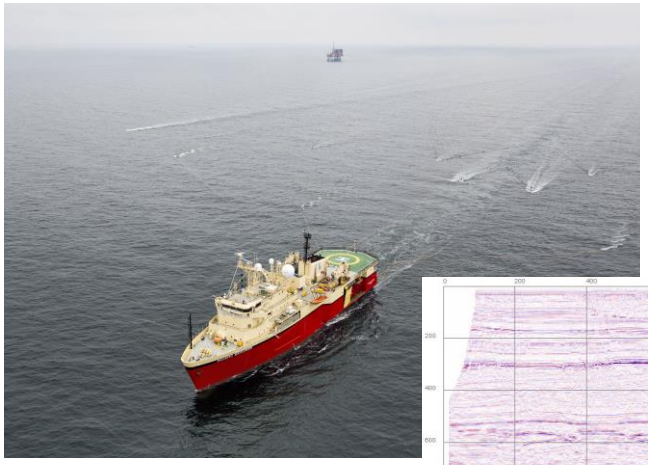
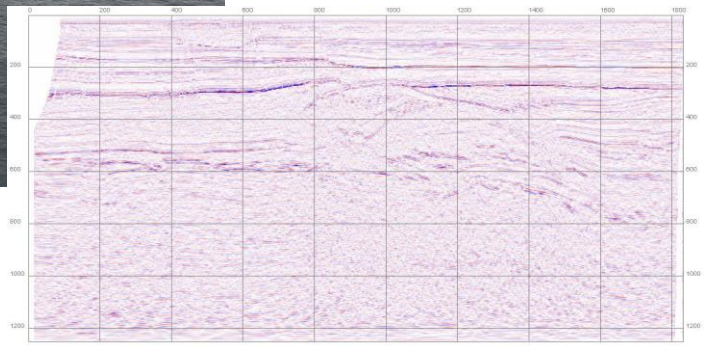
wintershall

Shaping the future.

Modeling, Testing and Measuring Underwater Sound from Seismic

Seismic surveys…





Sound...or…

…noise…?

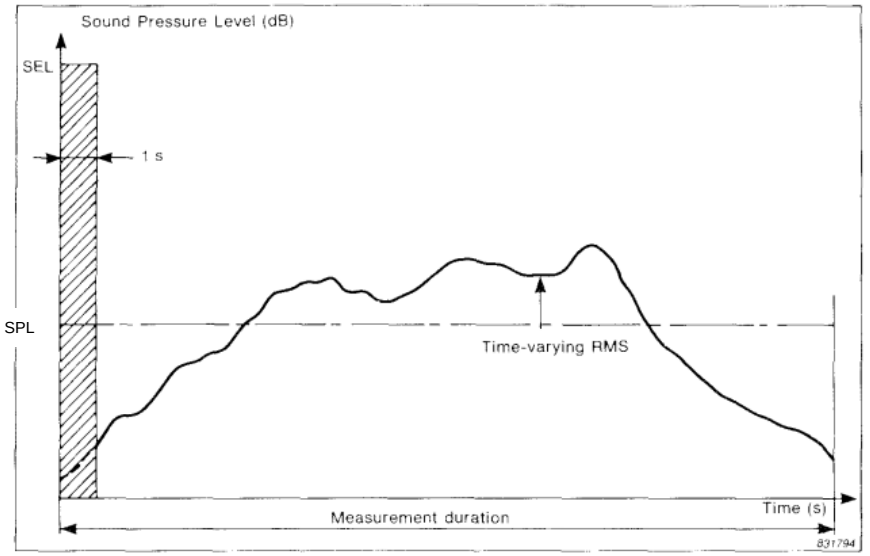
Sound – Some definitions

Sound Pressure Level SPL

(of sound, at given location for a given time interval T)

$$SPL_{shot} = 10log_{10}\frac{1}{T}\int_0^T \frac{p^2(t)}{p^2_{ref}}dt \qquad [\text{dB re 1 } \mu\text{Pa}^2]$$

p_{ref} is the reference pressure (taken equal to 1 μPa for water)



Sound Exposure Level SEL

(of sound, at given location for a given time interval T)

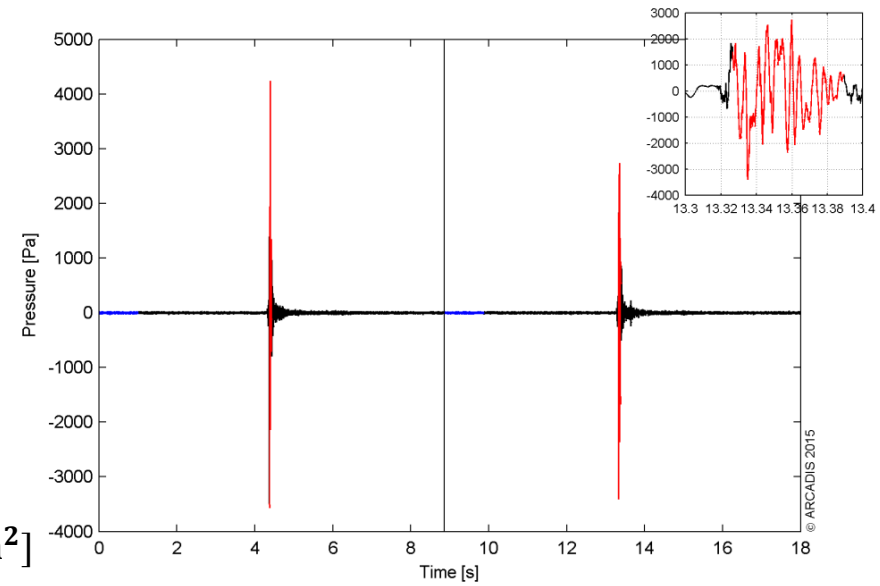
$$SEL_{shot} = 10log_{10}\frac{1}{T_0}\int_0^T \frac{p^2(t)}{p^2_{ref}}dt \qquad [\text{dB re 1 } \mu\text{Pa}^2\text{s}]$$

p_{ref} is the reference pressure (taken equal to 1 μPa for water)
and T_0 is the reference time of 1 second

Peak-to-Peak Pressure level Lpp

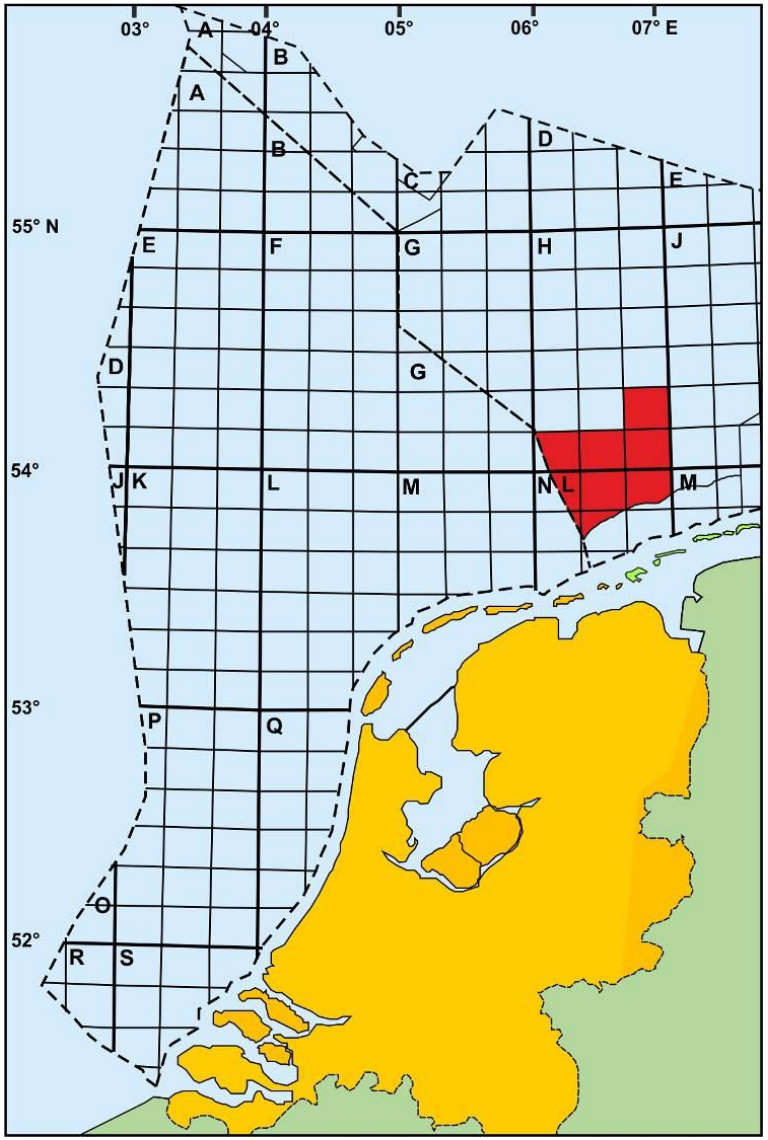
(of sound, at given location for a given time interval T)

$$Lpp_{shot} = 20log_{10}(max(p(t)) - min(p(t))) \ [\text{dB re 1 } \mu\text{Pa}^2]$$



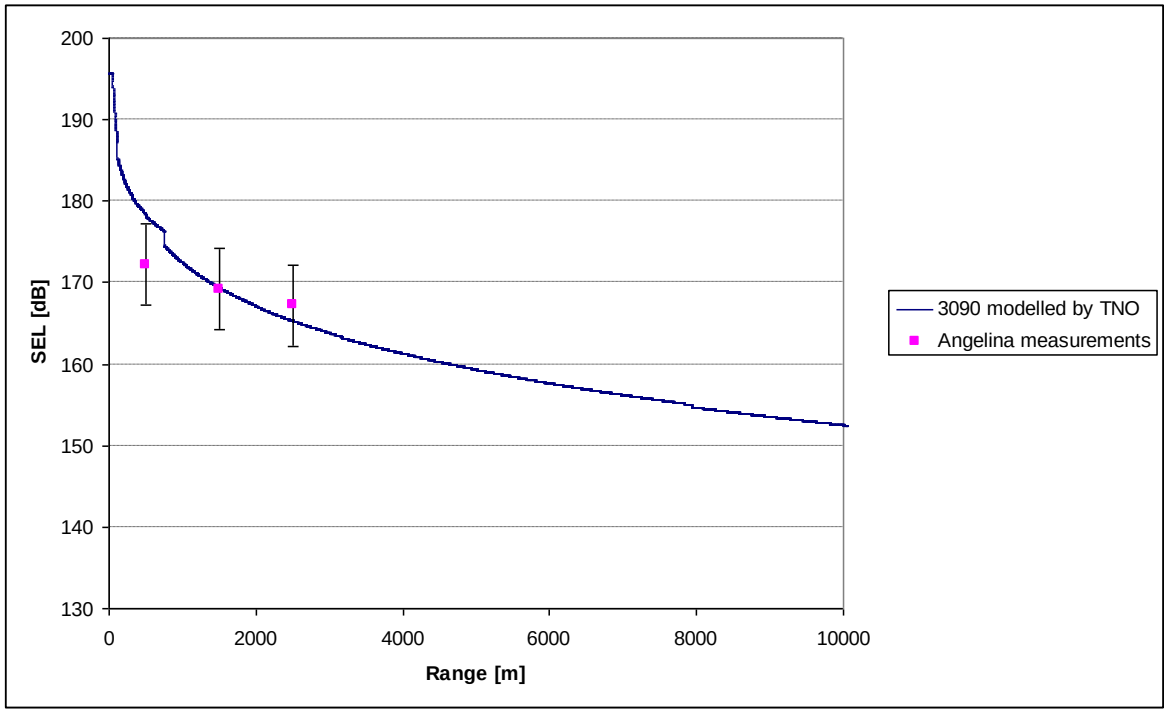
German Environmental Restrictions

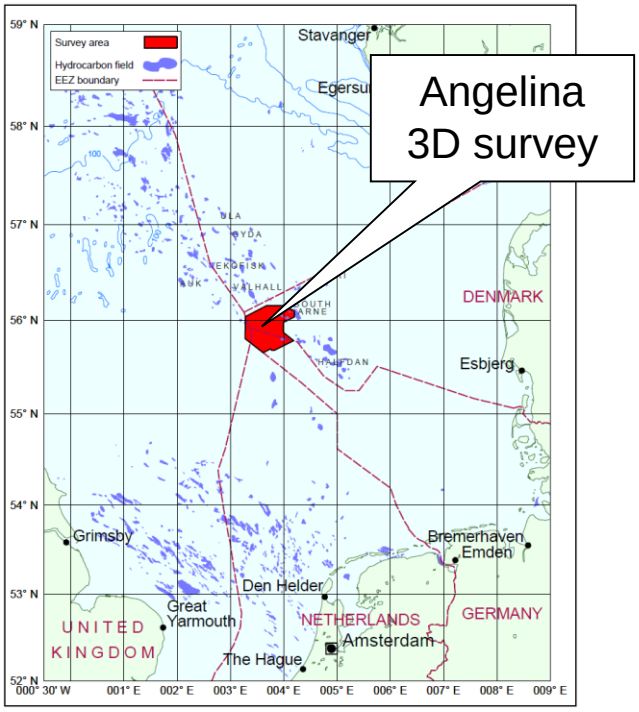
- Wintershall and partner group face stringent underwater sound level restrictions that prevent seismic acquisition in their German H&L blocks:
  - < 160 dB Sound Exposure Level (SEL) or 190 dB peak-to-peak at a radius of 750 meter from the source.
  - Mammals may not be chased away from more than 10% of the Flora and Fauna Habitat. Sound disturbance effects will be felt up to 138 dB.



Modelling Compared to Measurements

- During the Angelina survey (2007) underwater sound from the seismic source was recorded at 500 m, 1500 m and 2500 m.
- Below the measurements are compared to TNO modelling of the same source.





Acknowledgements

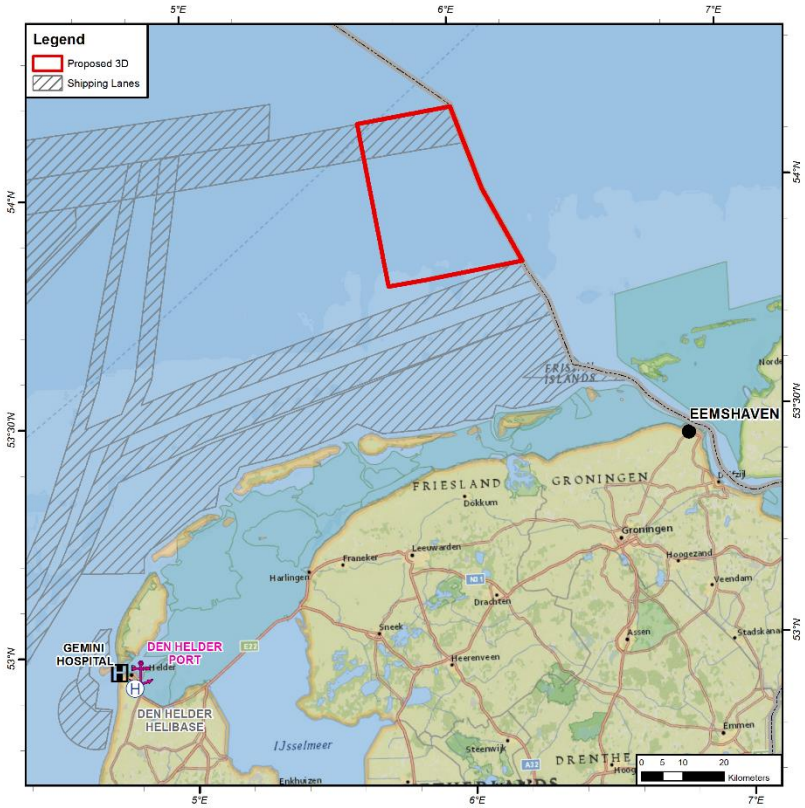
- NAM, Sterling Resources and Hansa Hydrocarbons acquired seismic in 2014; part of the permitting conditions was to acquire underwater sound measurements during a seismic acquisition.
- ENGIE, Hansa Hydrocarbons and Wintershall contributed to the underwater sound measurements as German H&L partner group

Acknowledgements

- ENGIE
- Hansa Hydrocarbons
- NAM
- Sterling Resources

Objectives of the Underwater Sound Measurements

- In summer 2014 Hansa acquired 3D seismic on the Dutch side, adjacent to the German H&L blocks
- Objectives:
  - Alternative Source Test Line: Test different source designs with reduced sound level
  - Sound measurements: Support calibration of sound propagation modelling for different source designs
- Measurements and modelling performed by Arcadis, Deep & TNO.



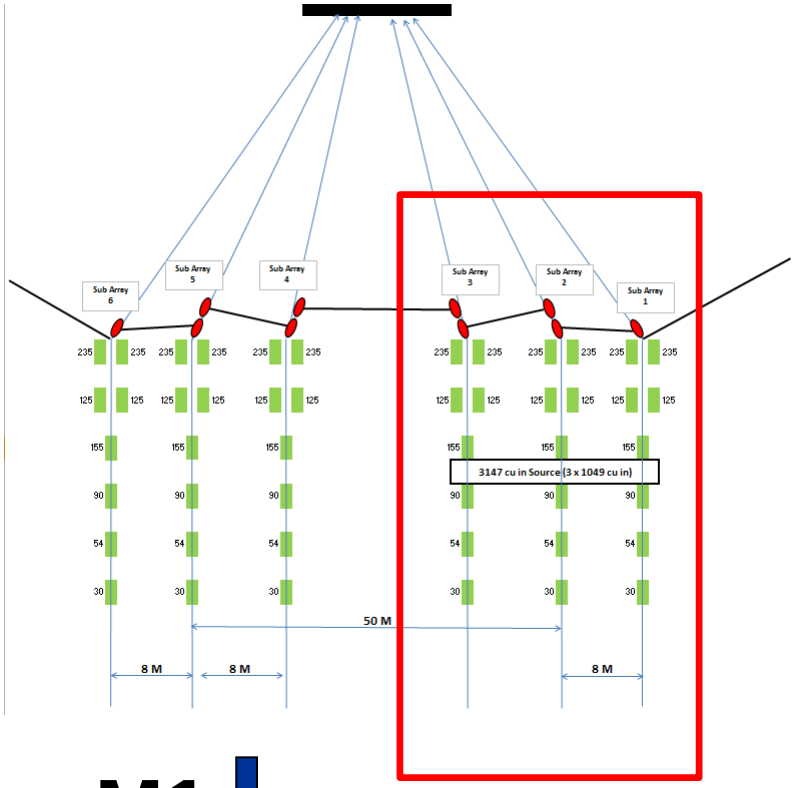
Seismic Source Designs

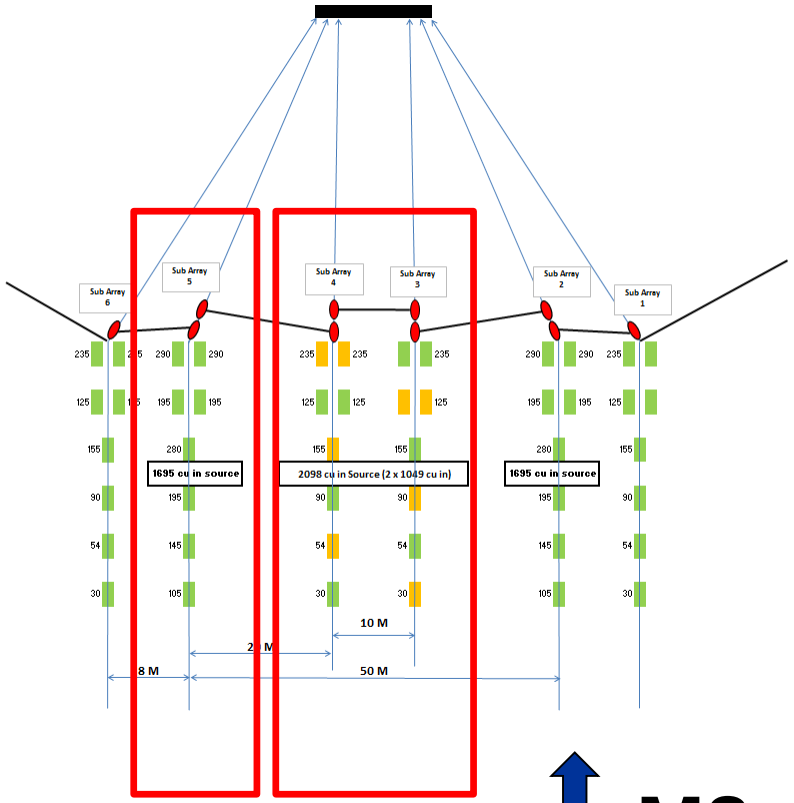
M1 Test – 1 Production Source

3147 cu.in, 3 sub-arrays, **2000 psi,** dual sources (M1)

M2 Test – 3 Alternative Sources

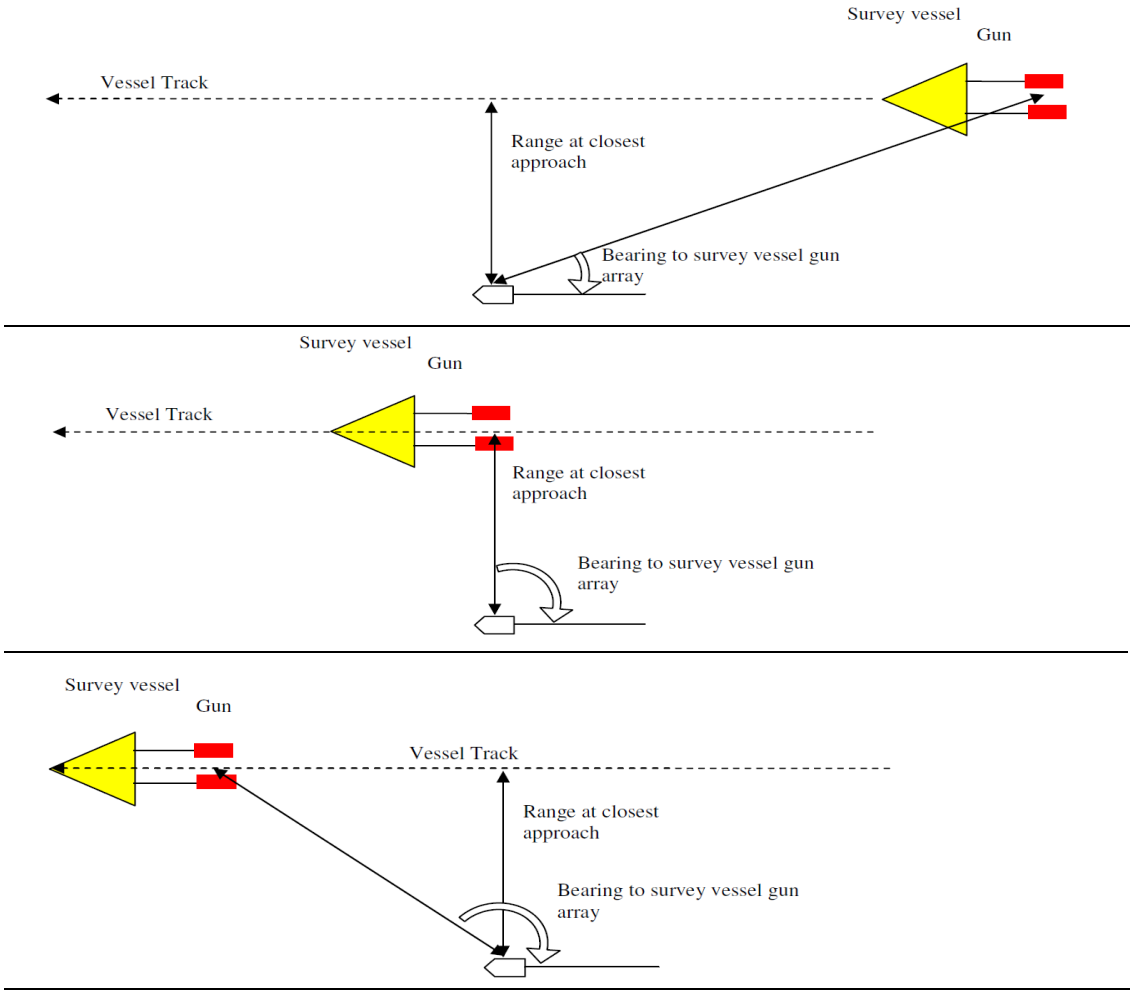
1695 cu.in, 2000 psi, 1 sub-array, dual sources (M2T2)
1049 cu.in, 2000 psi, 2 sub-arrays, single source (M2T1)
1049 cu.in, 1000 psi, 2 sub-arrays, single source (M2T3)



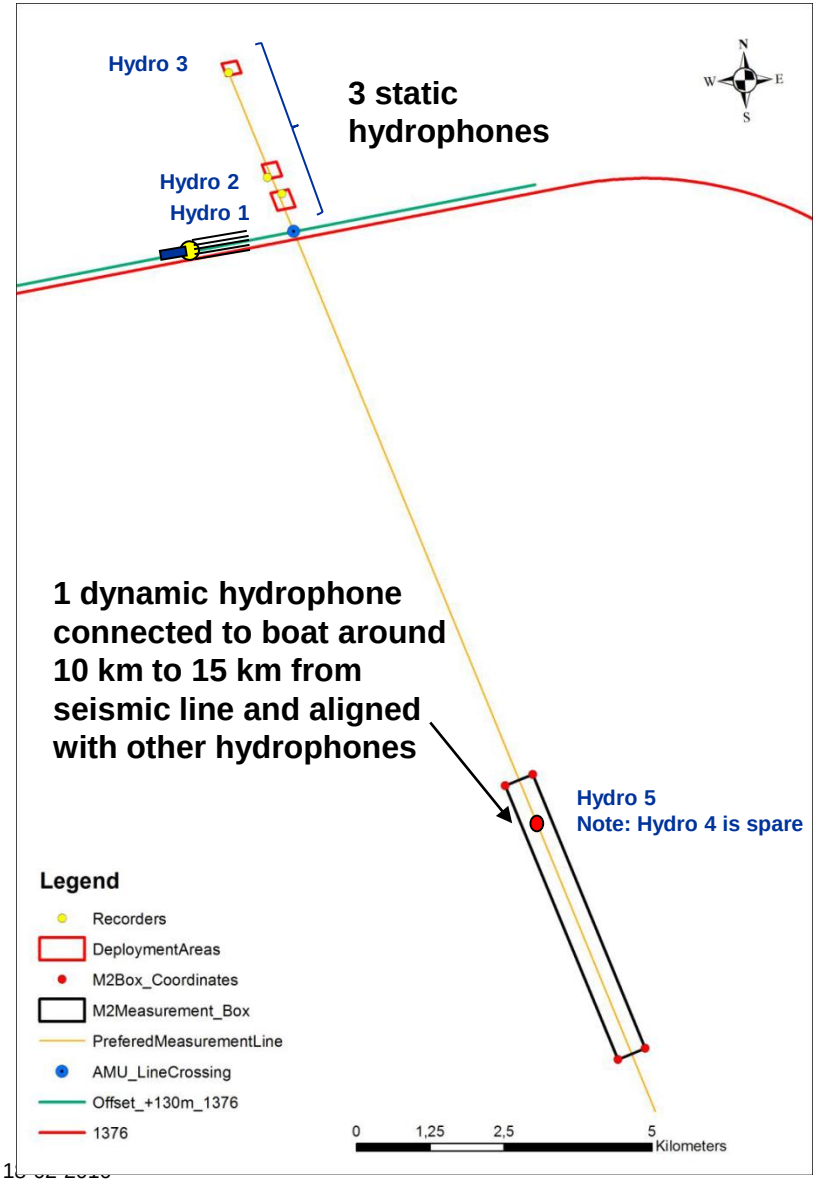


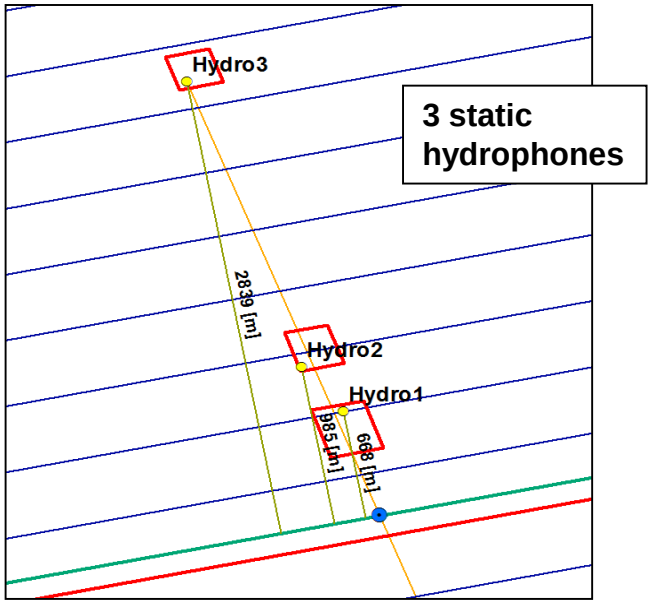
M1 → **Reconfiguration at end of 4Quads Survey** → **M2**

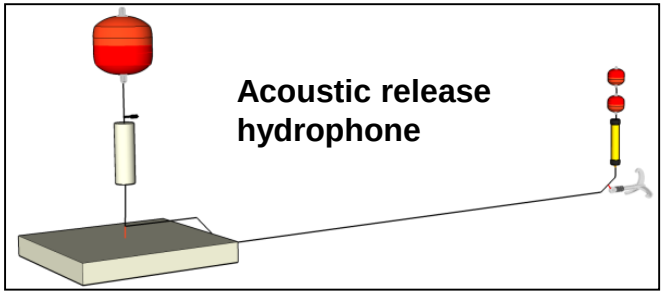
Hydrophone Set-up (1)

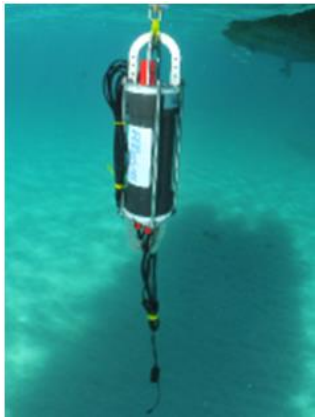


Hydrophone Set-up (2)

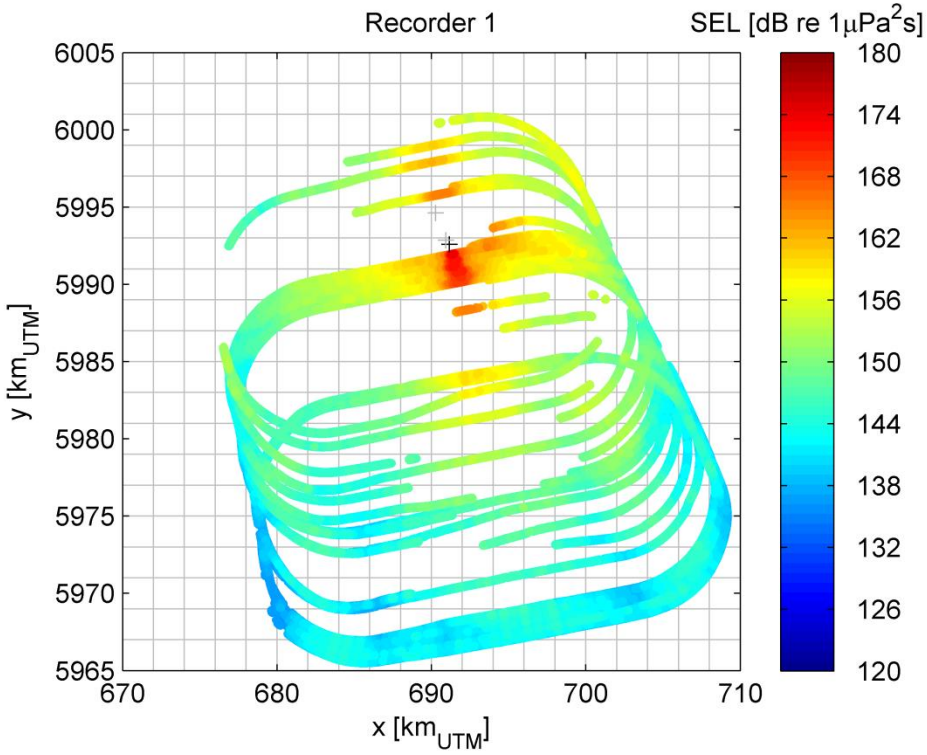






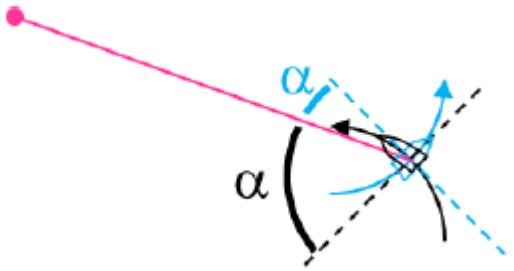


SEL Measurement during M1

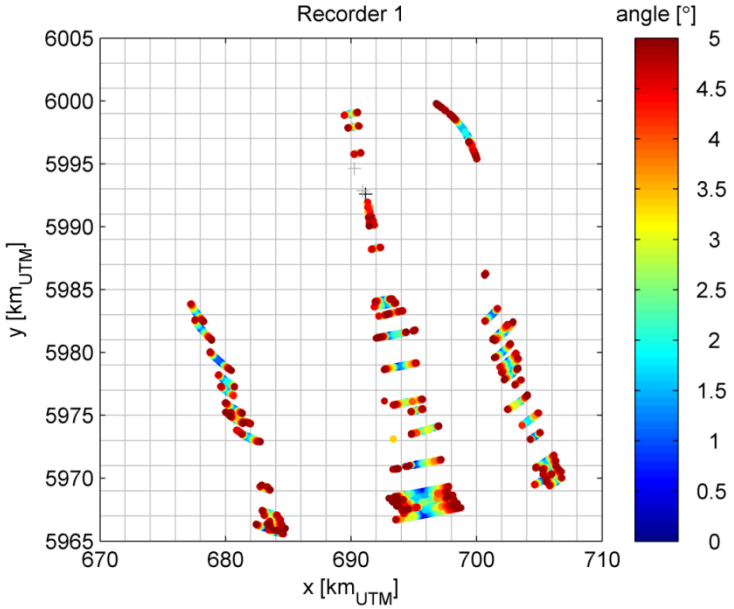


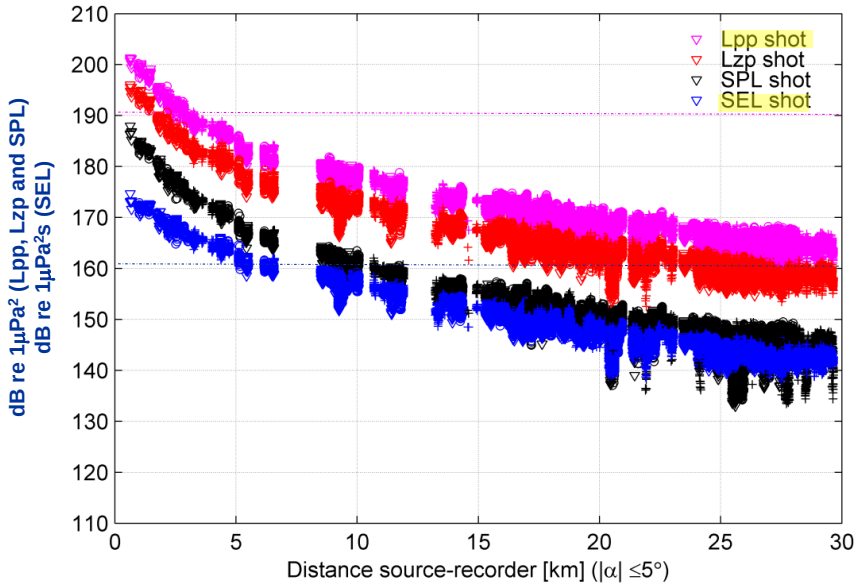
Map shows:

- 2-week coverage of continuous SEL measurements at hydrophone 1 during production seismic survey with M1 (biggest) source
- Variation of SEL with angle bearing and distance



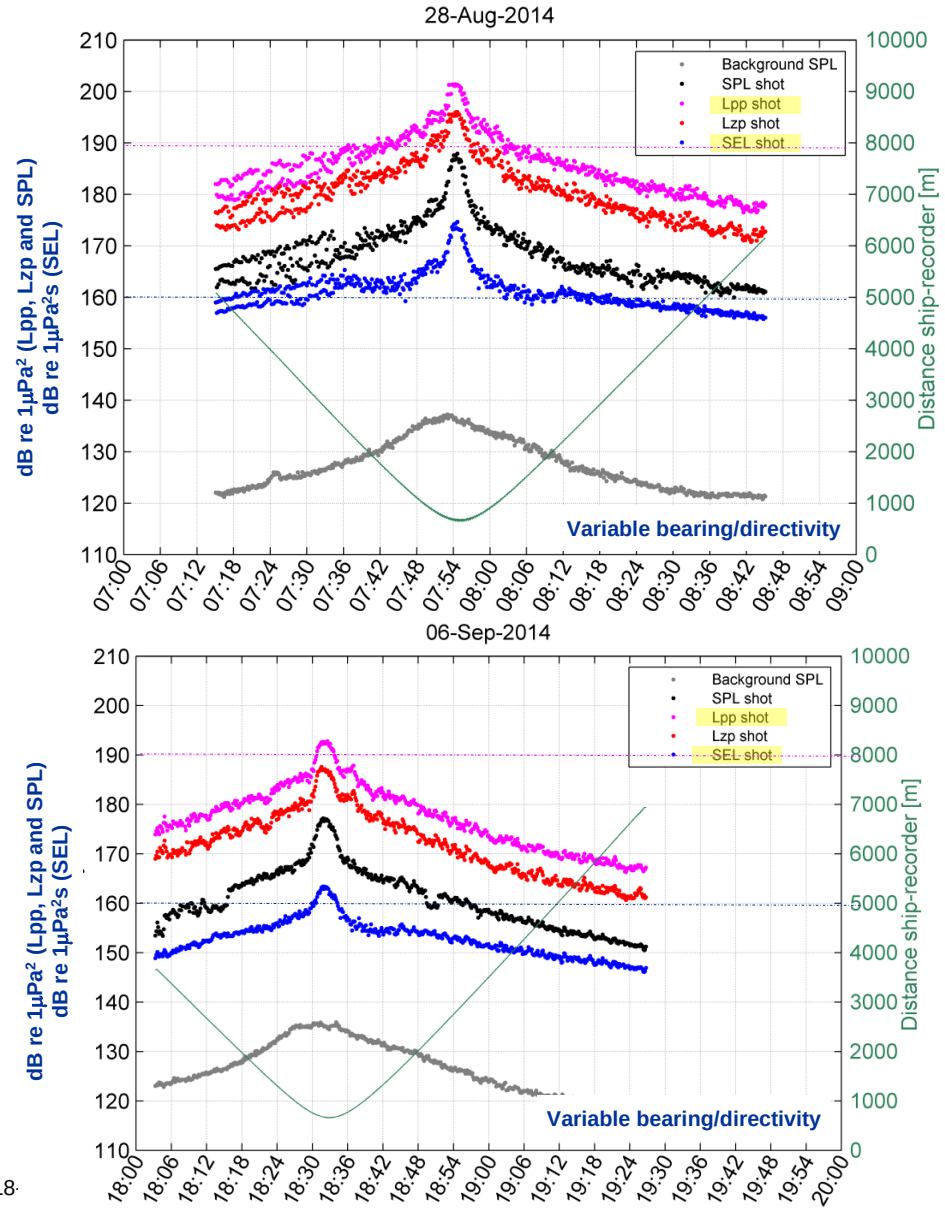
M1 Sound Measurements vs Distance

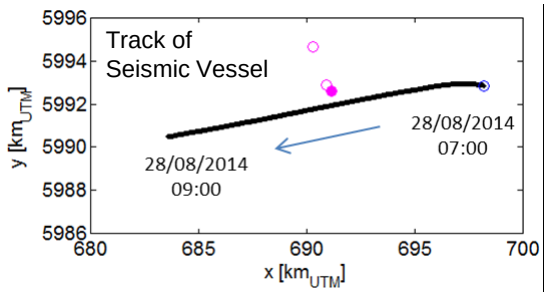




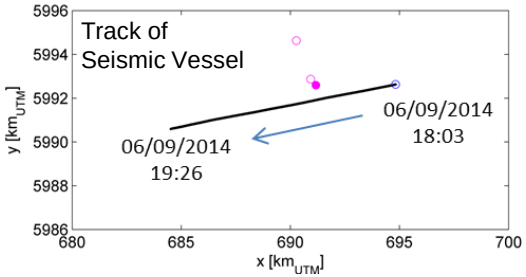
- To avoid directivity influence, only data with angles +/- 5 degrees are considered
- Measurements taken from the hydrophone receivers 1, 2 & 3 are plotted against distance

Sound Measurements – Time Series



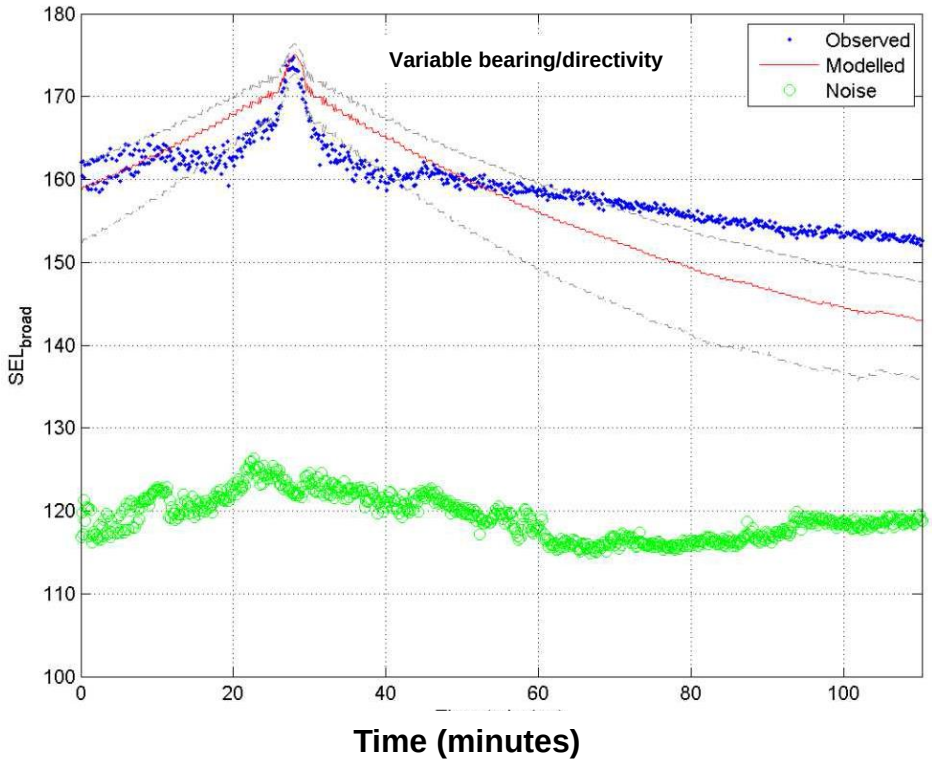


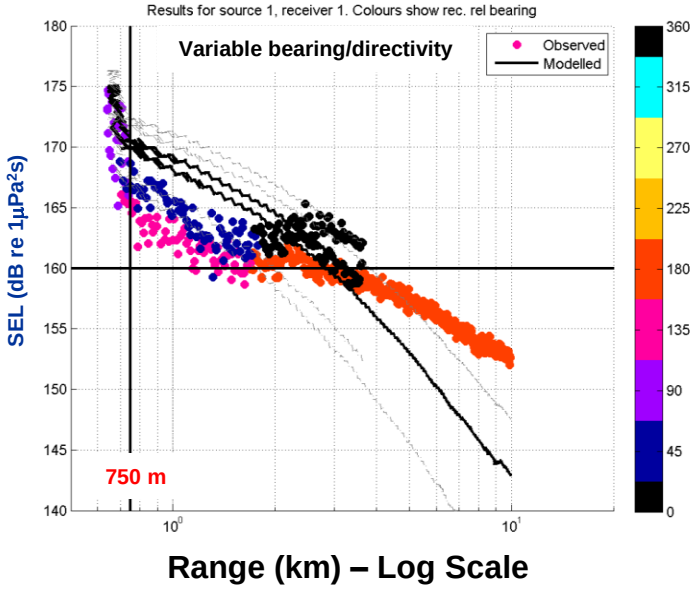
M1 source (biggest)
3147 cu.in. – 2000 psi

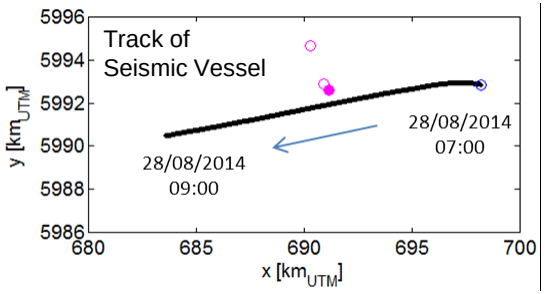


M2T3 source (smallest)
1049 cu.in. – 1000 psi

M1 SEL Sound Measurements vs Modeling

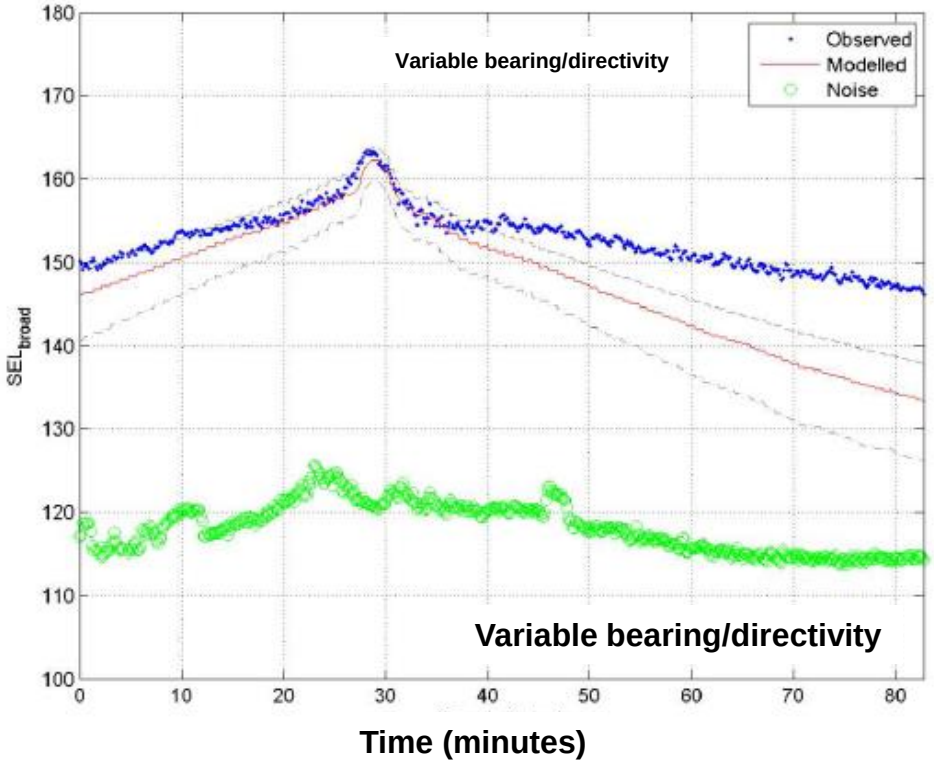


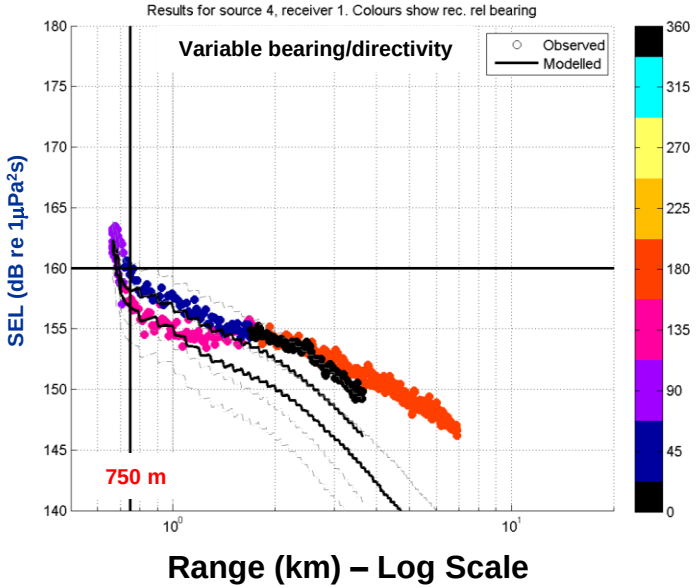


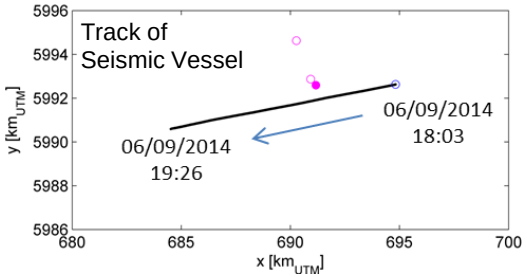


M1 source (biggest)
3147 cu.in. – 2000 psi
Recorded at hydrophone 1

M2T3 SEL Sound Measurements vs Modeling

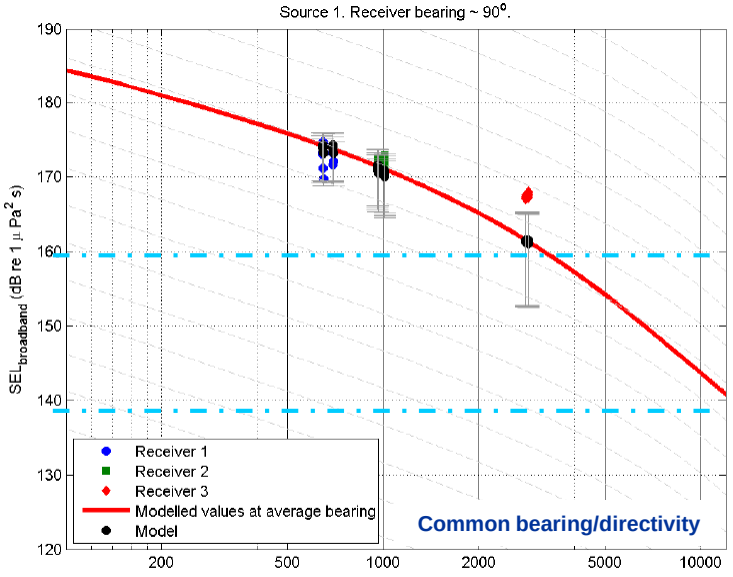


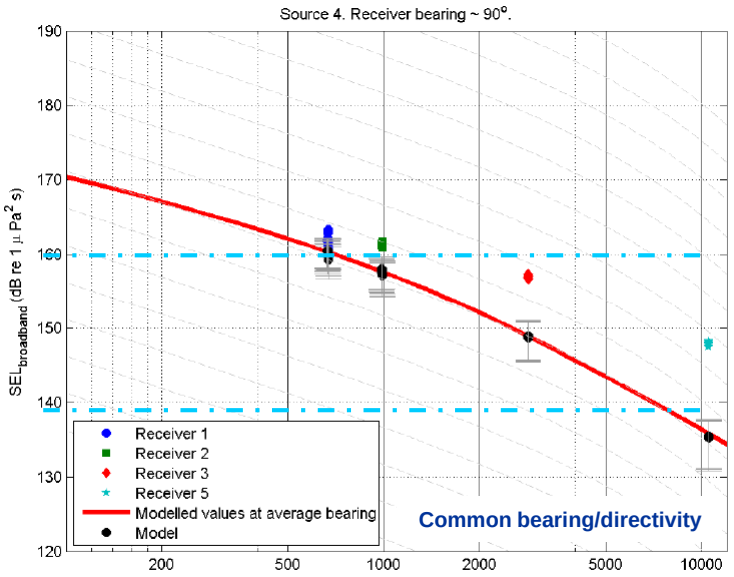


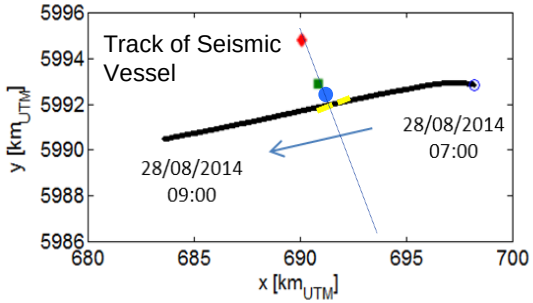


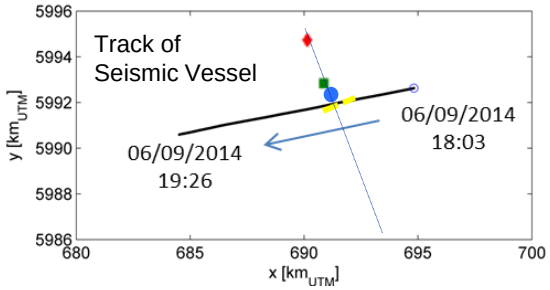
M2T3 source (smallest)
1049 cu.in. – 1000 psi
Recorded at hydrophone 1

Sound measurements vs Modeling







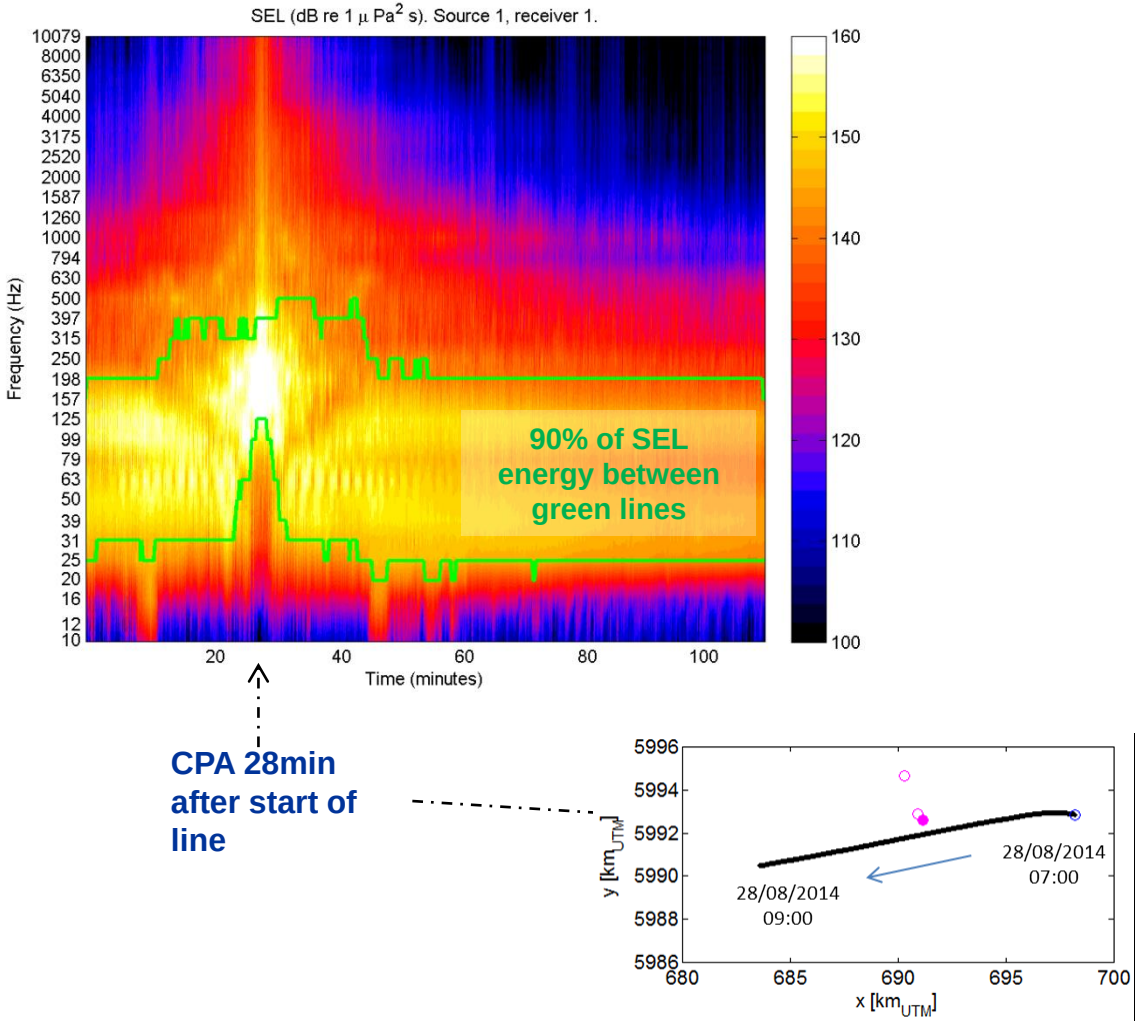


M1 source (biggest)
3147 cu.in. – 2000 psi

M2T3 source (smallest)
1049 cu.in. – 1000 psi

SEL vs Frequency

M1 Source (3147 cu.in, 2000 psi) at hydrophone 1



Conclusions

- Complex project with many stakeholders
- Carefully consider HSE and safety
- SEL and peak-to-peak SPL (Lpp) significantly decrease with lower source energies
- Modeling overestimated sound attenuation at far range: this remains unexplained
  - Are acquistion conditions (very quiet/flat sea, very reflective) the reasons for lack of far range attenuation?
  - More efforts on the TNO modelling are required

4th International Conference

- "The Effects of Noise on Aquatic Life", Dublin, Ireland 10-16 July 2016, an abstract on the 4Quads underwater sound measurements & modelling will be submitted by TNO:

  Sound Exposure Level Measurements and Model Predictions for a Marine-Seismic Airgun Array in a Shallow-water Environment.

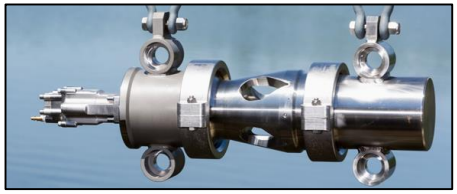
  M.K. Prior, M.A. Ainslie, B. Binnerts, S. Giodini, O. Sertlek

- Airgun Modelling Workshop organized on Saturday, 16 July 2016, by Michael Ainslie, TNO

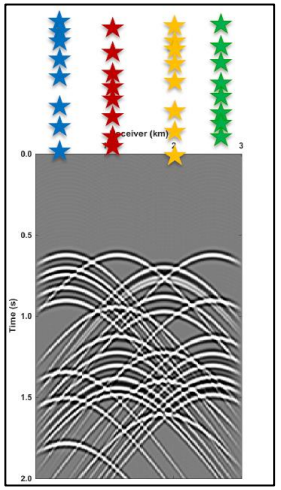
Alternatives

- Marine vibroseis

- eSource Schlumberger



- Incoherent shooting of conventional airguns and deblending during processing



Questions?