Sonar Imaging summary

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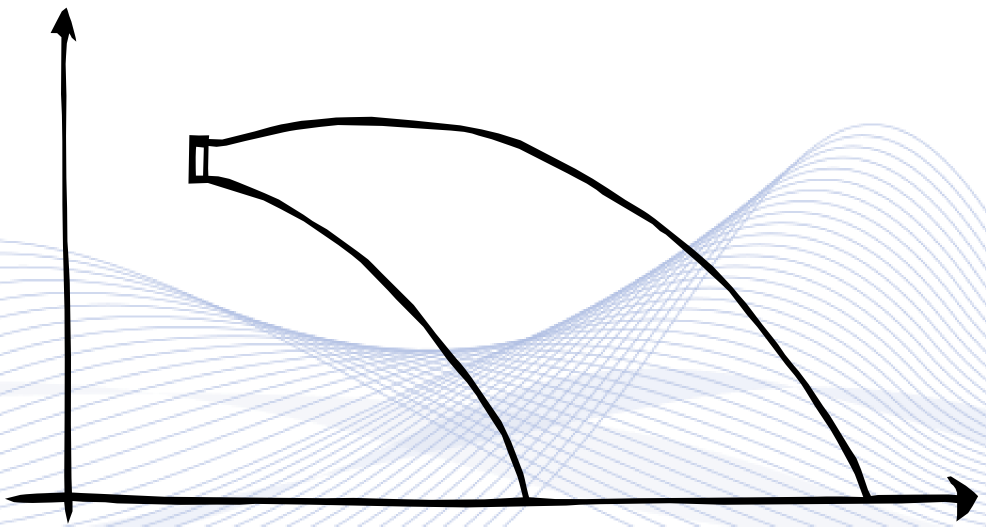
Active Sonar Processing

- **Hydro Acoustics**
- Hardware
- Calibration
- Noise reduction
- Echograms
- Post Processing

Hydro Acoustics

Sound waves follow a non-linear path underwater due to refraction caused by their variable speed[1].



Not to scale

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Hardware

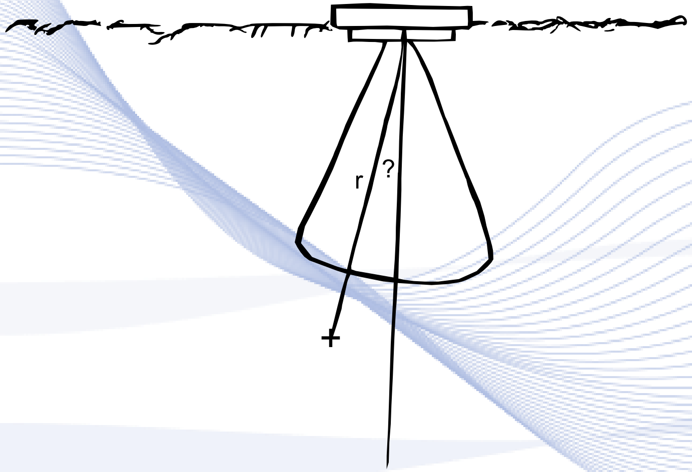
Sonars consist of an array of emitters/transducers and receivers/hydrophones for the collection of range and bearing data.

They come in different configurations of frequencies, beam sizes and mounting based on their intended use case.

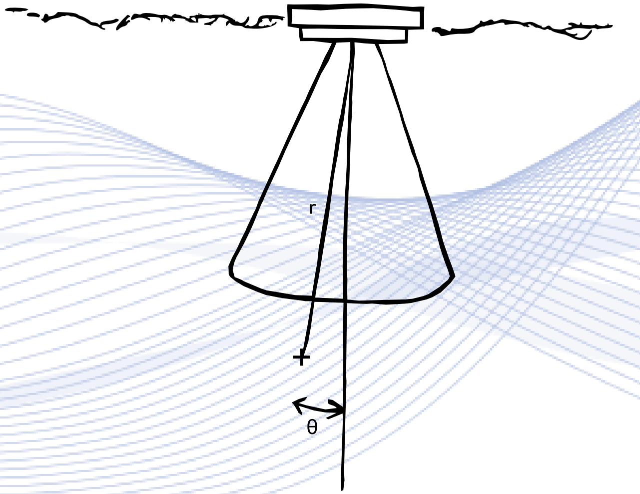
Sonar frequencies commonly used in research is 18~100kHz for seabed mapping and 100~400kHz for fisheries research[3].

Hardware – Mutli beam

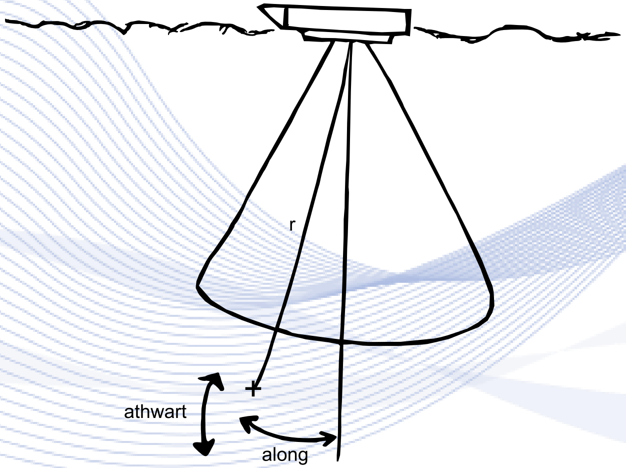
Direct development of single beam sonar, uses multiple receivers and beamforming to calculate the angle of the reflected object from the center of the beam[3]. Along with power data, alongship and athwartship angles are stored for each sample telegram[6].



Single Beam

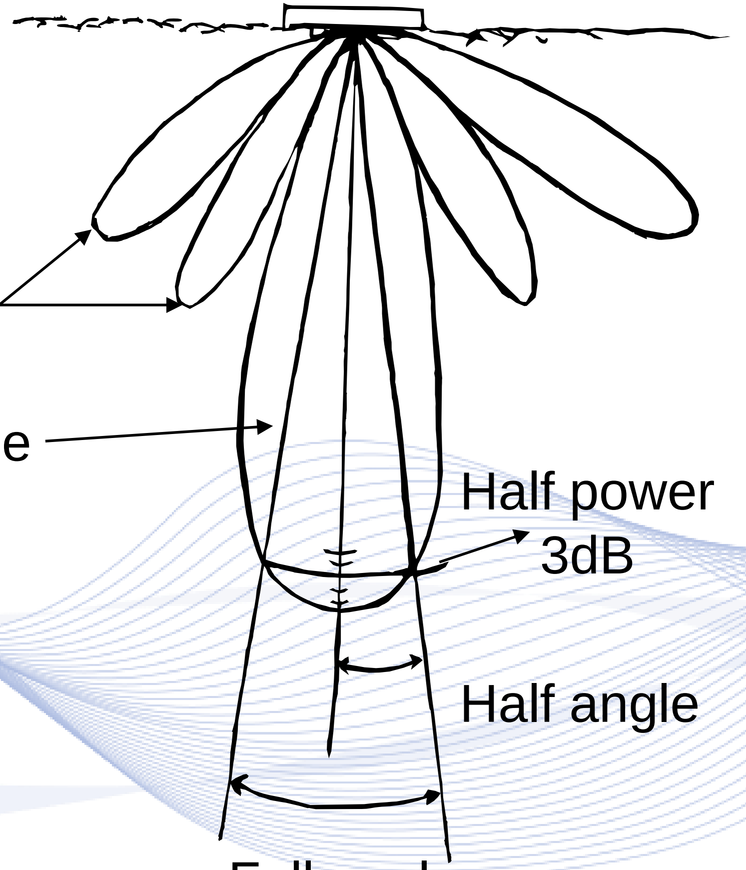


Dual Beam



Split Beam

Beam pattern – Angle



Transducers transmit a directional sound wave[3,7]. During processing the equivalent beam angle ψ is required for Sv calculations.

$$\psi = \frac{5.78}{(ka)^2},$$

$$\alpha = \frac{1.6}{k\sin(\theta_{3dB}/2)}$$

where:

α is the active radius,

θ_{3dB} is the half power beam angle,

$k = 2\pi/\lambda$ and λ is the wavelength.

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Calibration

Before the survey, the *target strength*(TS) gain for each frequency is adjusted against either a copper or tungsten sphere with standard, known TS[3,9].

Frequency (kHz)	Calibration Sphere	Nominal TS (dB)
38	60.0 mm Cu	-33.60
38	38.1 mm WC	-42.04
70	32.1 mm Cu	-39.10
70	38.1 mm WC	-40.56
120	23.0 mm Cu	-40.40

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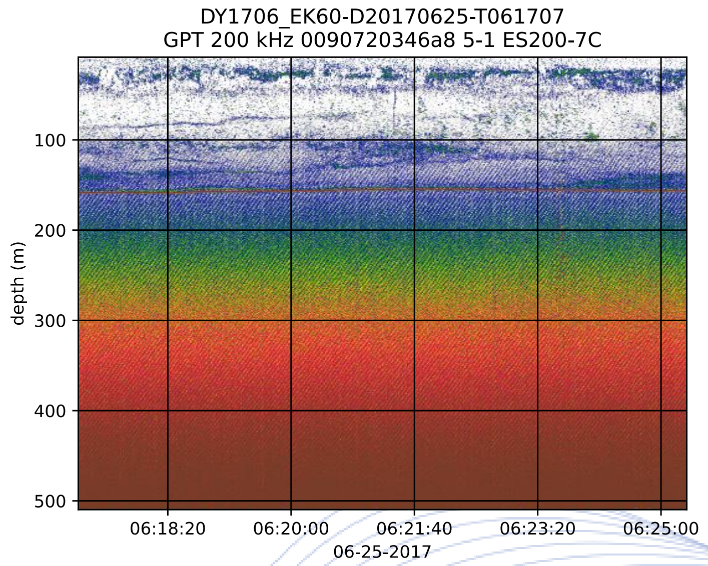
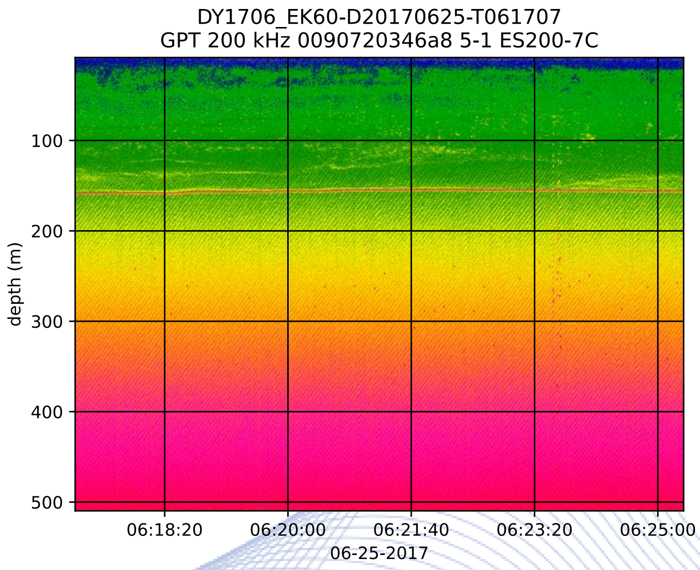
Noise reduction - SNR





DY1706 survey

Left: S_v

Right: TS

An example of a 200kHz beam being limited by SNR after 200m. Noise is caused by the vessel's electrical systems, propeller, engine and other ambient noises. Noise levels remain constant with depth, but signal levels decrease due to spreading and absorption[3].

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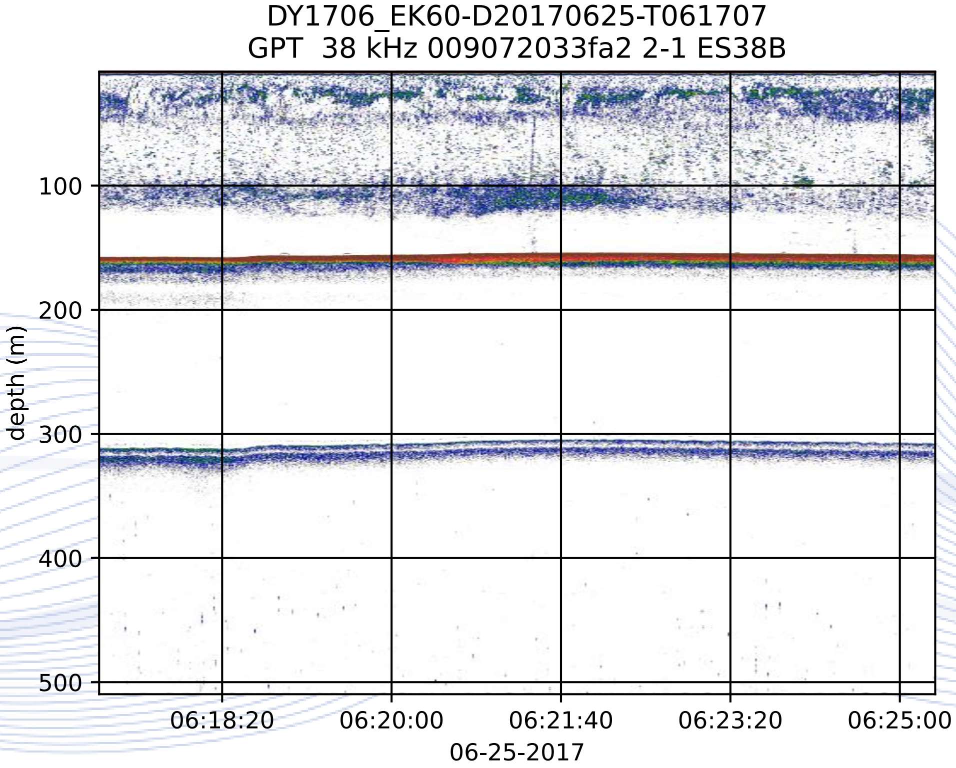
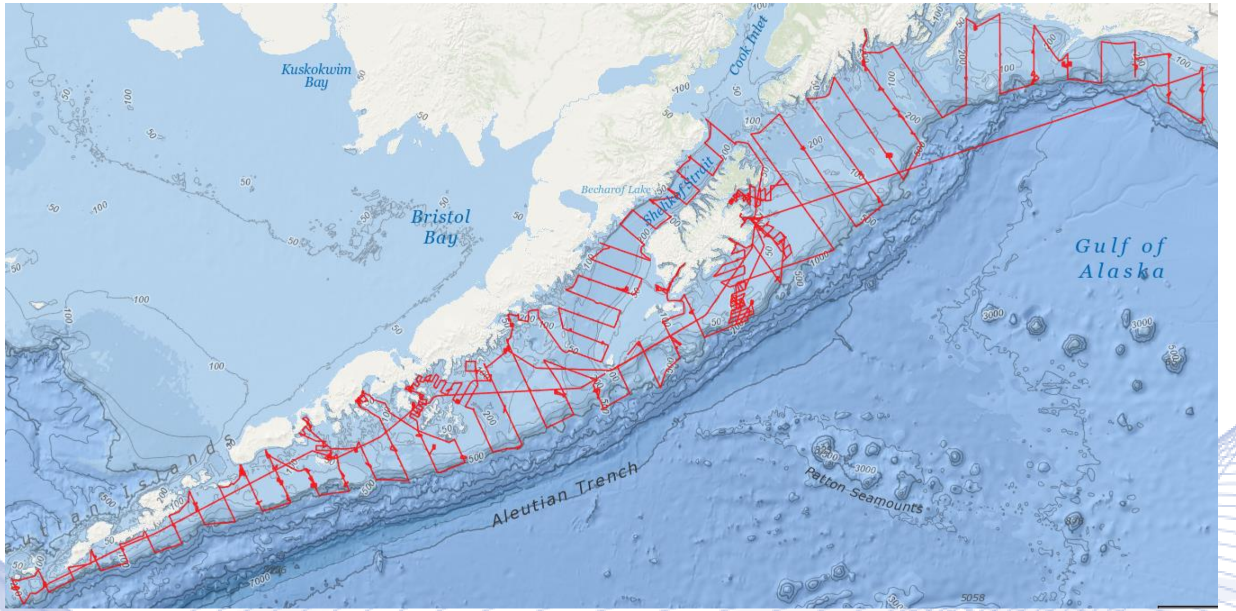
Echograms

Raw data is processed and visualized in S_v and TS echograms.

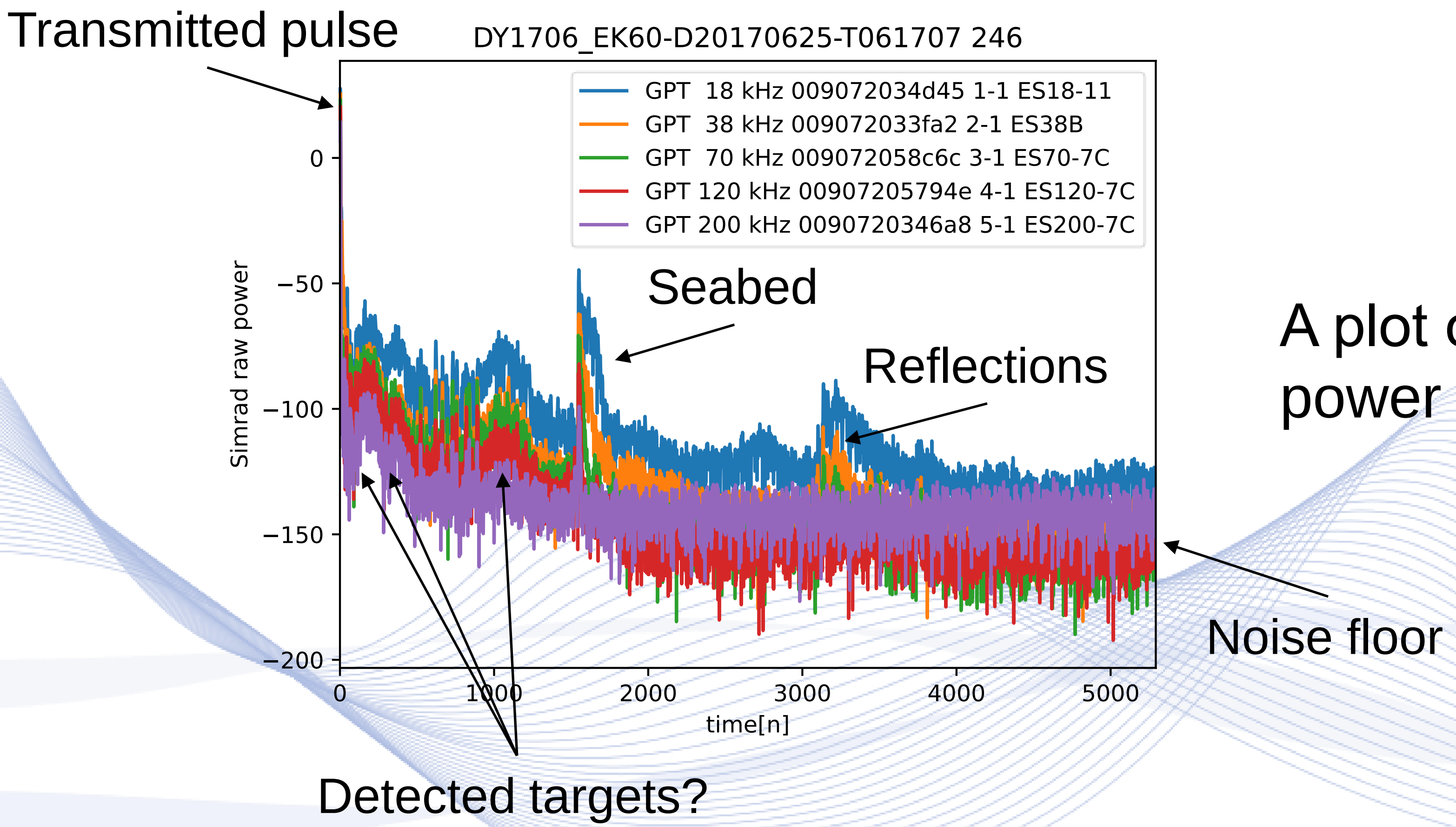


Echograms - DY1706



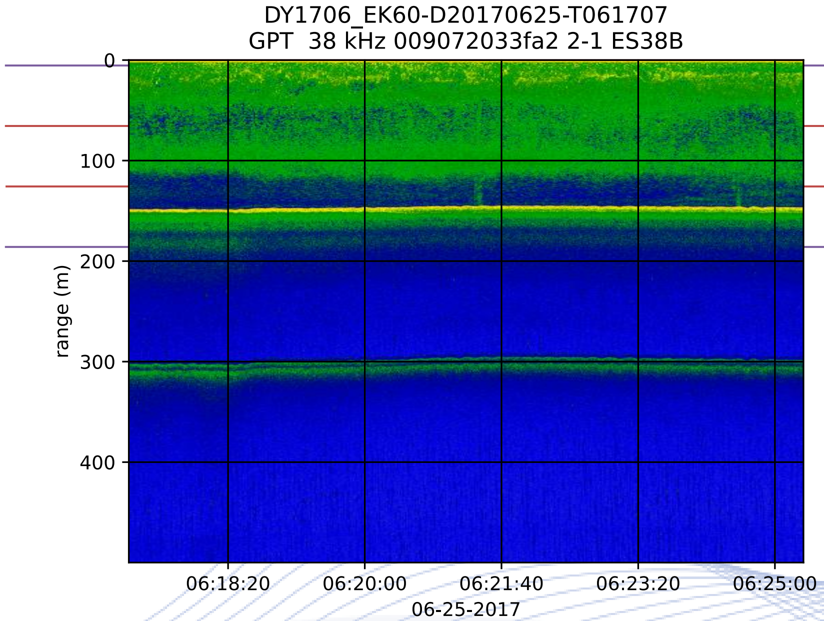
DY1706[13] was a survey of fisheries around the Gulf of Alaska. Primary data collection was performed using a Simrad EK60 split-beam echosounder utilizing 18, 38, 70, 120, and 200 kHz beams.

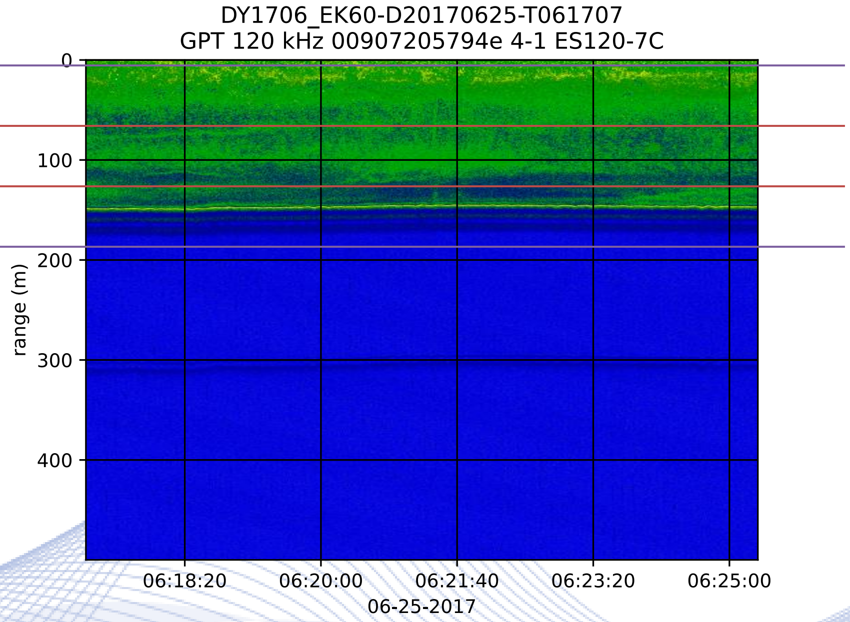
Echograms - DY1706



A plot of a single ping's raw power measurements.

Echograms - DY1706





Echograms of processed power data. 3 distinct areas with detections can be seen, but no further information can be derived from this stage.

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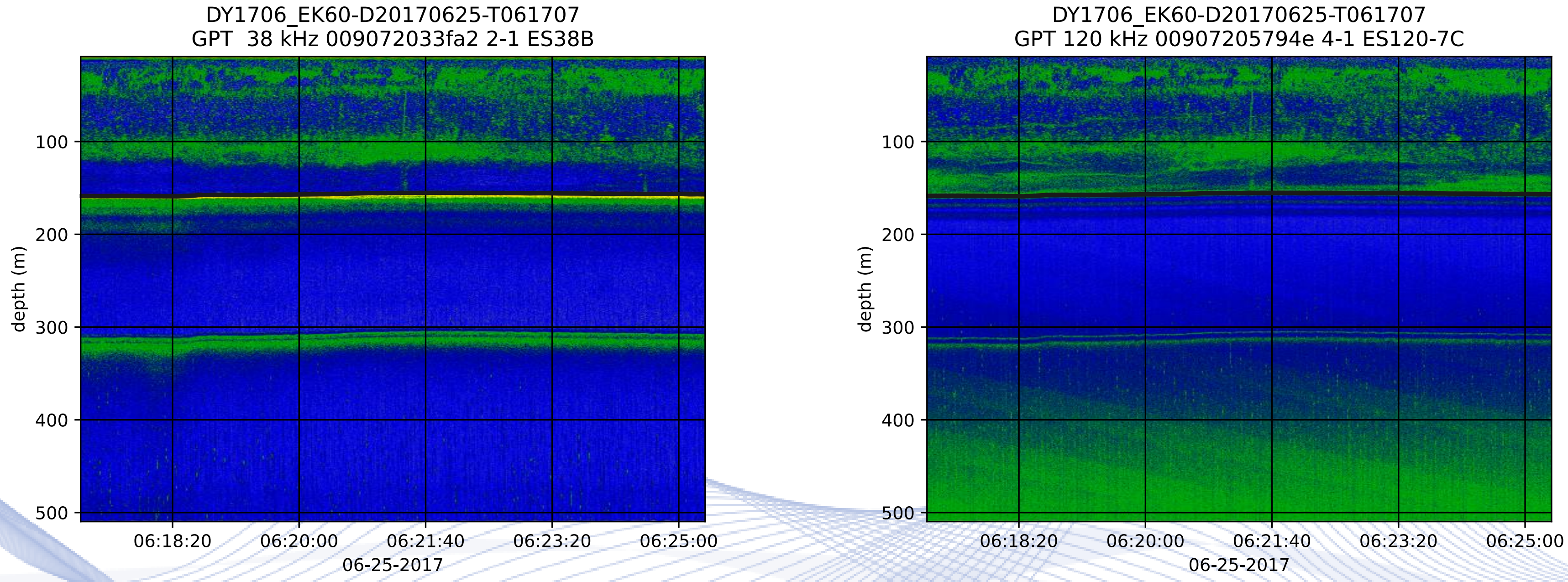
Bottom Detection



The seabed has a much higher reflection coefficient than other common targets. Therefore, the most common bottom detection method is amplitude-based detection applied on S_v data[14].

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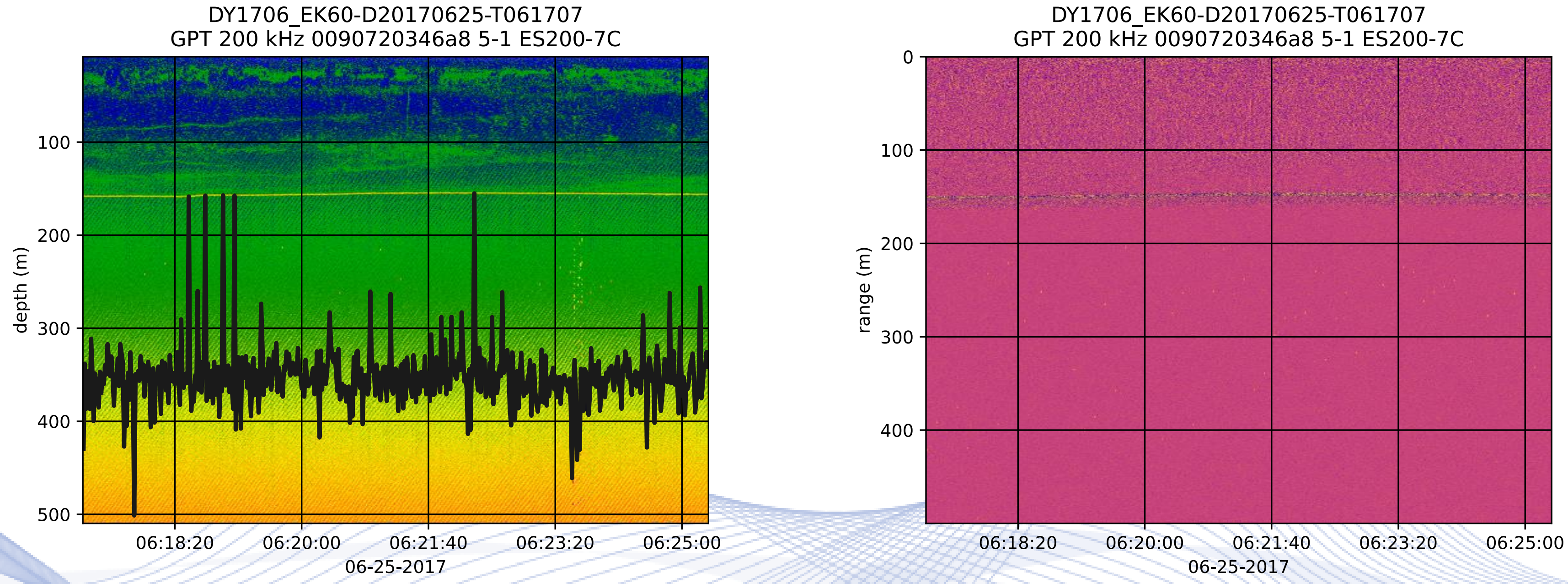
Bottom Detection

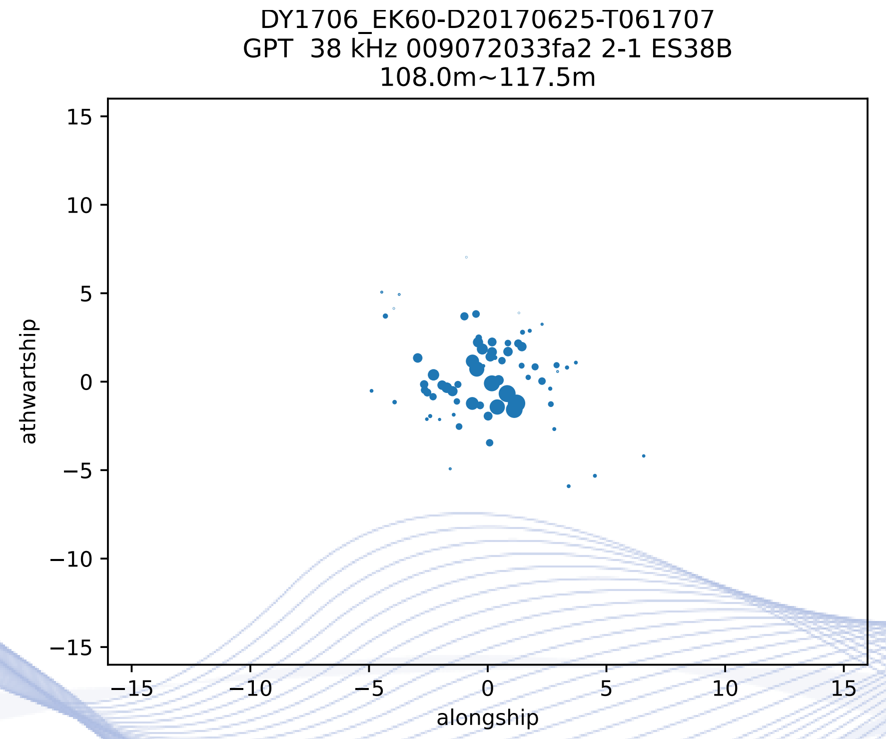


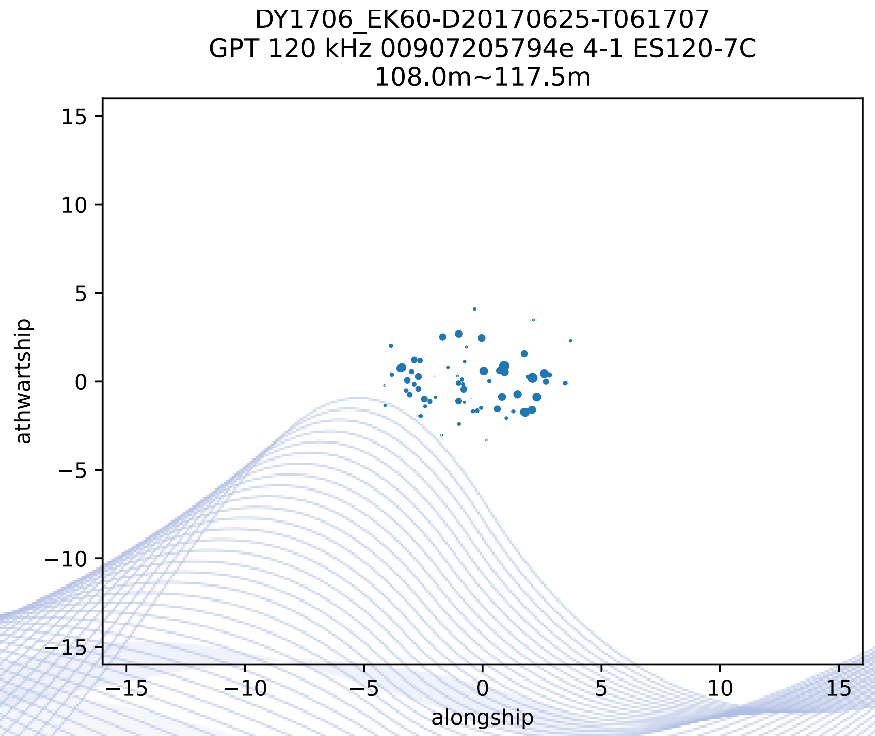
Example of erroneous amplitude-based bottom detection on noisy data. In these cases, a statistical framework can be used that also takes account the spatial continuity in alongship and athwartship directions[14].

3D Mapping

Split-beam sonar data can be directly visualized as cloud point data. Points are selected based on a TS threshold, x, y position is the angle and the z axis is the depth.

3D Mapping





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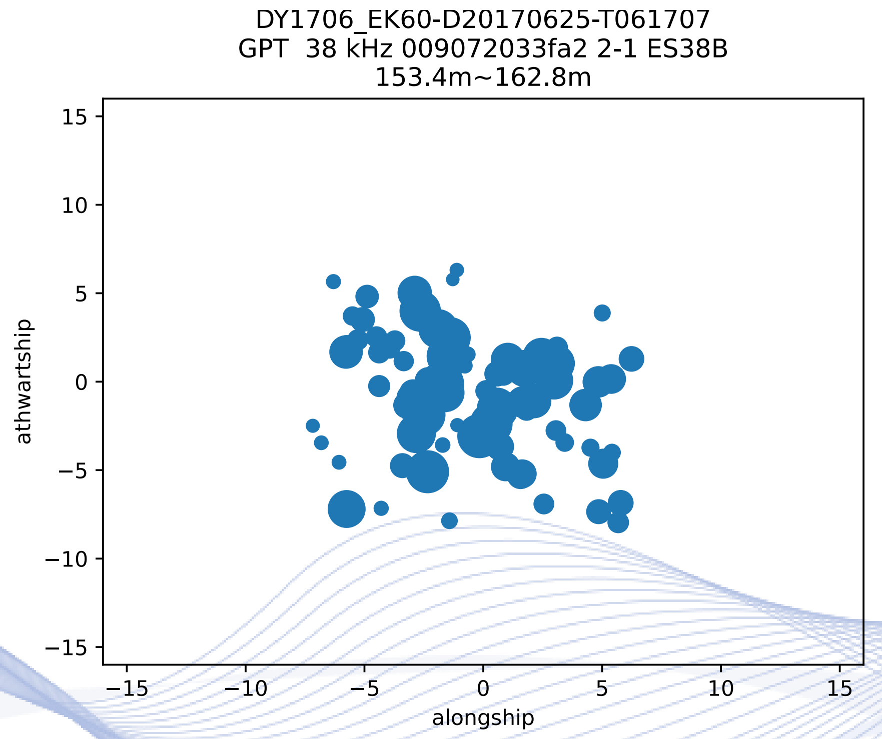
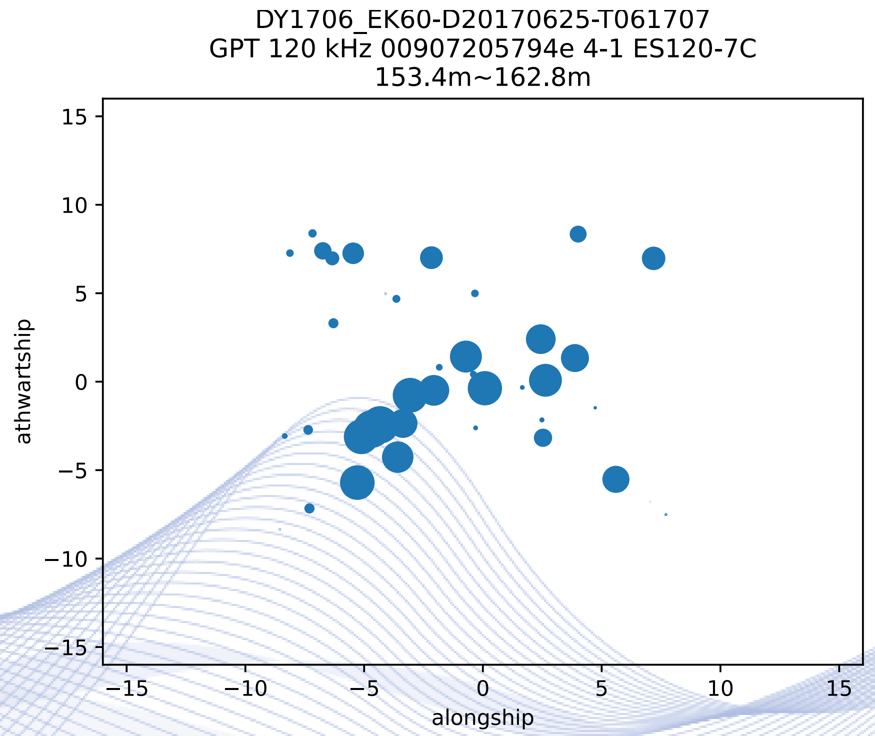
3D Mapping





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Further works

More advanced works combine multiple pings of a split beam system to reconstruct the sampled 3D environment[15] or to solve the bundle adjustment problem in AUVs[16].

Neural networks used in image segmentation can also be used for classification of s_v sonar images where the number of input channels equals the number of frequencies[17].

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Bibliography

1. Kenneth V., Mackenzie (1981). ”Discussion of sea-water sound-speed determinations”. Journal of the Acoustical Society of America. 70 (3): 801–806.
2. Rudstam L, Sullivan P. [Internet]. Acoustics Unpacked. New York Sea Grant; [cited 2021Feb6]. Available from: https://web.archive.org/web/20210415021231/http://www.acousticsunpacked.org/
3. Kongsberg. [Instruction manual]. EM Series Multibeam echo sounders Datagram formats.
4. Jech JM, Michaels WL. A multifrequency method to classify and evaluate fisheries acoustics data. Canadian Journal of Fisheries and Aquatic Sciences. 2006;63(10):2225–35.

Bibliography

6. Kongsberg. [Instruction manual]. Reference manual, Simrad EK60, Scientific echo sounder.
7. Johannesson, K. A., & Mitson, R. B. (1983). Fisheries acoustics. A practical manual for aquatic biomass estimation. Fao ftsh. Tech. Pap.,(240).
8. Ona E. Acoustic sampling and signal processing near the seabed: the deadzone revisited. ICES Journal of Marine Science. 1996;53(4):677–90.
9. Foote KG. Fish target strengths for use in echo integrator surveys. The Journal of the Acoustical Society of America. 1987;82(3):981–7.
10. De Robertis A, Higginbottom I. A post-processing technique to estimate the signal-to-noise ratio and remove echosounder background noise. ICES Journal of Marine Science. 2007;64(6):1282–91.
11. Wall CC, Jech JM, McLean SJ. Increasing the accessibility of acoustic data through global access and imagery. ICES Journal of Marine Science. 2016;73(8):2093–103.

Bibliography

12. Maclennan D. A consistent approach to definitions and symbols in fisheries acoustics. ICES Journal of Marine Science. 2002;59(2):365–9.
13. Alaska Fisheries Science Center. 2017. 'EK60 Water Column Sonar Data Collected During DY1706'. NOAA National Centers for Environmental Information. doi:10.7289/V5H1308T April 2021
14. Bourguignon S, Berger L, Scalabrin C, Fablet R, Mazauric V. Methodological developments for improved bottom detection with the ME70 multibeam echosounder. ICES Journal of Marine Science. 2009;66(6):1015–22.
15. Guerneve T, Subr K, Petillot Y. Three-dimensional reconstruction of underwater objects using wide-aperture imaging SONAR. Journal of Field Robotics. 2018;35(6):890–905.
16. Huang TA, Kaess M. Towards acoustic structure from motion for imaging sonar. 2015 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). 2015;

Bibliography

17. Brautaset O, Waldeland AU, Johnsen E, Malde K, Eikvil L, Salberg A-B, et al. Acoustic classification in multifrequency echosounder data using deep convolutional neural networks. ICES Journal of Marine Science. 2020;77(4):1391–400.

Bibliography

[PIT2021] I. Pitas, “Computer vision”, Createspace/Amazon, in press.

[PIT2017] I. Pitas, “Digital video processing and analysis” , China Machine Press, 2017 (in Chinese).

[PIT2013] I. Pitas, “Digital Video and Television” , Createspace/Amazon, 2013.

[NIK2000] N. Nikolaidis and I. Pitas, “3D Image Processing Algorithms”, J. Wiley, 2000.

[PIT2000] I. Pitas, “Digital Image Processing Algorithms and Applications”, J. Wiley, 2000.

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