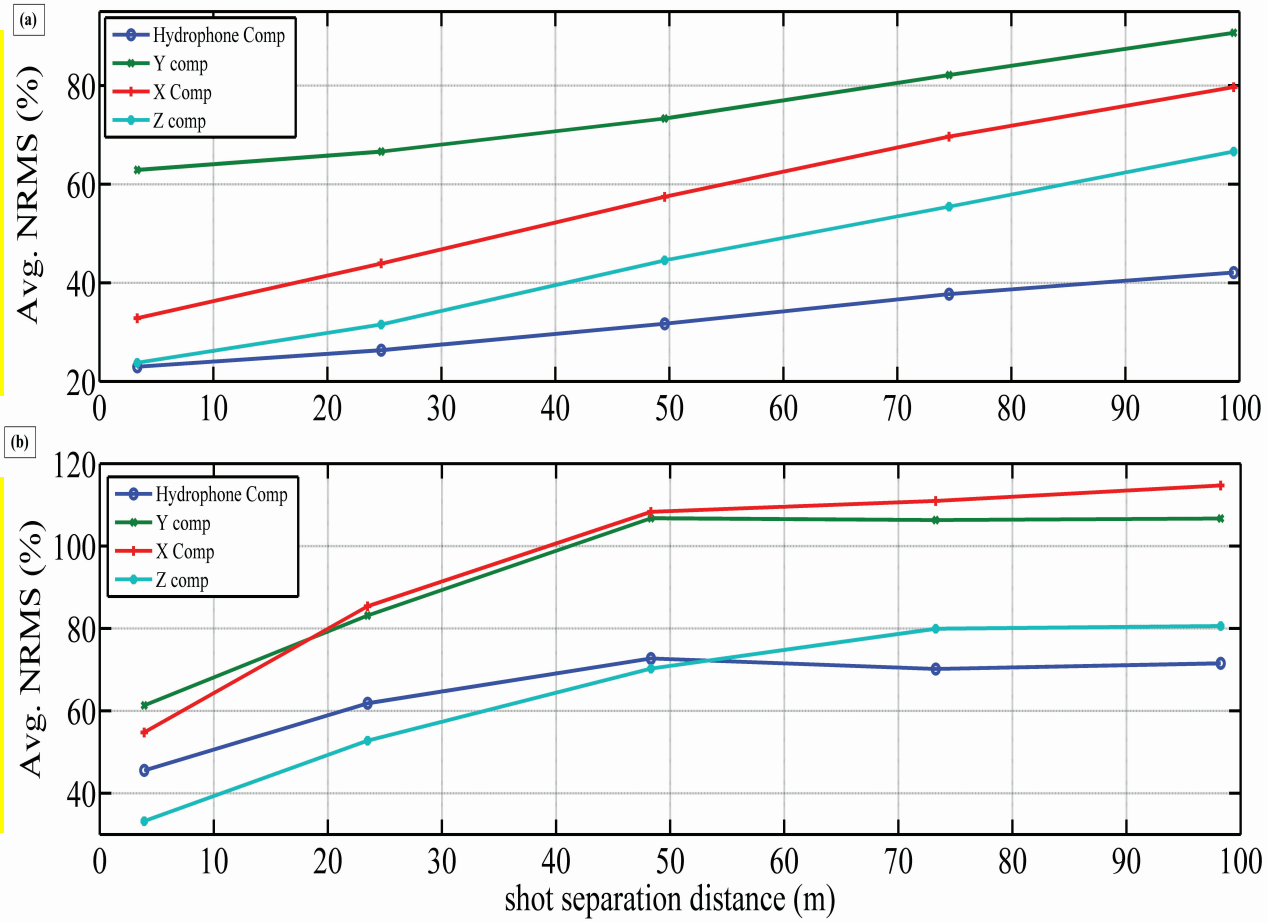


- Refracted event is more repeatable than reflected event (of both the reservoir and overburden zones)
- The sea-bottom reflection shows the highest repeatability at the least shot separation distance
- Reflected event from the overburden shows higher non-repeatability than the reflected event of the reservoir zone.
- Water column noise event shows the lowest degree of repeatability at the least shot separation distance

Average NRMS values for various receiver components

Refracted event

Reflected event



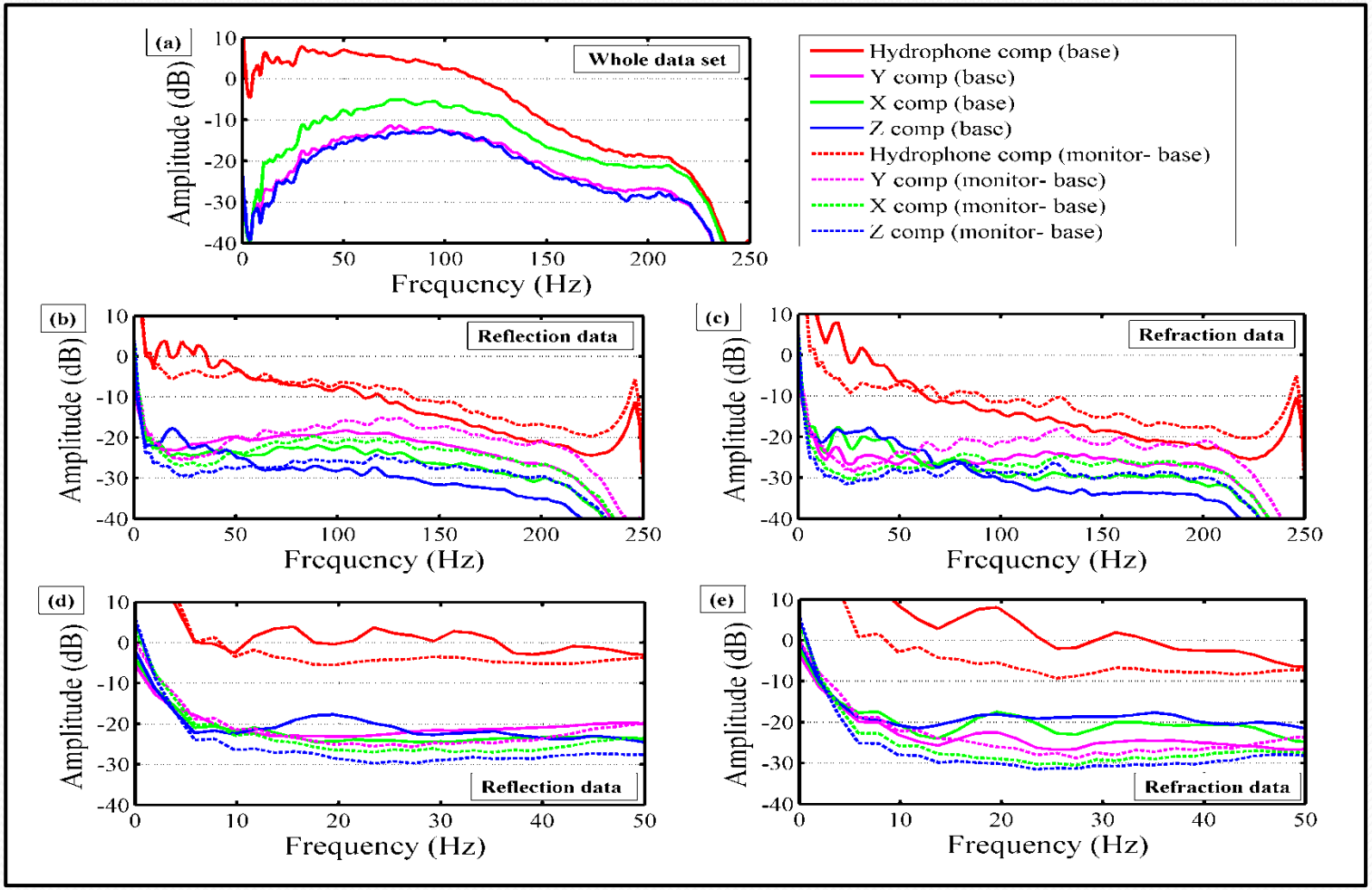
Refracted event

- The hydrophone component and Z-component show the same degree of repeatability, given the accuracy of about 5 m in source-positioning error
- The average NRMS value increases more rapidly for the Z-component than the hydrophone component.
- The X-component follows the same trend as the Z-component does, but with a lower degree of repeatability. The Y-component is highly non-repeatable even at a very low source-positioning error.

Reflected event

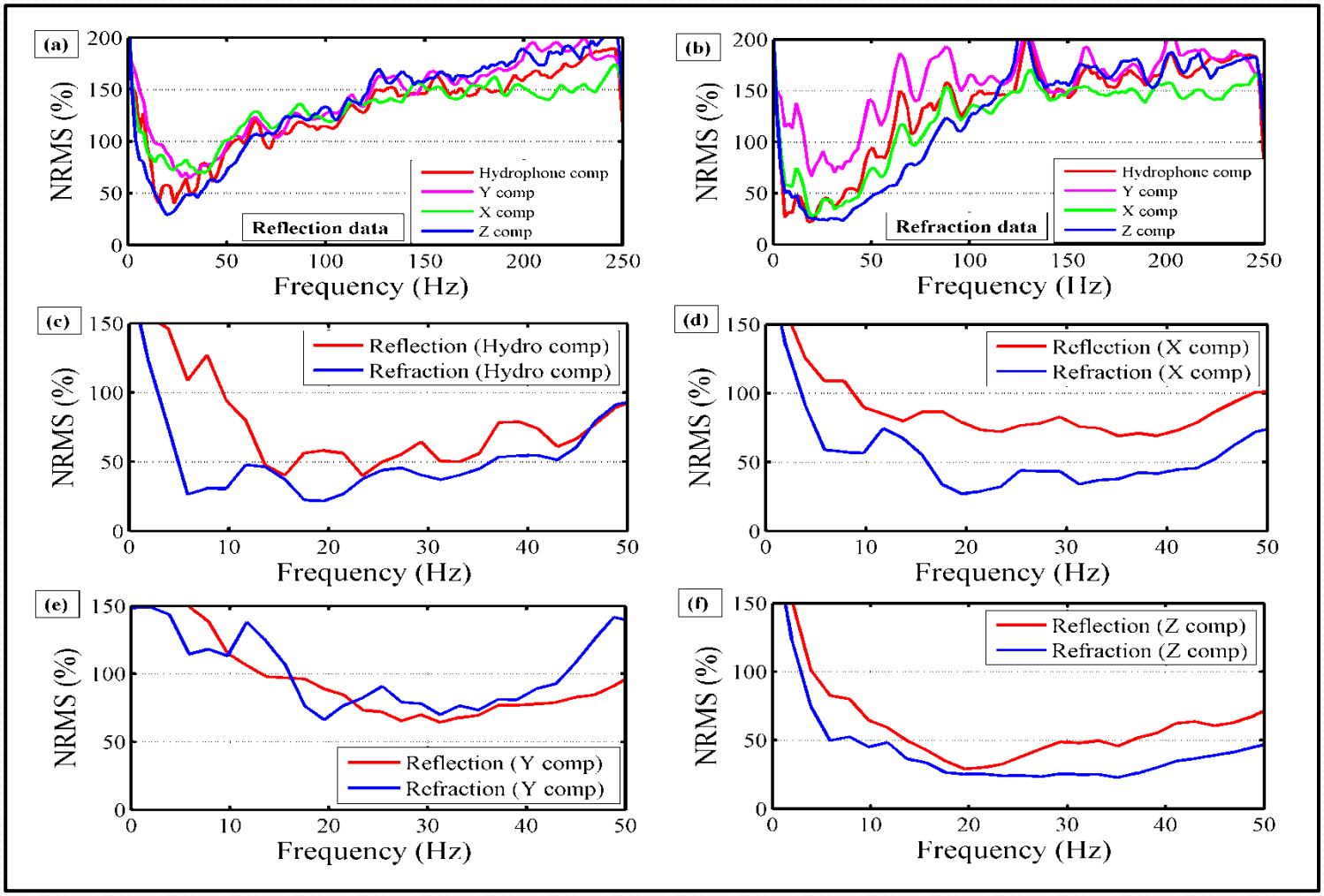
- The Z-component is the most repeatable among all component
- The X and Y-components are comparable in terms of repeatability.

Frequency spectra for various receiver components



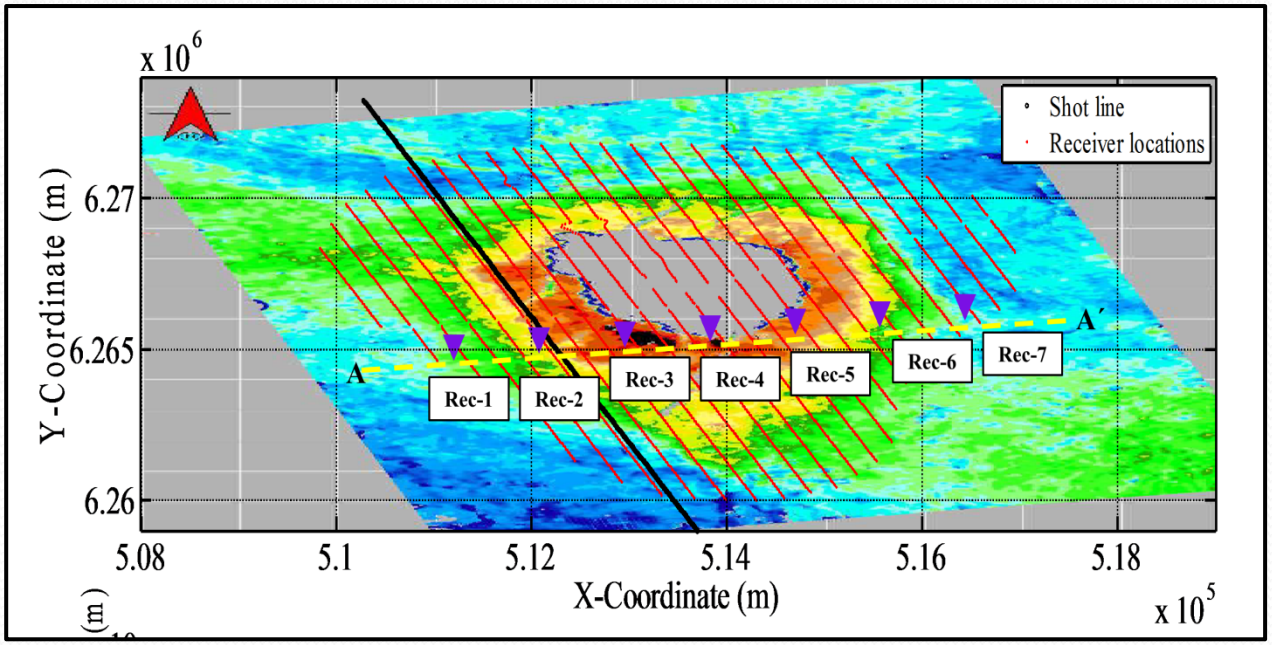
A time-window of 250 ms is used for the frequency analysis, for both refracted and reflected events

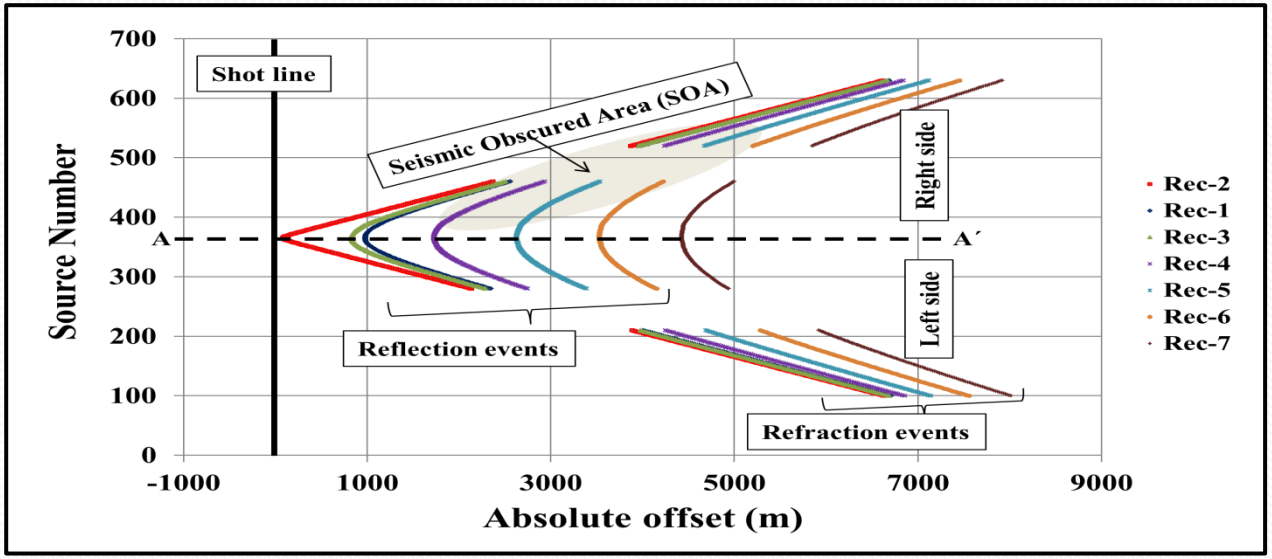
NRMS analysis in frequency domain for various receiver components



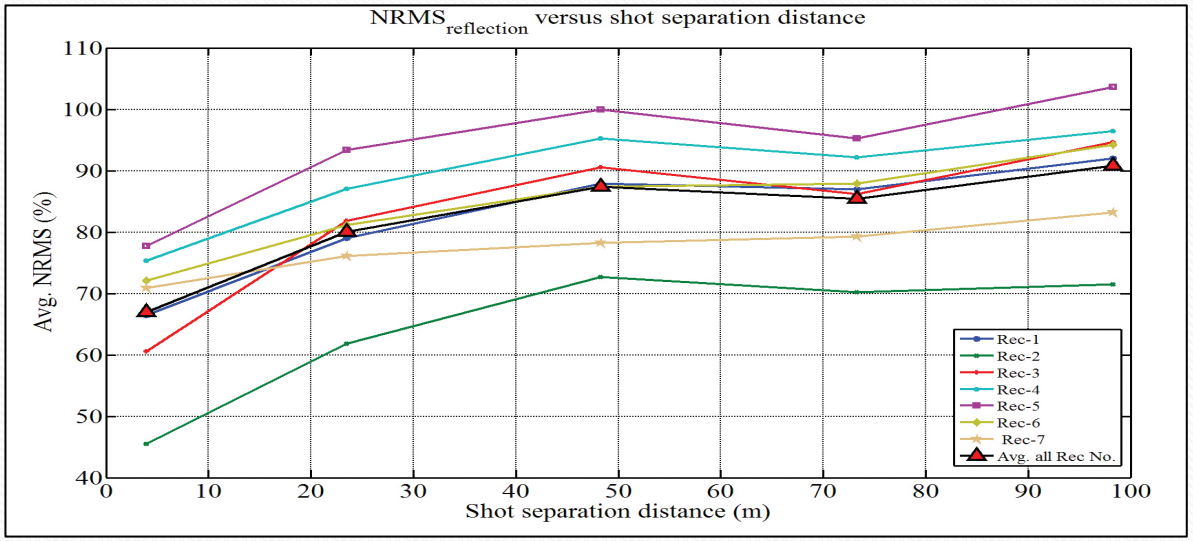
- All receiver components follow the same trend
- Except Y-comp, the calculated NRMS values for refracted event are lower than reflected event

Repeatability analysis for several receivers along a line (AA´)

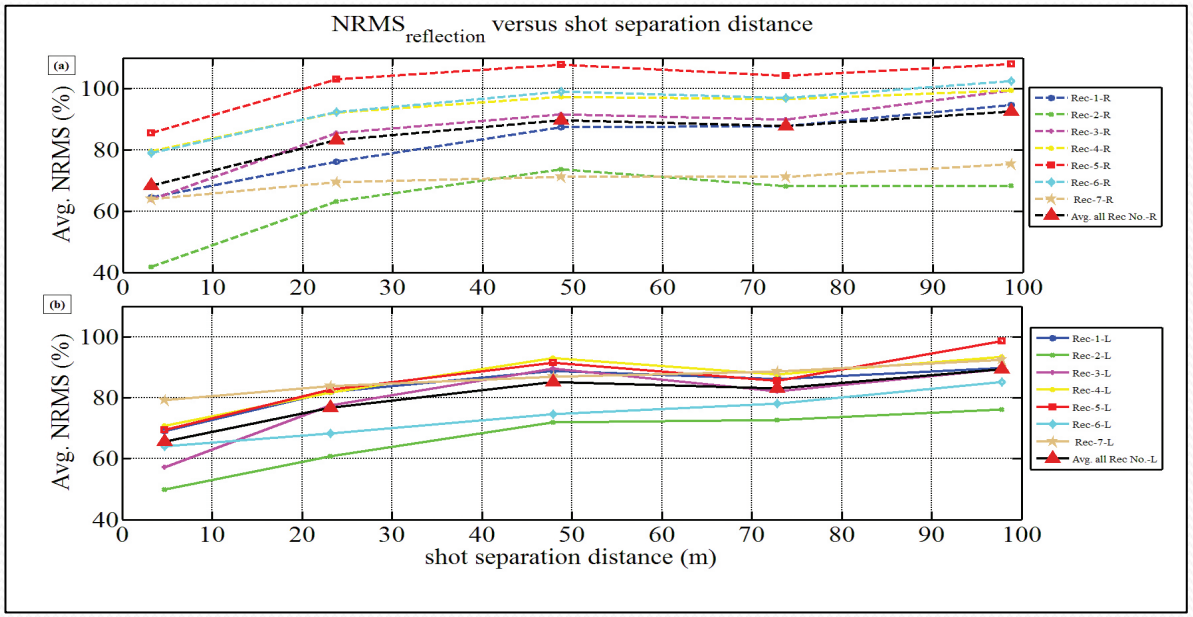




Repeatability analysis on reflection events

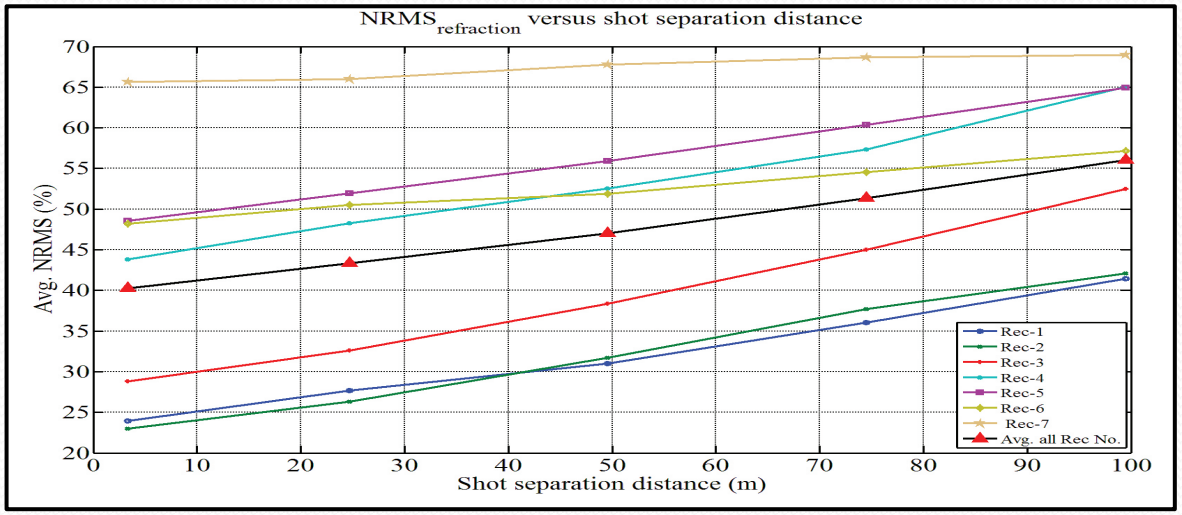


Average NRMS trends of reflected event for 7 different receivers. Observe that the NRMS value of Rec-5 is the highest among all receivers due to the effect of seismic obscured area (SOA).

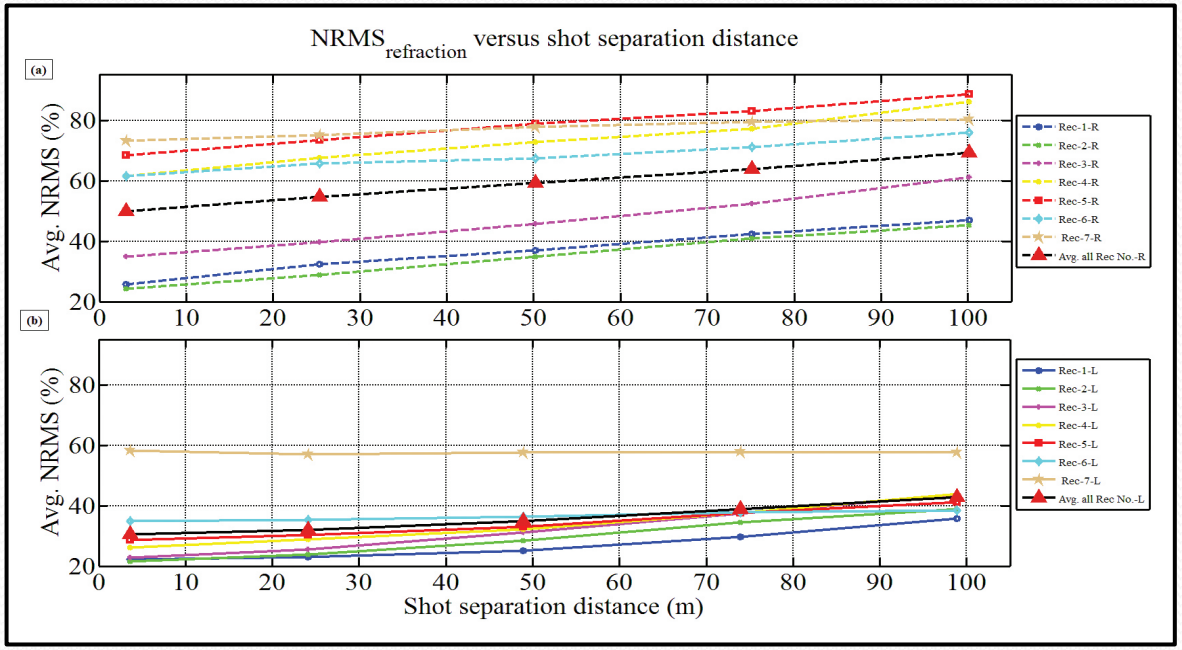


- Average NRMS trends of reflected event for 7 different receivers, where the traces are divided into two groups: **(a)** traces coming from the right hand side of the cross-line (AA´) and **(b)** the traces coming right side of the cross line.
- Observe that repeatability is low for the right hand side traces, mostly for the rec-5, rec-6 and rec-4. This is mainly due to the effect of SOA for those particular traces.

Repeatability analysis on refraction events

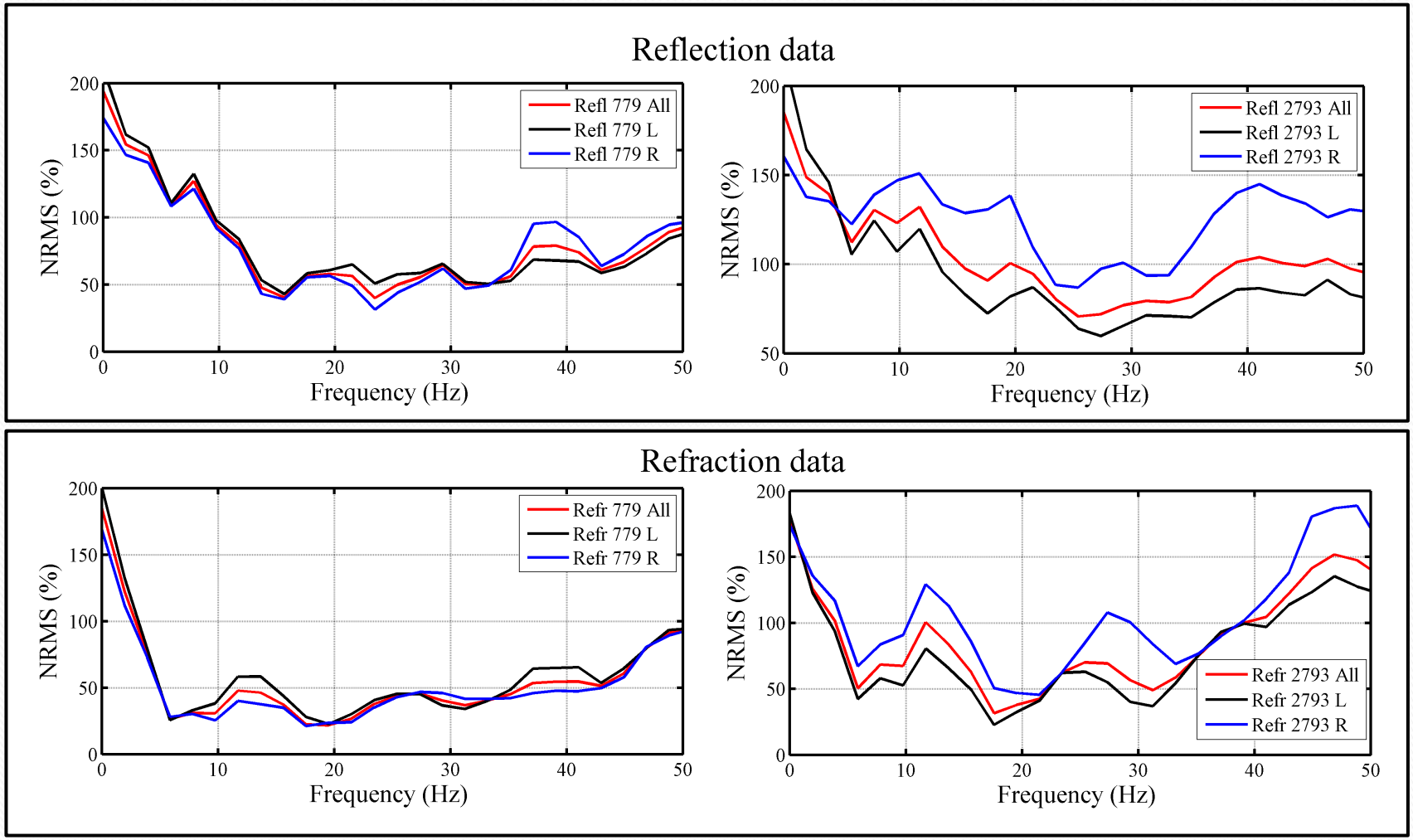


Average NRMS trends of refracted event for 7 different receivers. Observe that repeatability varies with the receiver positions.

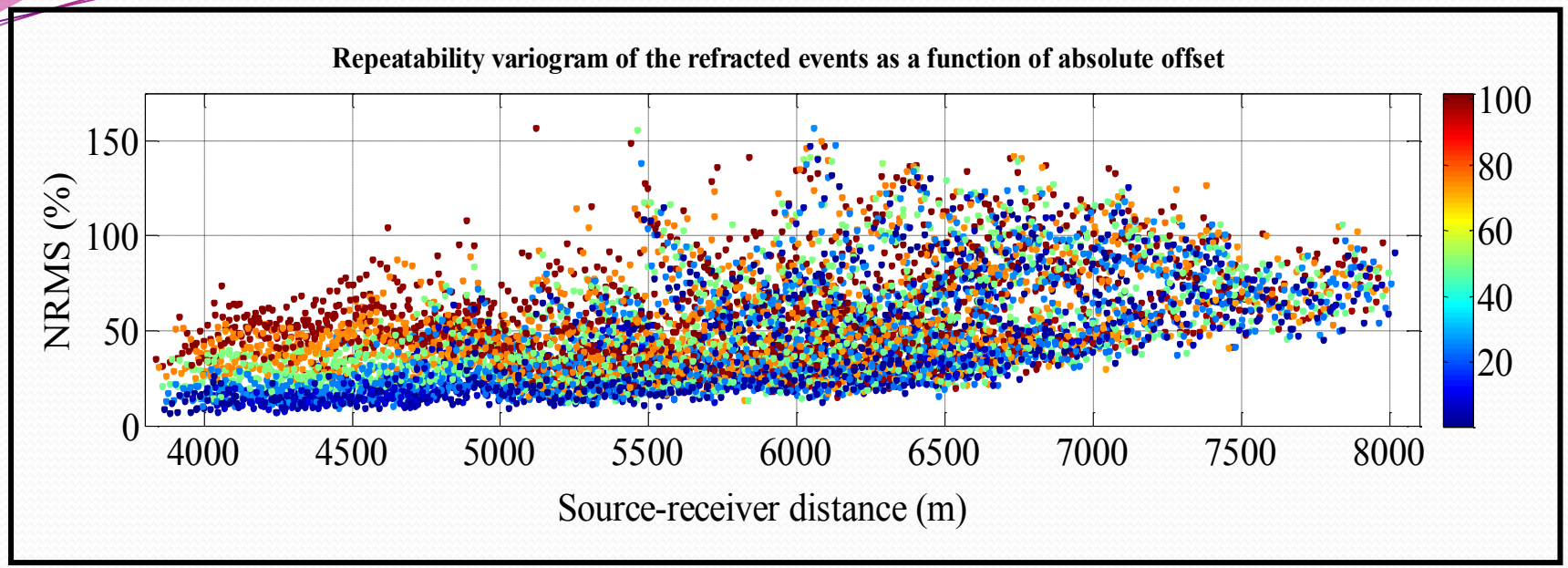


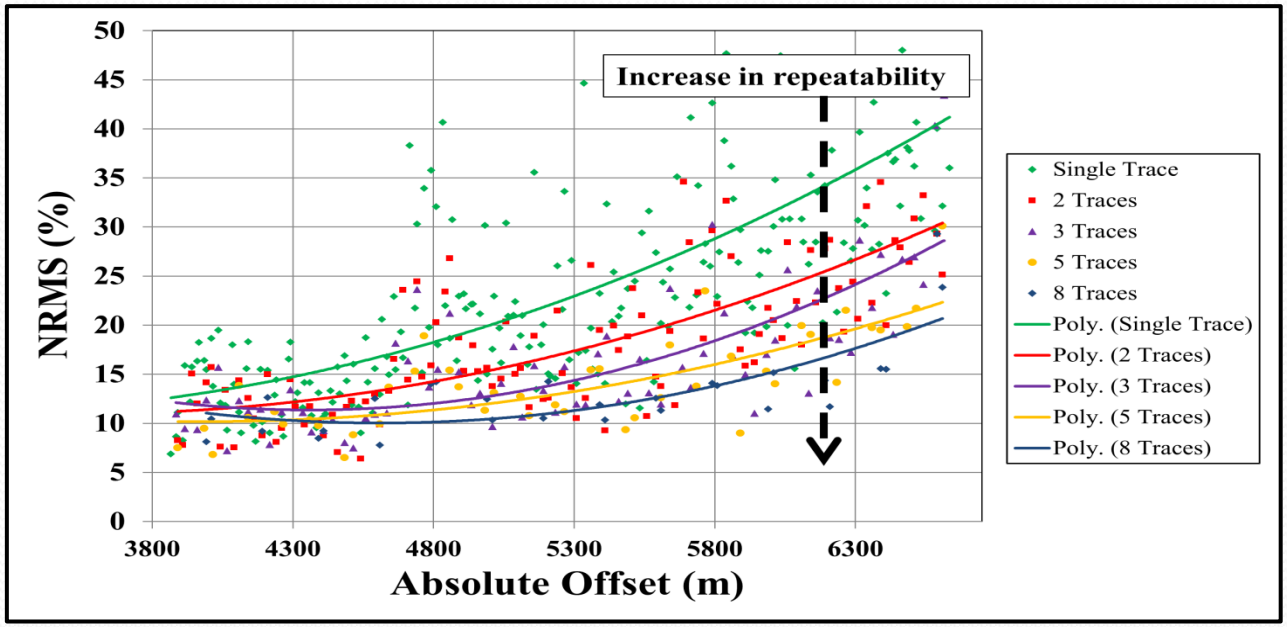
- Average NRMS trends of refracted event for 7 different receivers, where the traces are divided into two groups: (a) traces coming from the right hand side of the cross-line (AA′) and (b) the traces coming right side of the cross line.
- Observe that repeatability is low for the right hand side traces, mostly for the rec-5, rec-6 and rec-4 and also rec-7. This is mainly due to the presence of SOA.

NRMS analysis in frequency domain

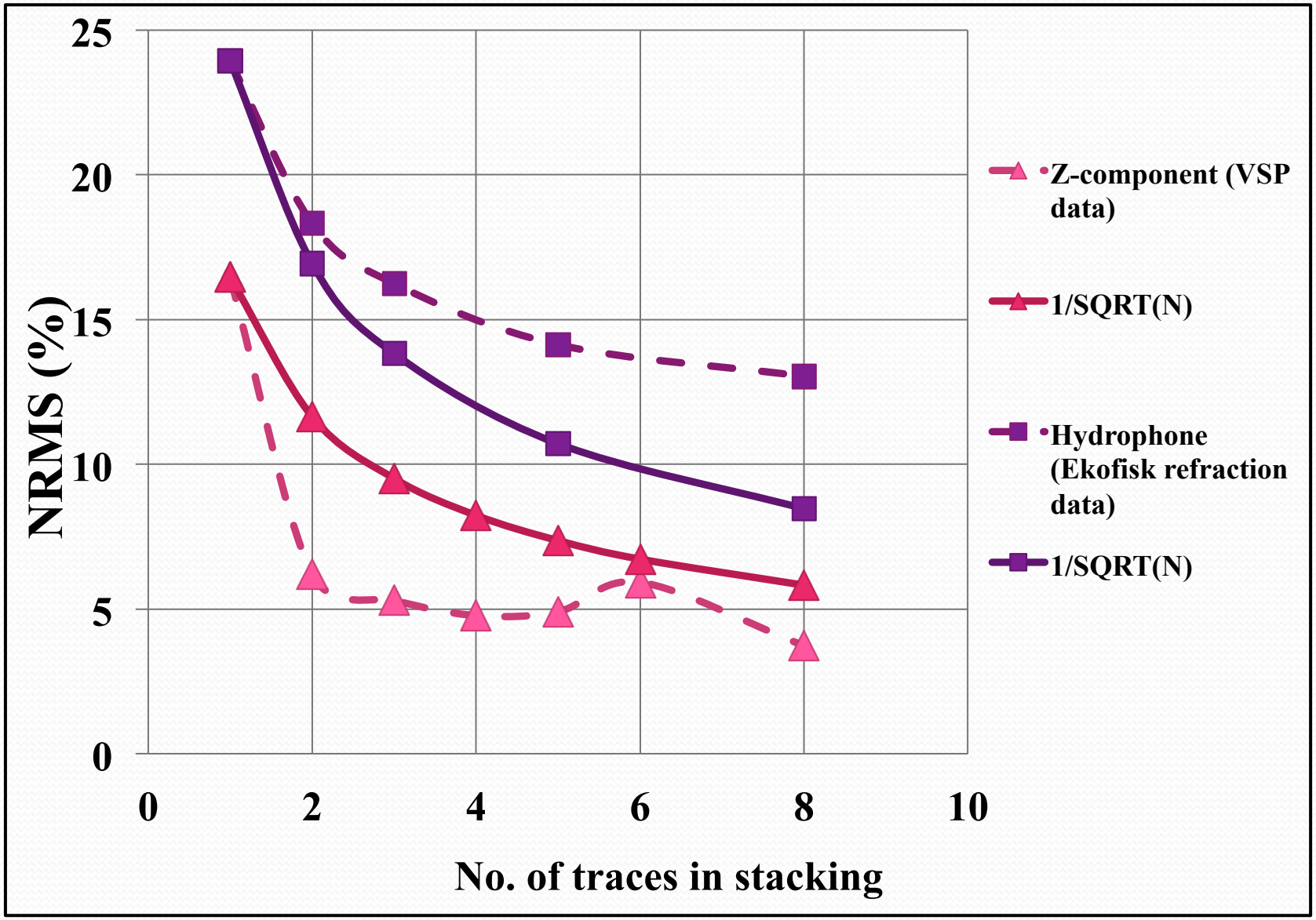


Repeatability versus stacking





Repeatability versus stacking



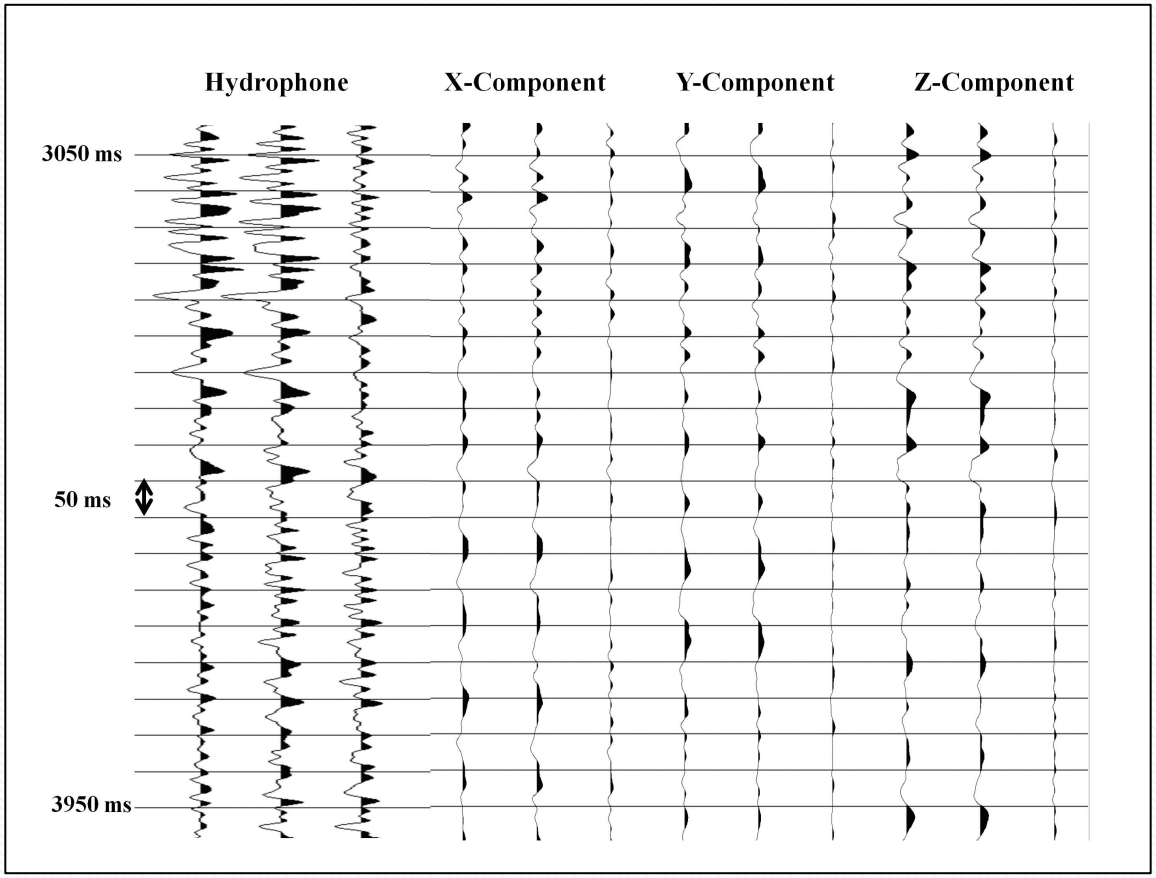
Discussion and Conclusions

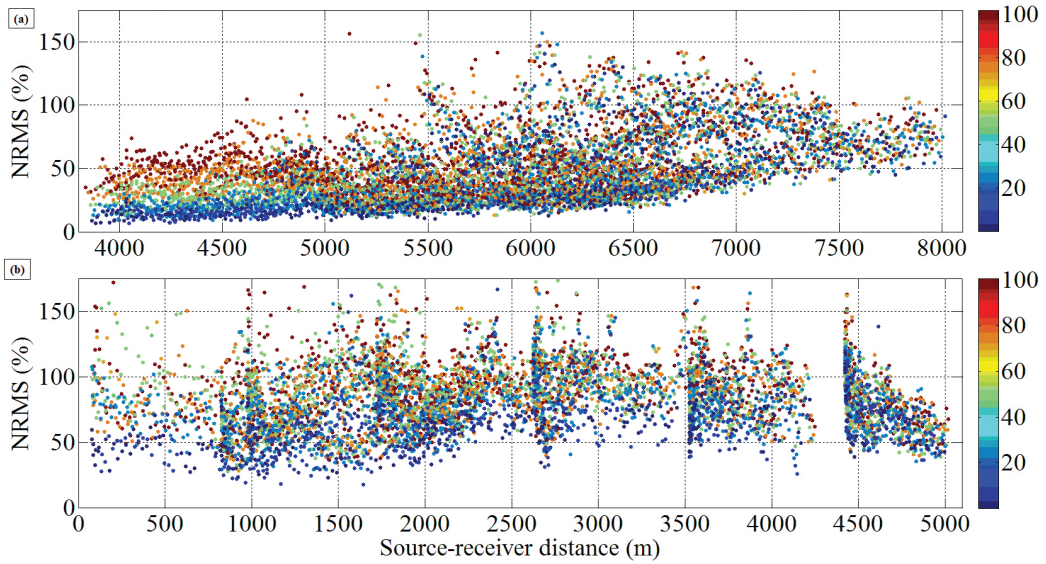
- We compare the pre-stack repeatability of the hydrophone component for various seismic events, such as refraction, reflection, sea-bottom reflection , water column noise and tank noise.
  - We find that the different seismic events have different degree of repeatability.
  - Shot positioning inaccuracies do not have the same impact on different seismic events.
- Various receiver components do not exhibit the same degree of repeatability, even for the same seismic events.
  - Z-comp shows the highest repeatability among all the components, whereas, Y-comp shows the lowest repeatability; both for reflected and refracted events.
- We find that the seismic obscured area (SOA) has great influence on the repeatability for the both refraction and reflection events.
- For refracted event, repeatability increases with the stacking.

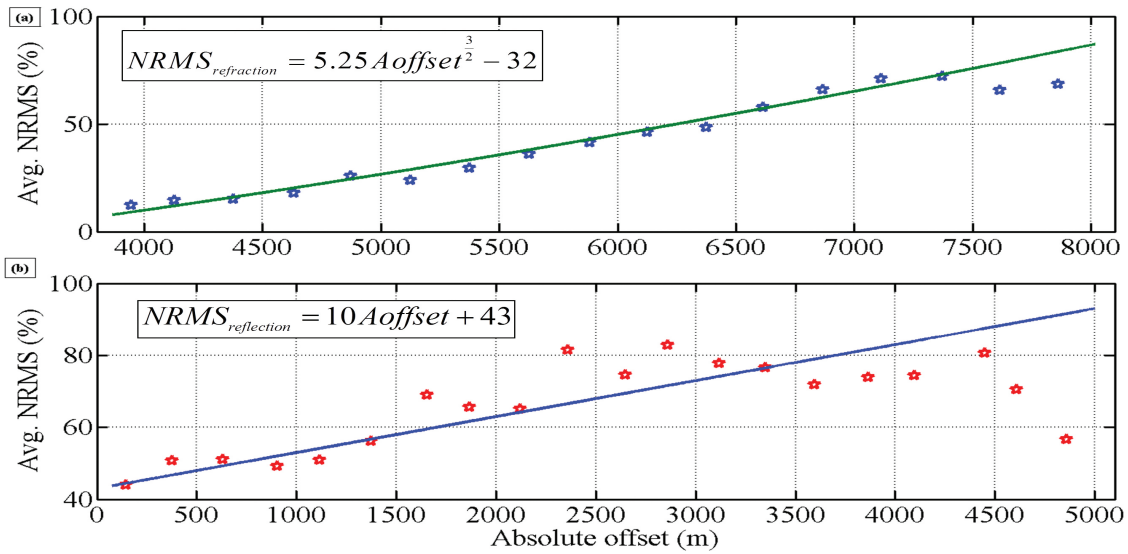
Acknowledgements

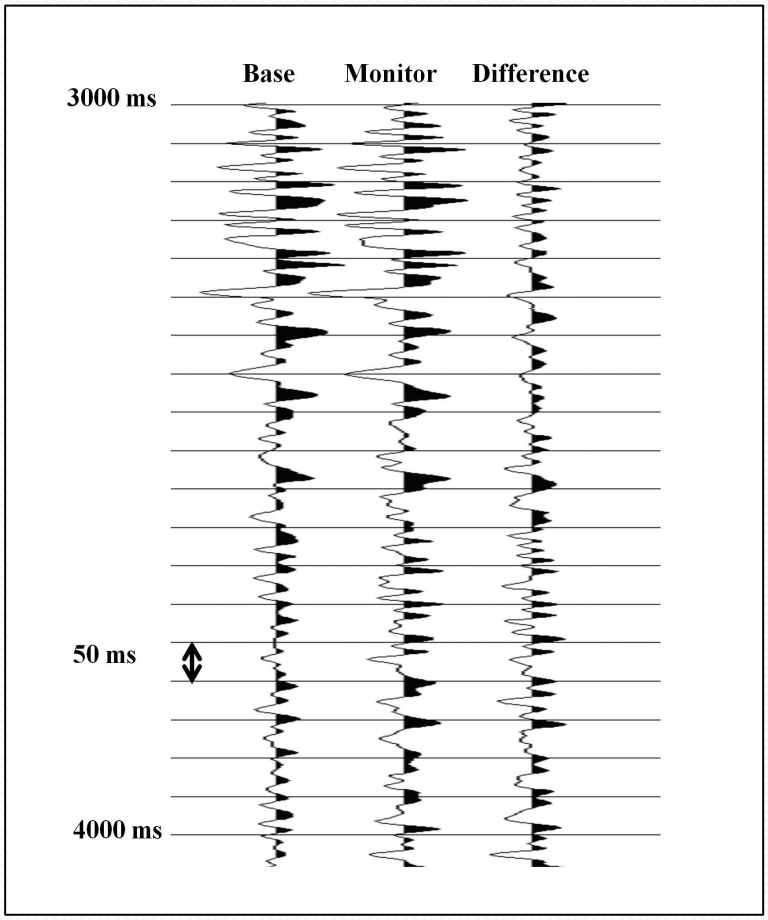
- Total E&P Norge for sponsoring my research
- The Ekofisk Partnership (Petoro AS, Statoil Petroleum AS, Eni Norge AS, ConocoPhillips Skandinavia AS, and Total E&P Norge AS) for providing the Ekofisk LOFS data
- The sponsors of the Rose Consortium

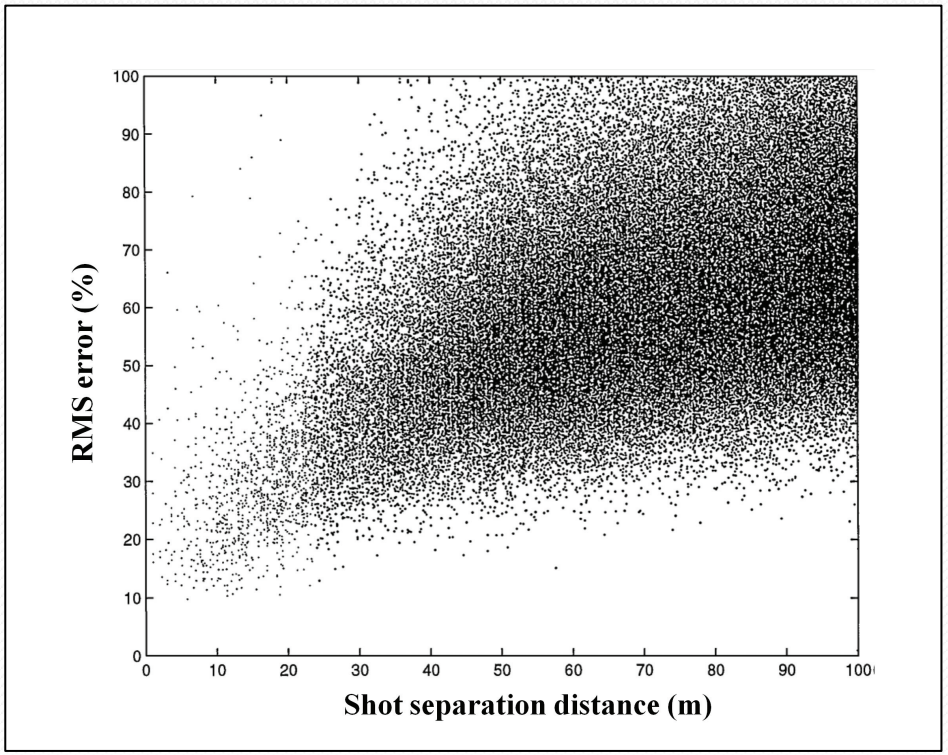
Questions ??????????


Hydrophone
X-Component
Y-Component
Z-Component
3050 ms
50 ms
3950 ms


(a)
NRMS (%)
150
100
50
0
4000
4500
5000
5500
6000
6500
7000
7500
8000
100
80
60
40
20
(b)
NRMS (%)
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Source-receiver distance (m)
100
80
60
40
20


(a)
Avg. NRMS (%)
100
50
0
$NRMS_{refraction} = 5.25 Aoffset^{\frac{3}{2}} - 32$
4000
4500
5000
5500
6000
6500
7000
7500
8000
(b)
Avg. NRMS (%)
100
80
60
40
$NRMS_{reflection} = 10 Aoffset + 43$
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Absolute offset (m)


Base
Monitor
Difference
3000 ms
50 ms
4000 ms


RMS error (%)
Shot separation distance (m)
0
10
20
30
40
50
60
70
80
90
100