Exploring the Oceans – Science for a Better World

Using Physics and Mathematics in the Seven Seas

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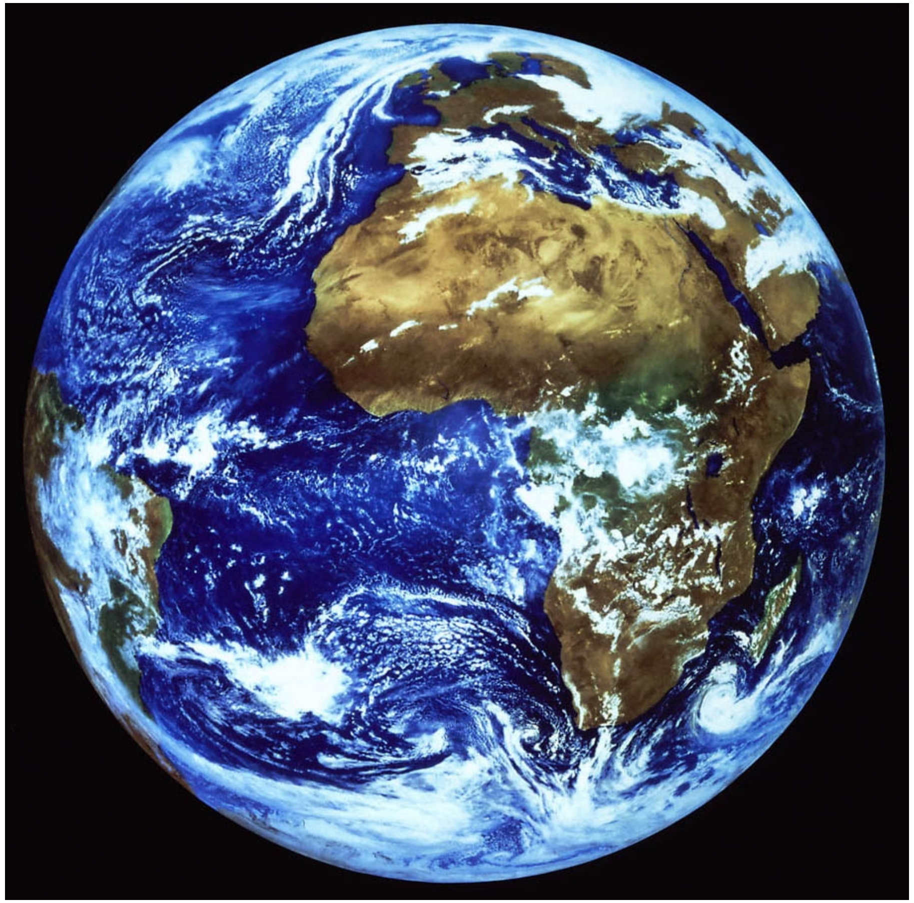
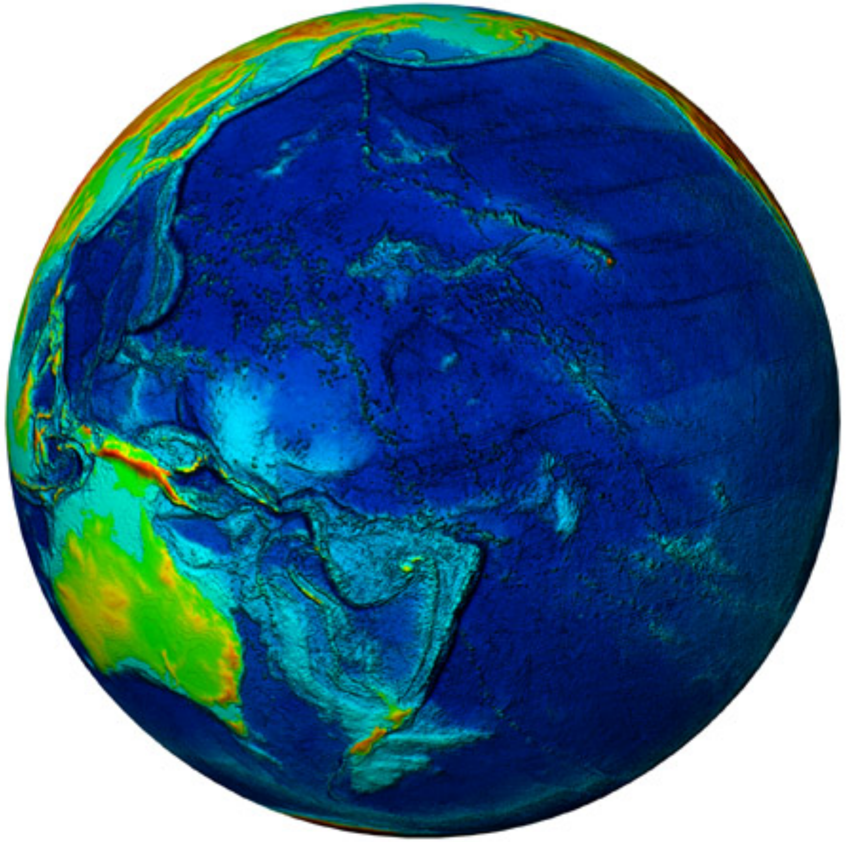
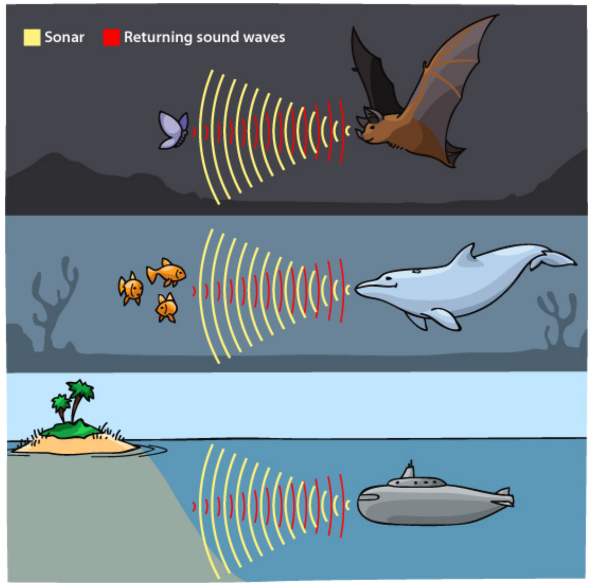
The *Blue Planet*



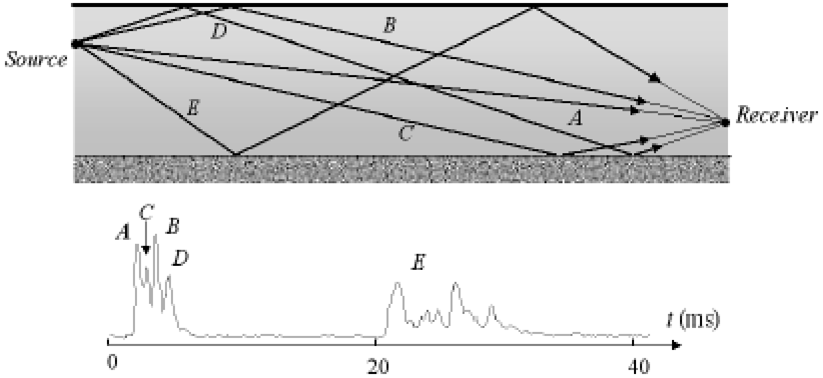


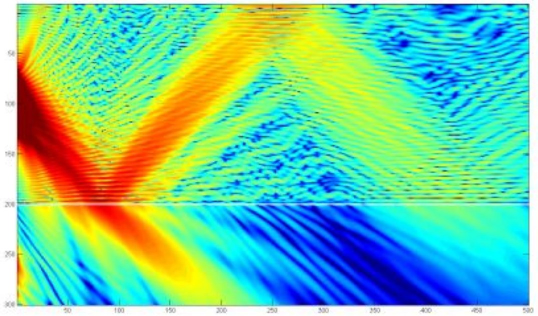
But what lies beneath the sea?

Underwater acoustics



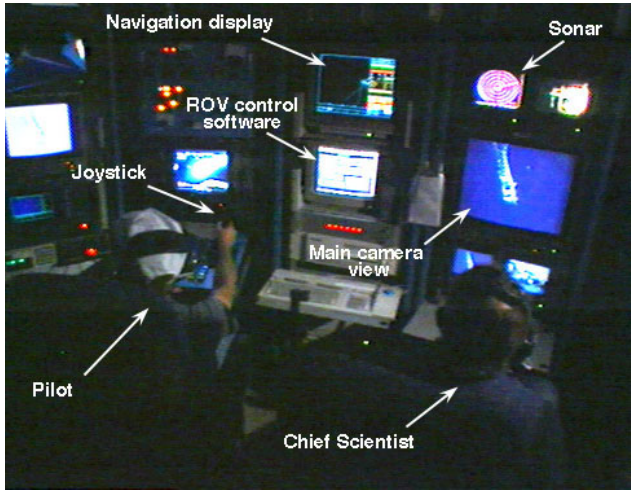
Listening for "echoes" – Not always easy (extra reflections, "dead" zones)





Underwater acousticians

Long “cruises”
Exotic locations
Deck activities

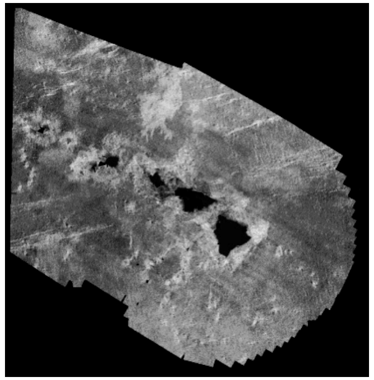


Active acoustics

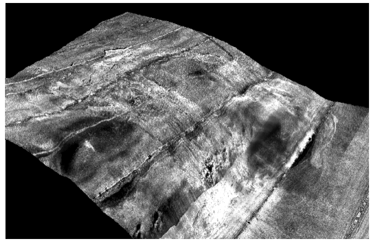
Passive acoustics

High frequencies (> kHz):
Smaller wavelengths
Higher transmission losses
But higher resolutions

1980's
6.5 kHz
60-m resolution

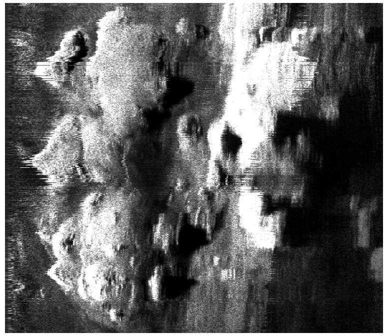


early 1990's
30 kHz
6-m resolution



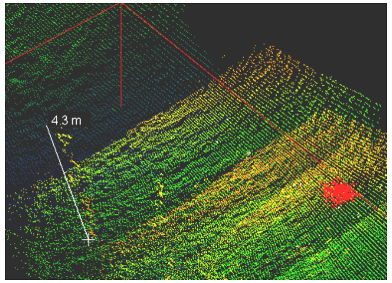
Oceans complex and noisy
Sound speeds vary with depth and time
Seabeds extremely complex
Surface <u>and volume</u> scattering

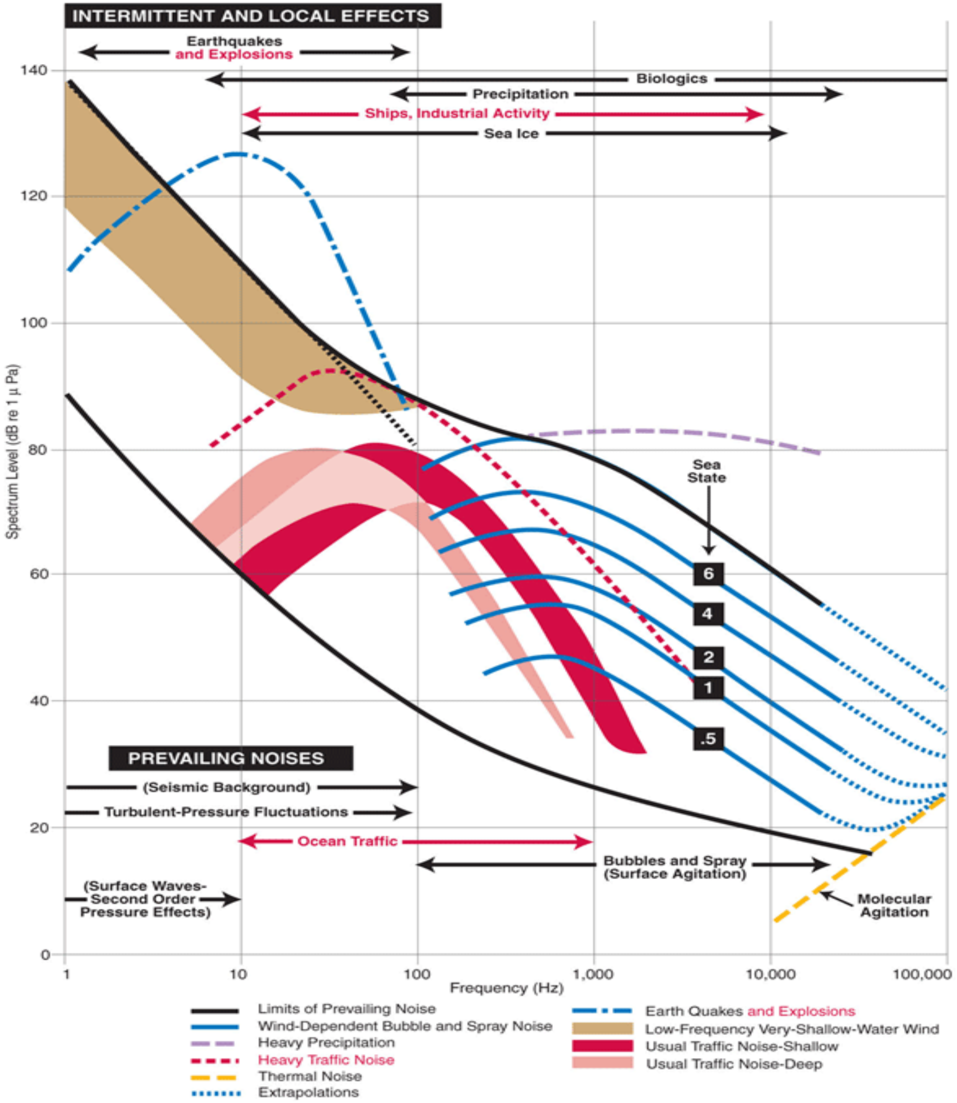
mid-1990's
120 kHz
60-cm resolution



Examples:
- Marine Renewable Energy
- Deep-sea observatories
- Polar glaciers
- Seismic mitigation

2000's
260 kHz
< 6-cm resolution





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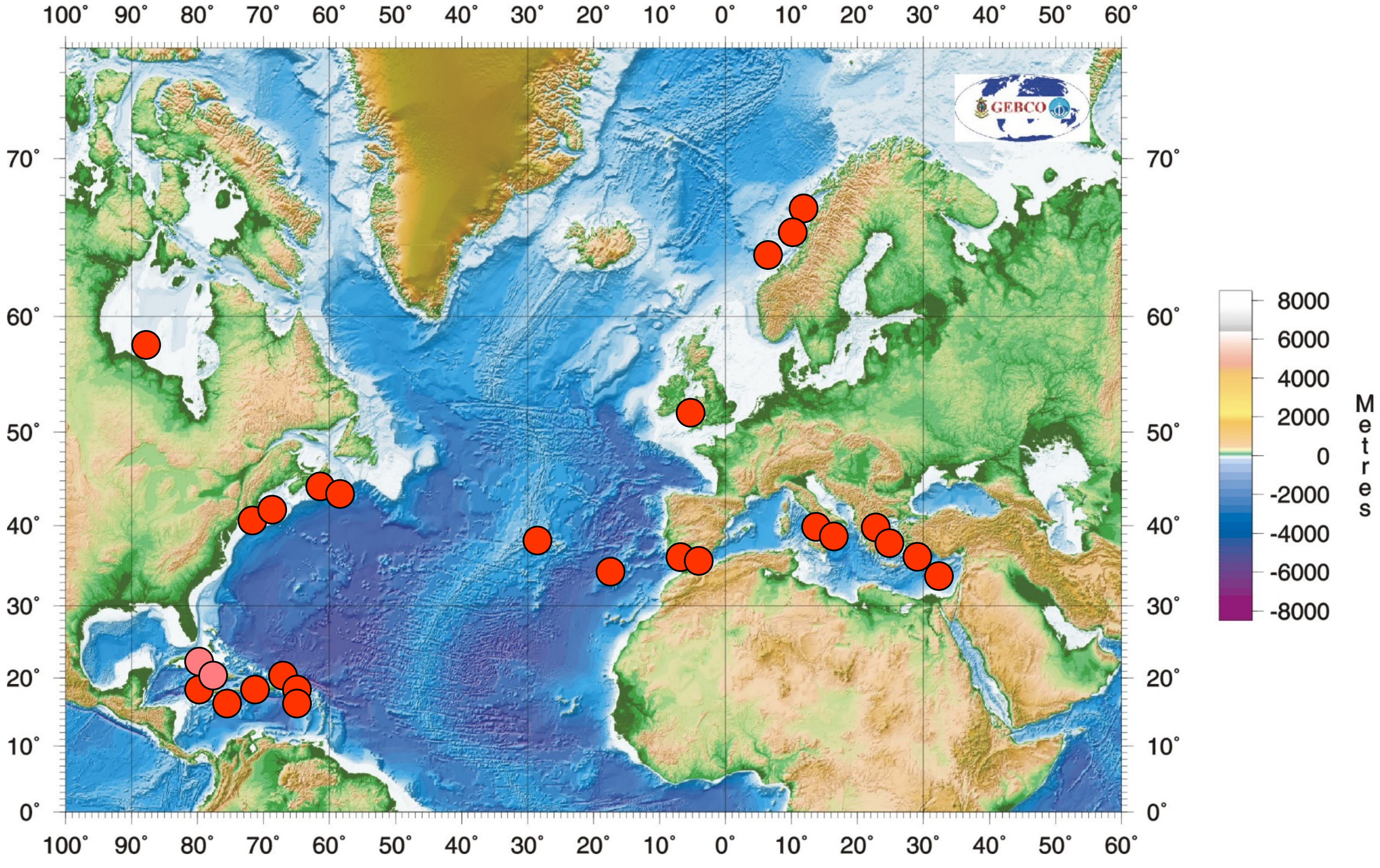
Tsunamis around Europe



Recorded tsunamis in recent times (1606-2006)

Azores (1850): 10-m high tsunami

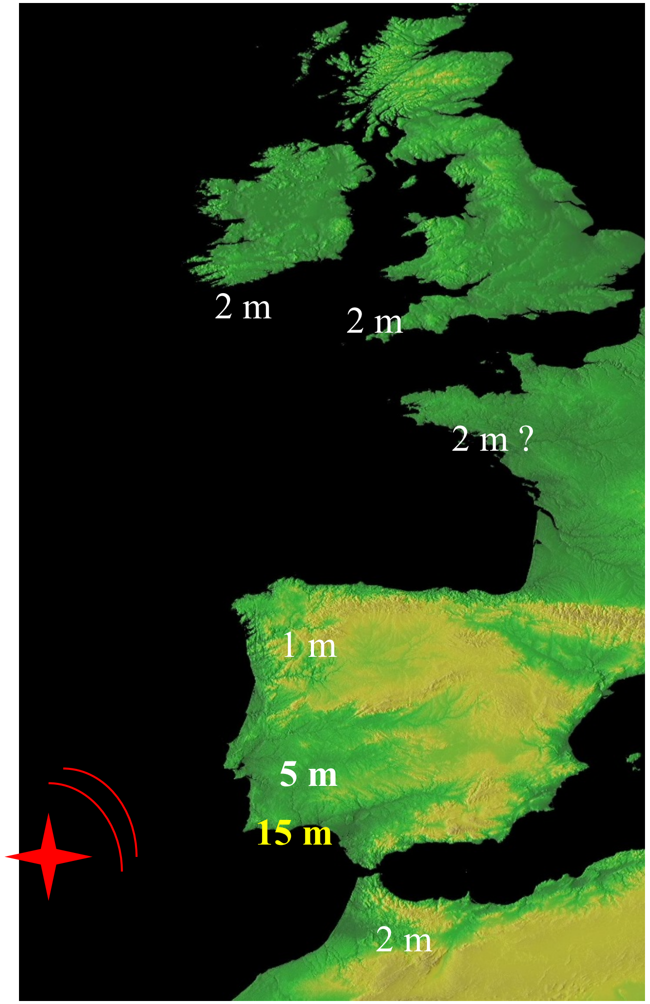
More common than thought

Similar issues all around the world

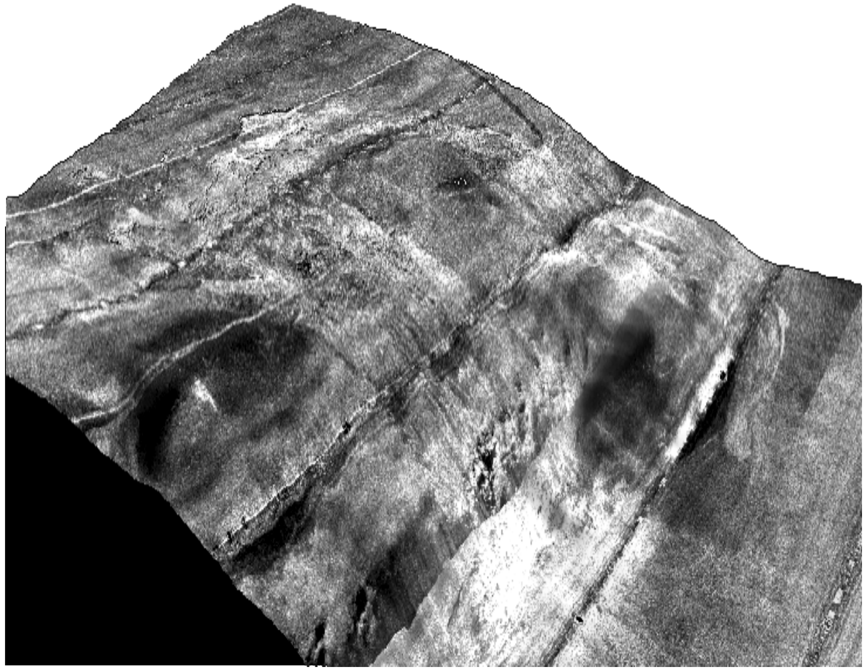
Seabed maps can reveal sources/causes

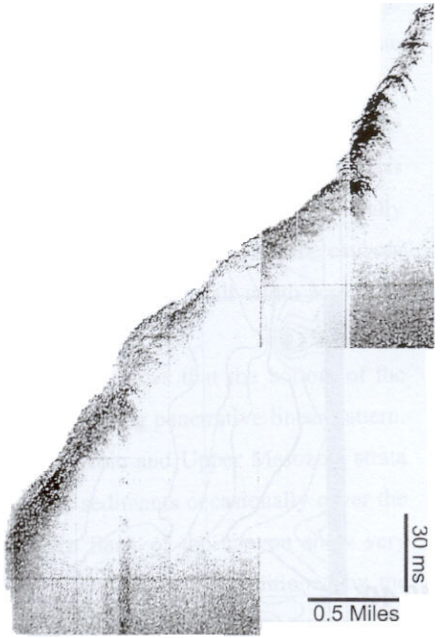
Tsunamis around Europe

Lisbon tsunami (1755)



Felt all over western Europe
Good measurements



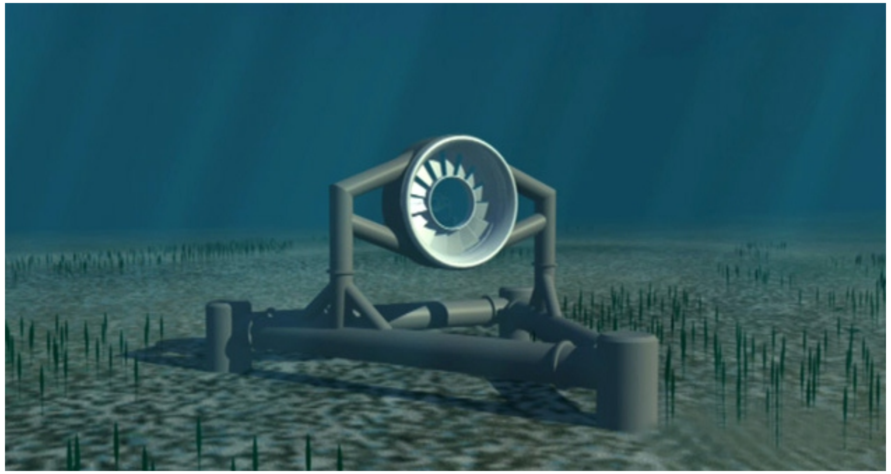


Sonar mapping reveals:

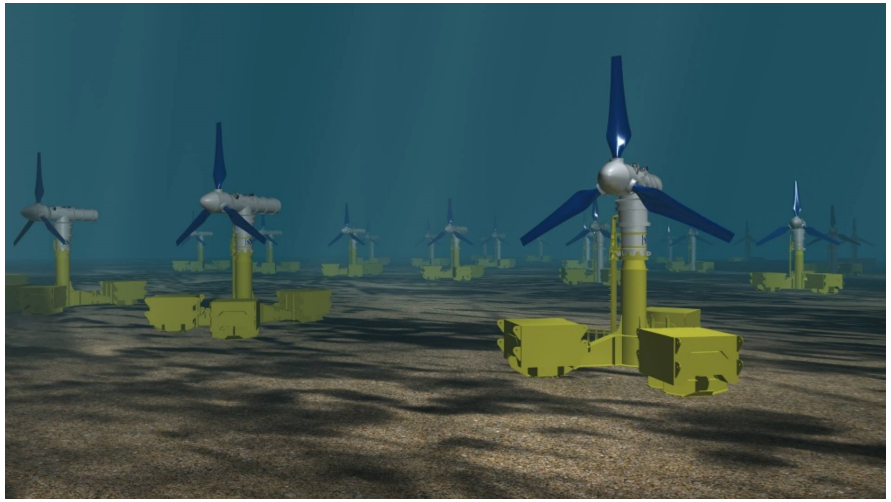
- Large landslide(s), over area 20 km x 13 km
- Very steep slopes (~ 1:20)
- Evidence of past landslides at relatively regular intervals

Identification of geo-hazard area(s).

Marine Renewable Energy



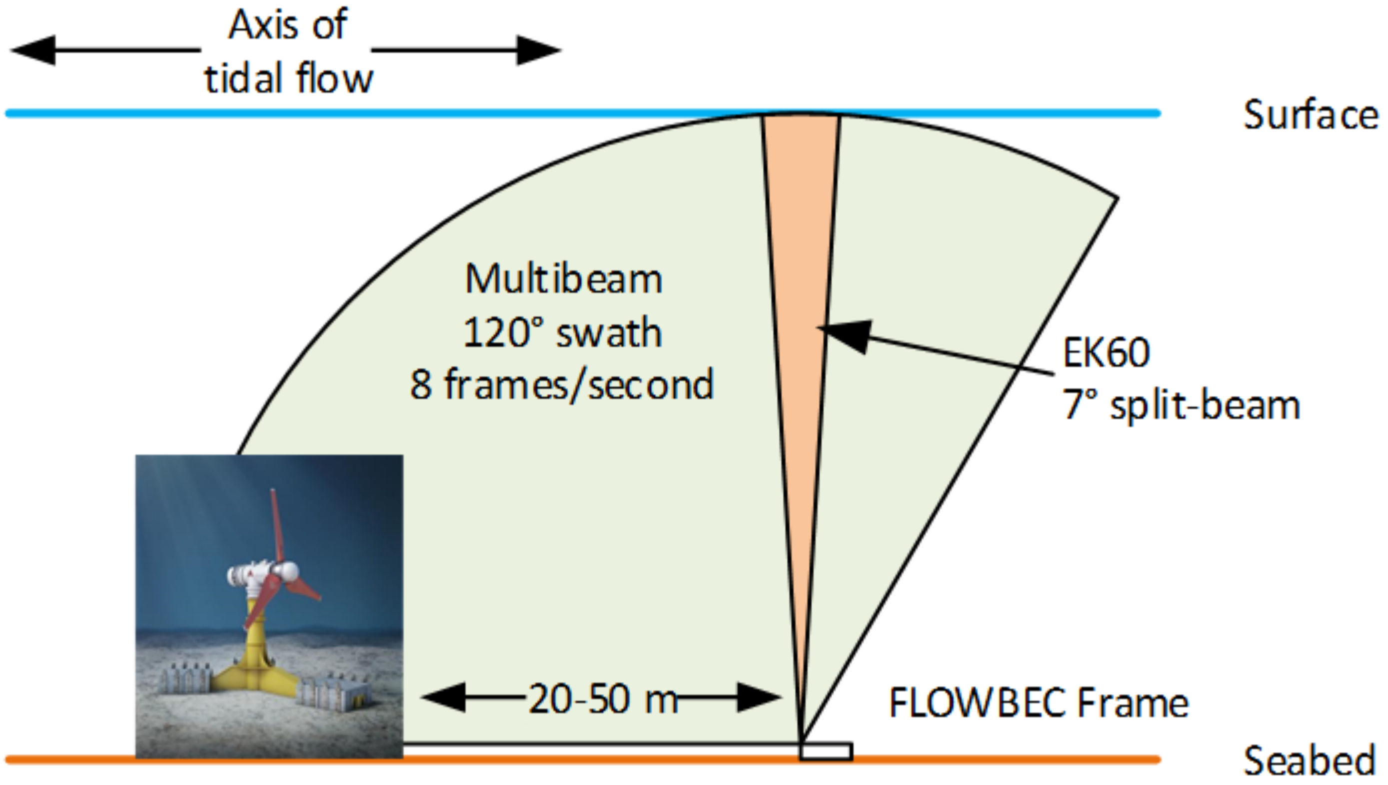
Tidal turbines
+
Wave Energy Converters
=
green energy?



Effects of large arrays?

Field measurements
Orkney (EMEC)
Falmouth Bay (FabTest)
Pentland Firth

FLOWBEC-4D platform



Multibeam (260 kHz):
- Target velocity, behaviour
- School morphology
- Predator-prey interaction
- Turbine encounter e.g. evasion

Co-registered targets
Information combined

EK60 (38, 120, 200 kHz):
- Higher sensitivity
- Calibrated multi-frequency ID
- Quantitative abundance
- Turbulence morphology

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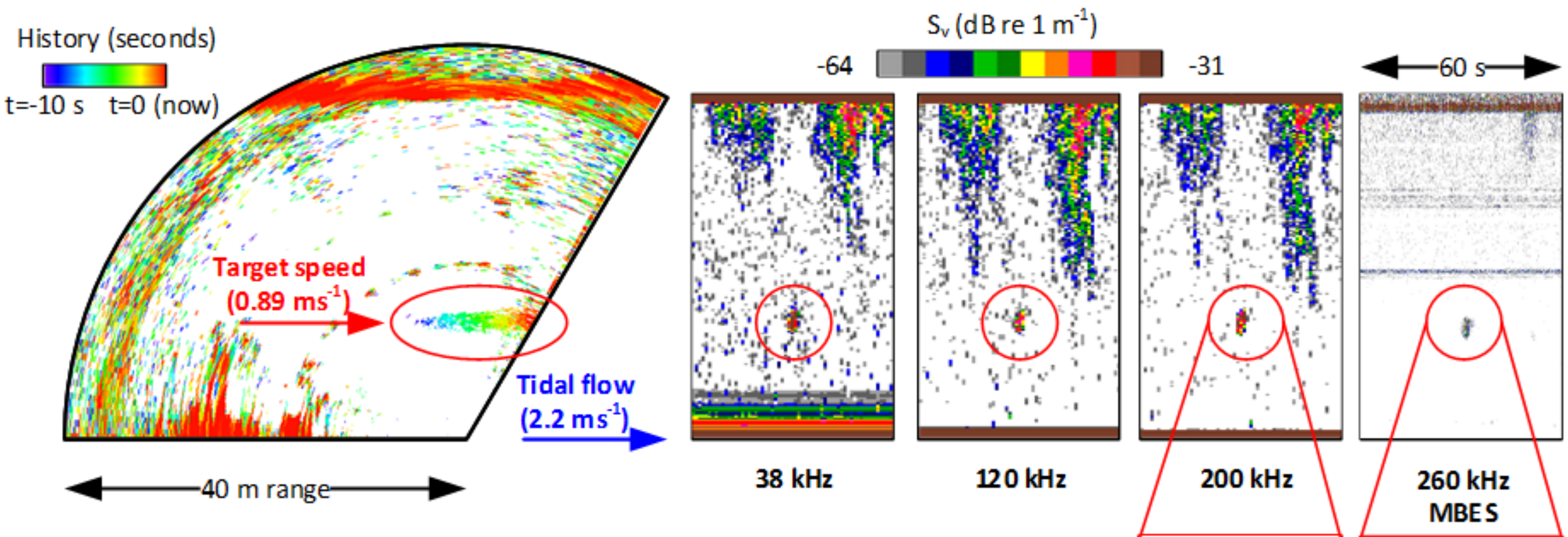
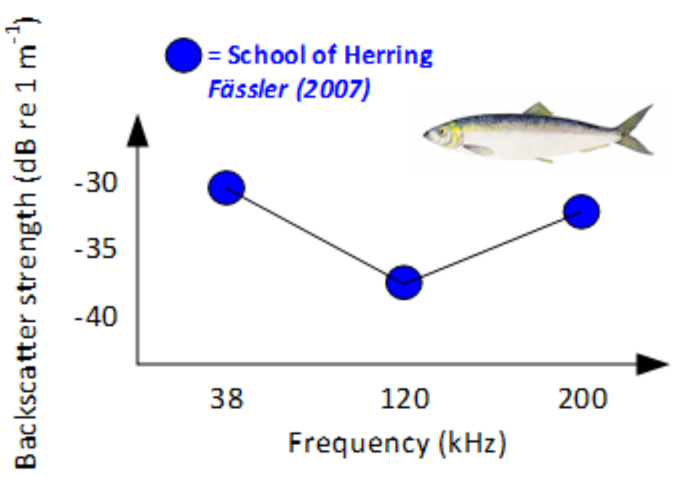
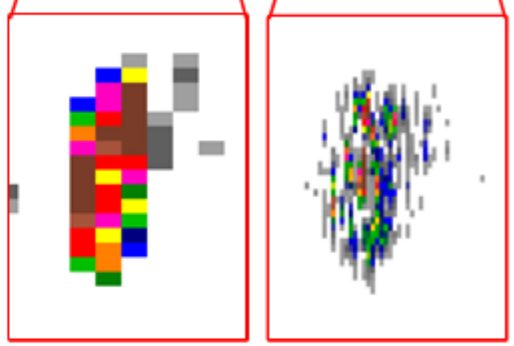
Combined acoustics







Adaptive processing of EK60 data
Target tracking in multibeam scans

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From acoustics to ecosystem effects

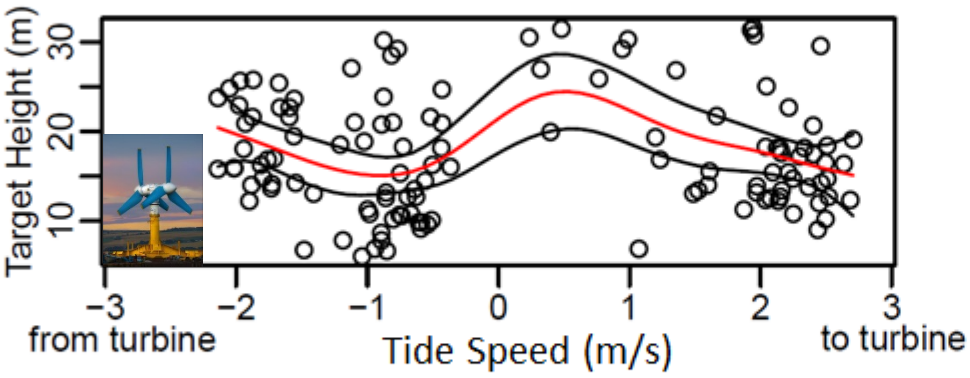
How do hydrodynamics affect animal behaviour in MRE sites?

- Current, waves, turbulent features aggregate / disorientate prey

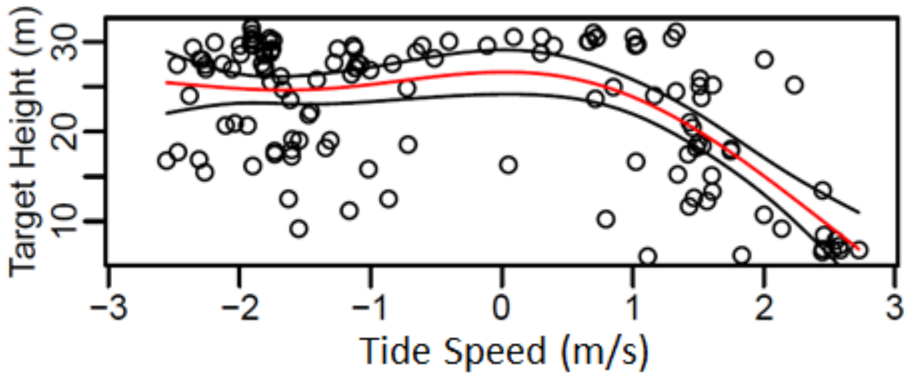
How do MREDs alter the behaviour of animals?

- Foraging efficiency drives population dynamics
- Depth/flow preferences and prey distribution determine collision risk

Turbine Structure



Control Site (no turbine)



- Fish school vertical distribution related to **tidal phase**
- Change in **behaviour in wake of turbine structure**

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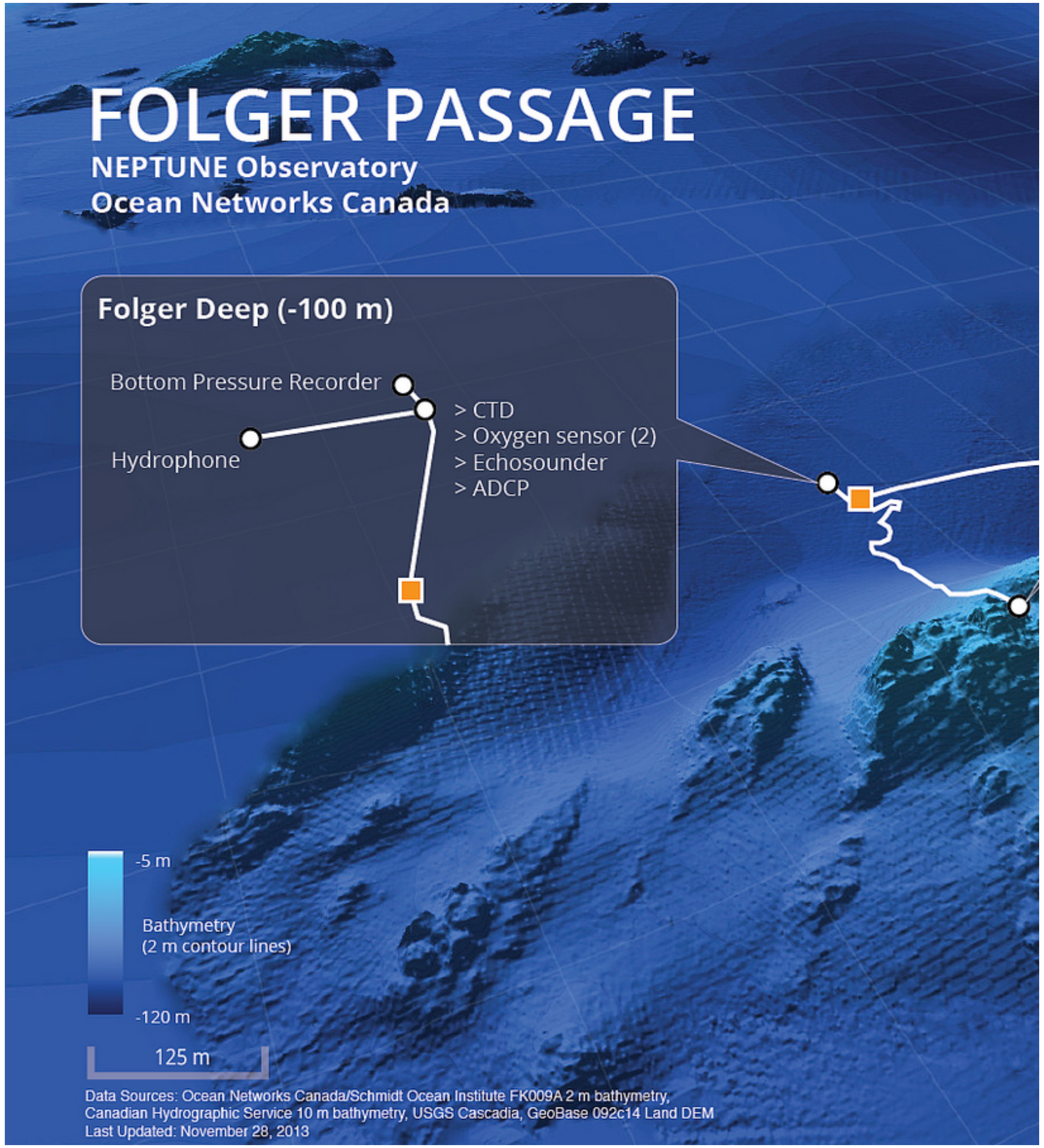
Deep-sea observatories



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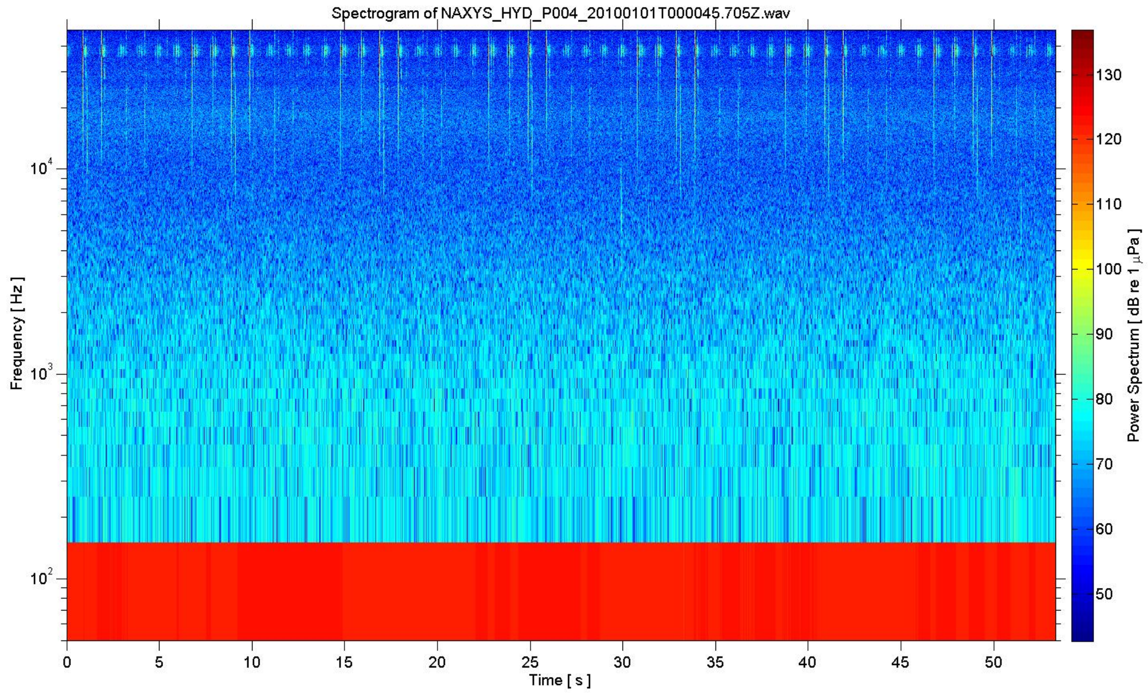
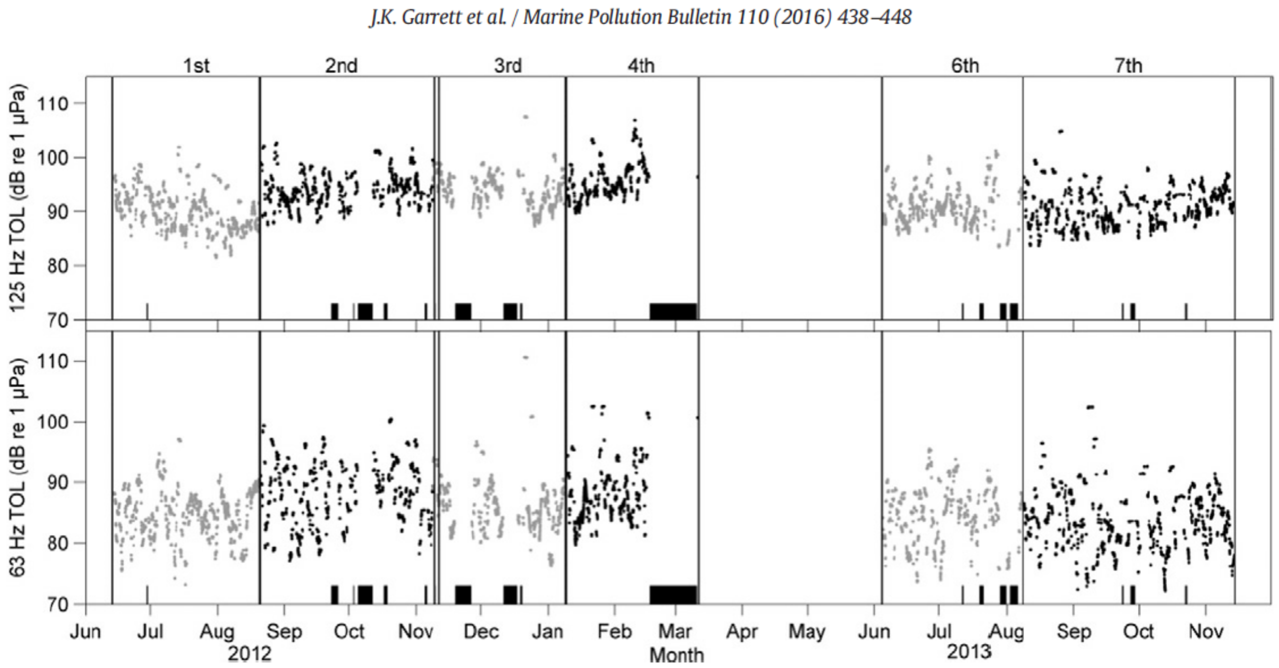
Long-term datasets





Very large datasets (typically 96 kS/s for years of measurements)

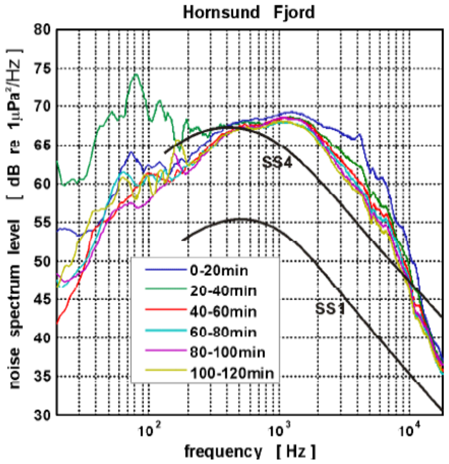
Drinking from the firehose

Processing costs very high (storage + time)

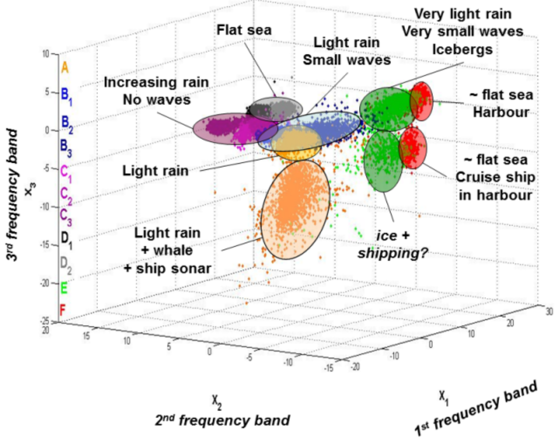
Where is the interesting data? What does it mean?

Human impacts - Biodiversity

The sound of climate change?



Tegowski et al,, 2011, Blondel et al., 2012

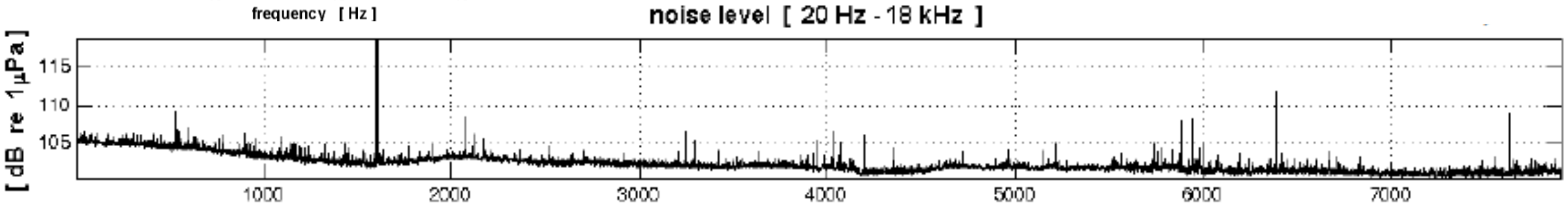


Keogh and Blondel, 2008

Arctic ice melting

Field surveys: 2007
2009
2013
2014

Experiments: 2008
2012



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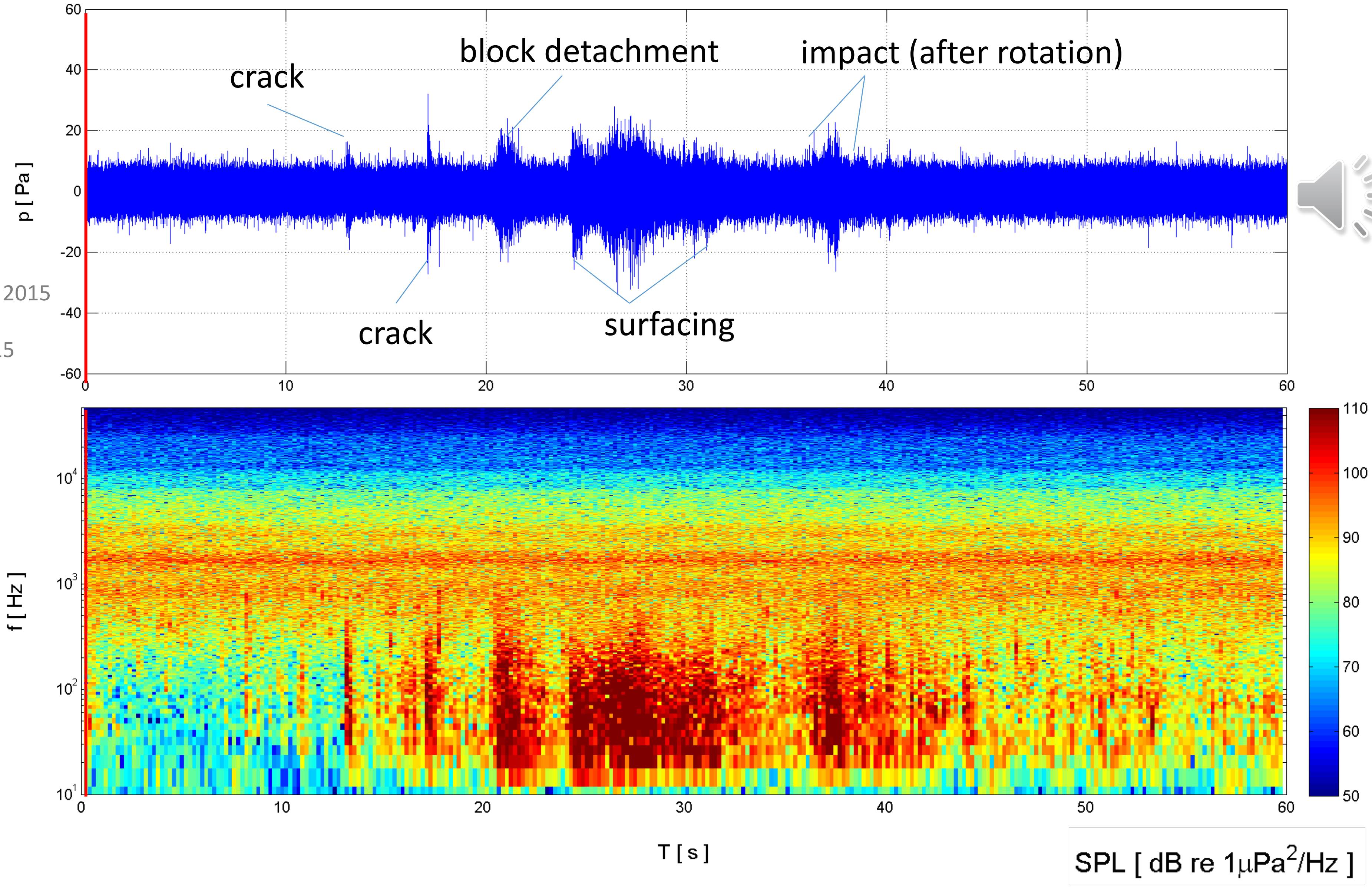
Glacier calving

Glacier calving – Acoustics



Glowacki et al., JASA-EL, 2015

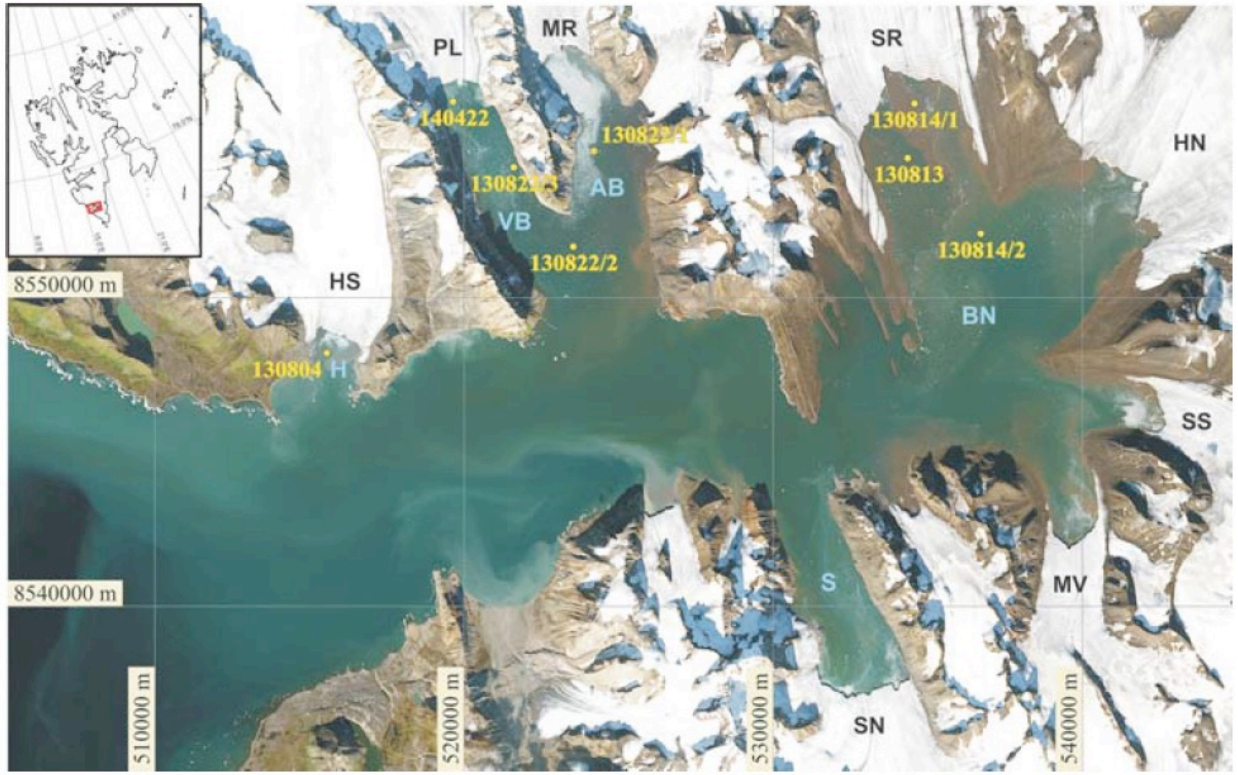
Glowacki et al., GRL, 2015

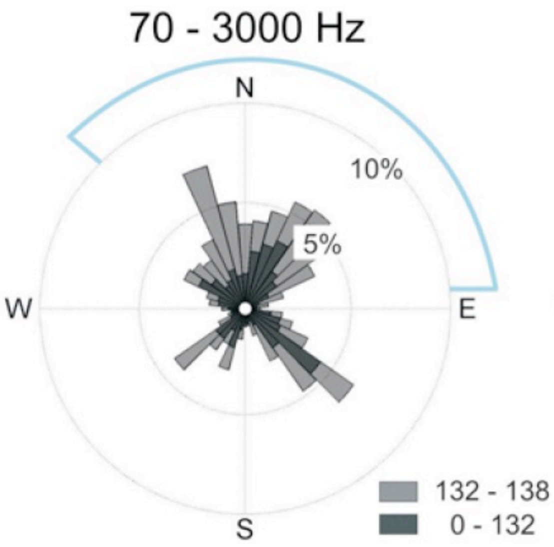
Used to identify noise sources (levels, locations)

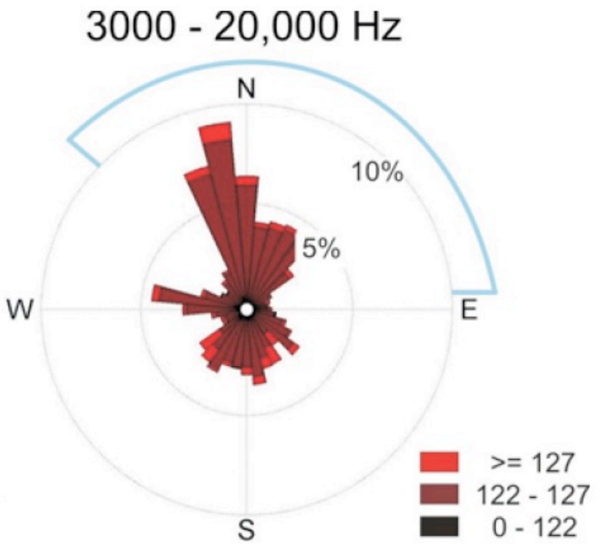
Glacier dynamics

Ice melting

Glacier dynamics







Underwater acoustics gives insights into glacier dynamics and effects of climate change in polar waters

Links with glaciologists and oceanographers

Seismic Mitigation

Knowledge Transfer Partnership with Seiche Ltd.

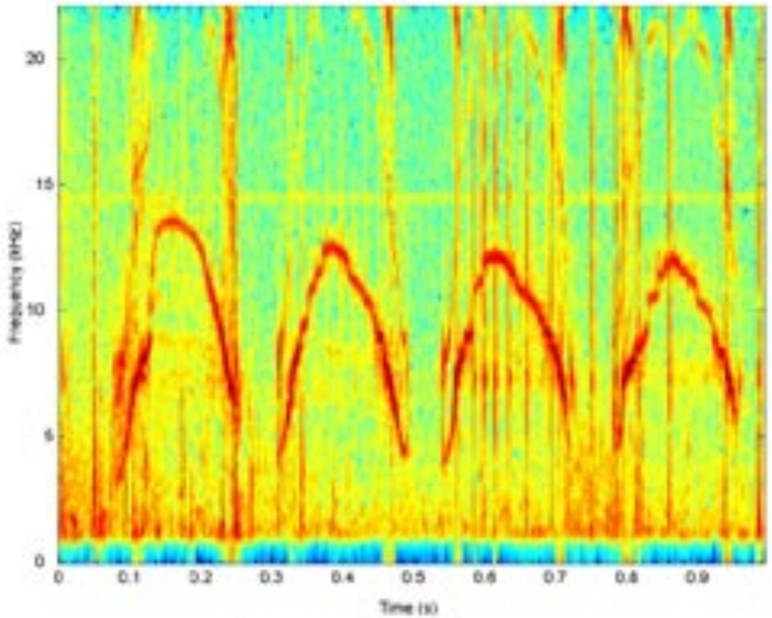
Seismic exploration is very noisy

Visual detection of cetaceans

if they are at the surface

if visibility is good

is used for mitigation



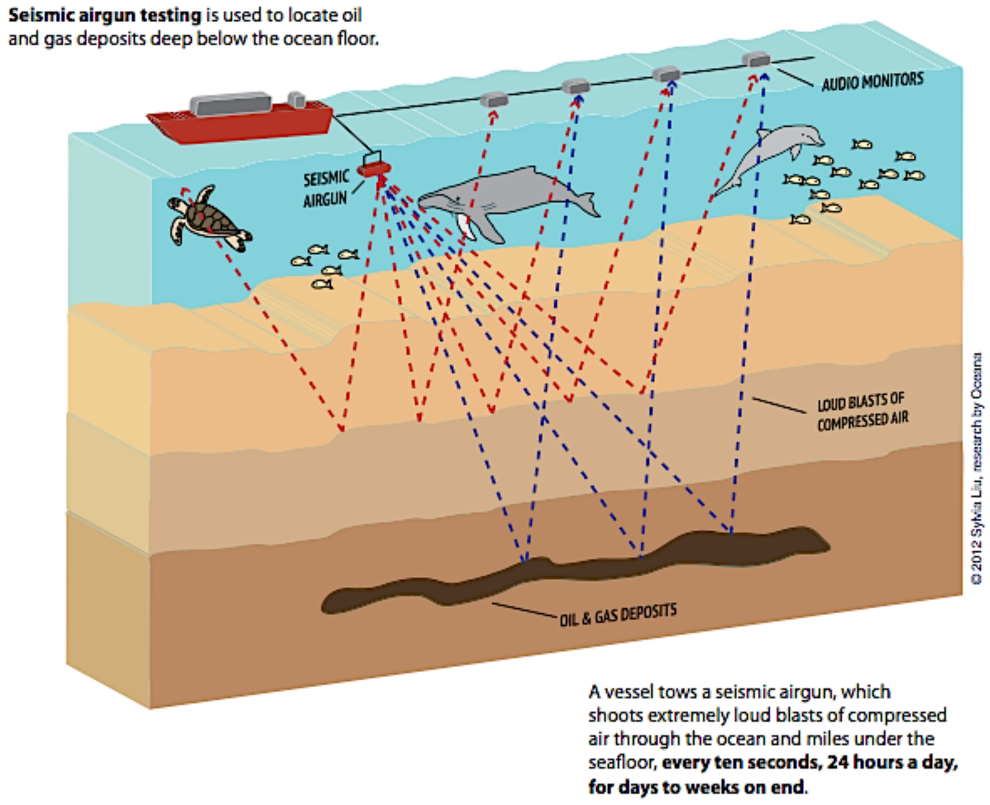
Acoustic detection of cetaceans

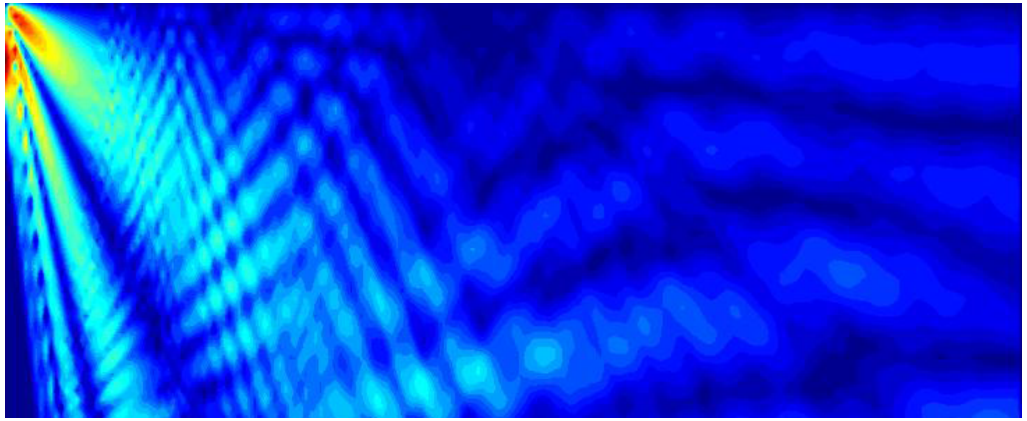
if they are vocalising

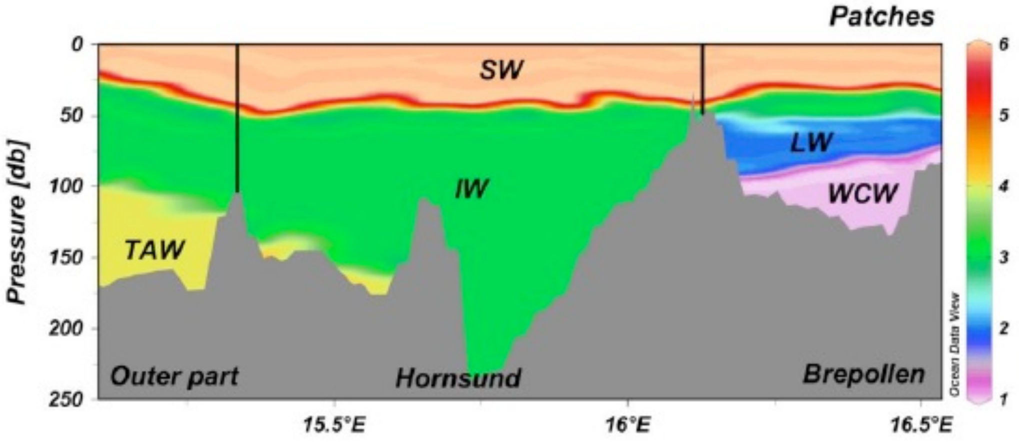
is used to find them

Seismic exploration

Complex and variable environments

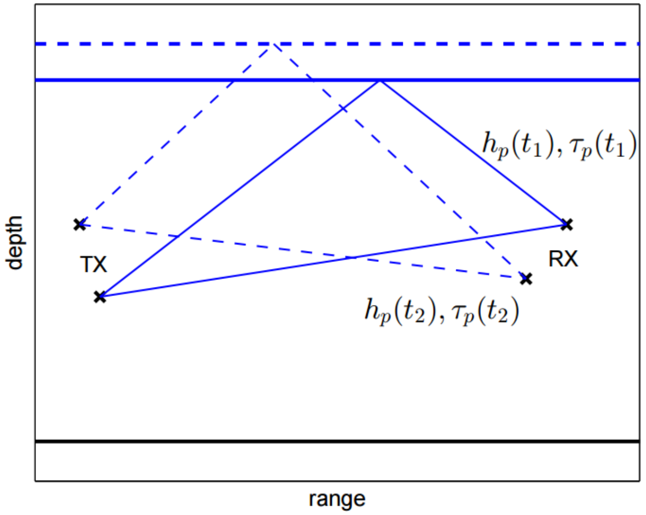


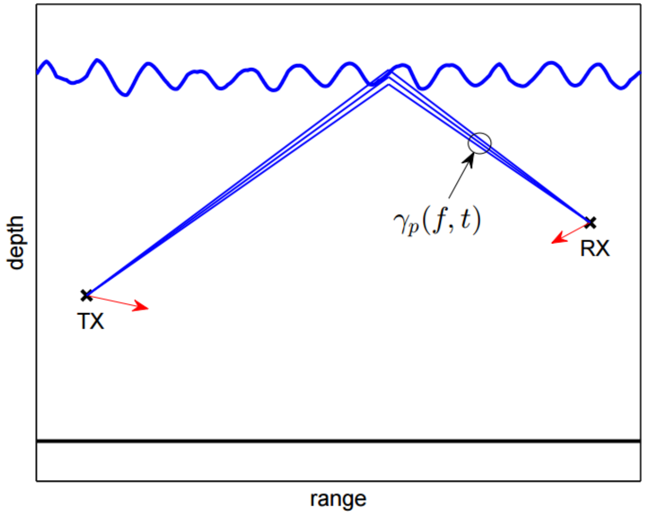




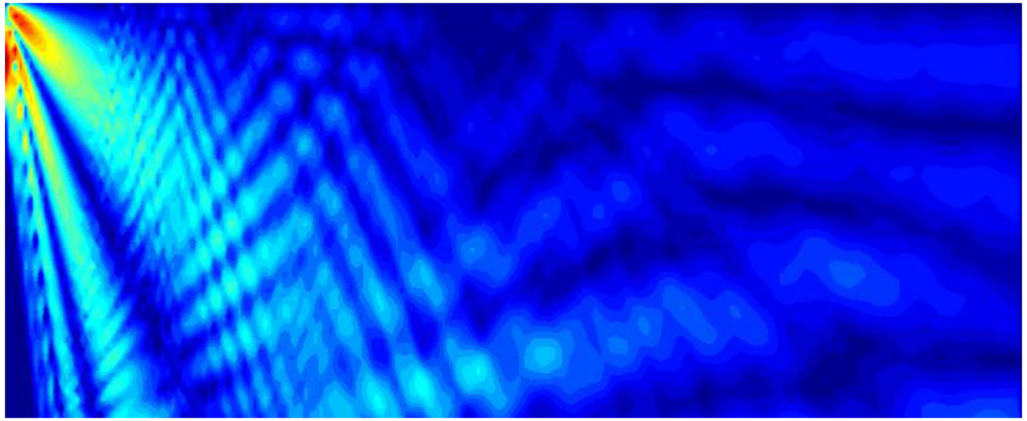
Acoustic propagation

Higher frequencies: geometrical ray-tracing





Lower frequencies: Parabolic Equation / Normal Mode equations



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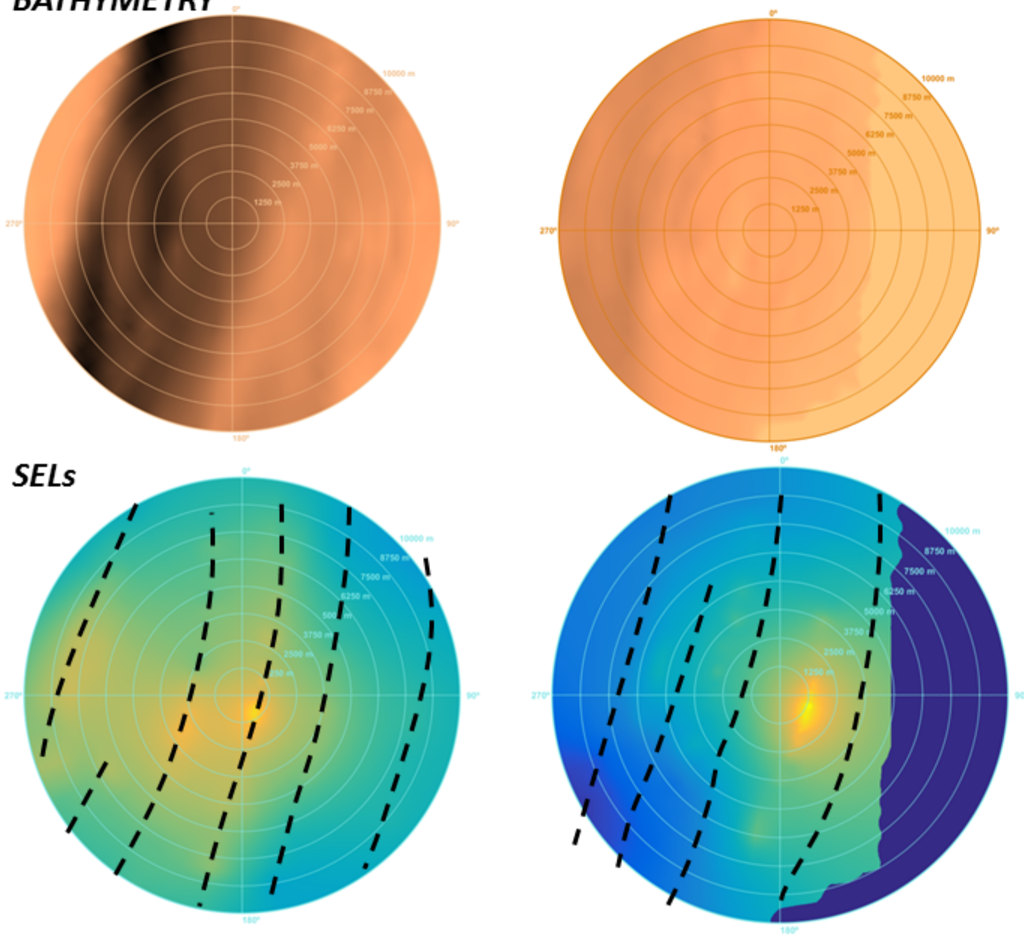
Mitigation ranges

BATHYMETRY

SELs



SHALLOW
(10 – 50 m)

VERY SHALLOW
(2 – 10 m)

Blondel et al., 2016 (in press)

How far does sound propagate?

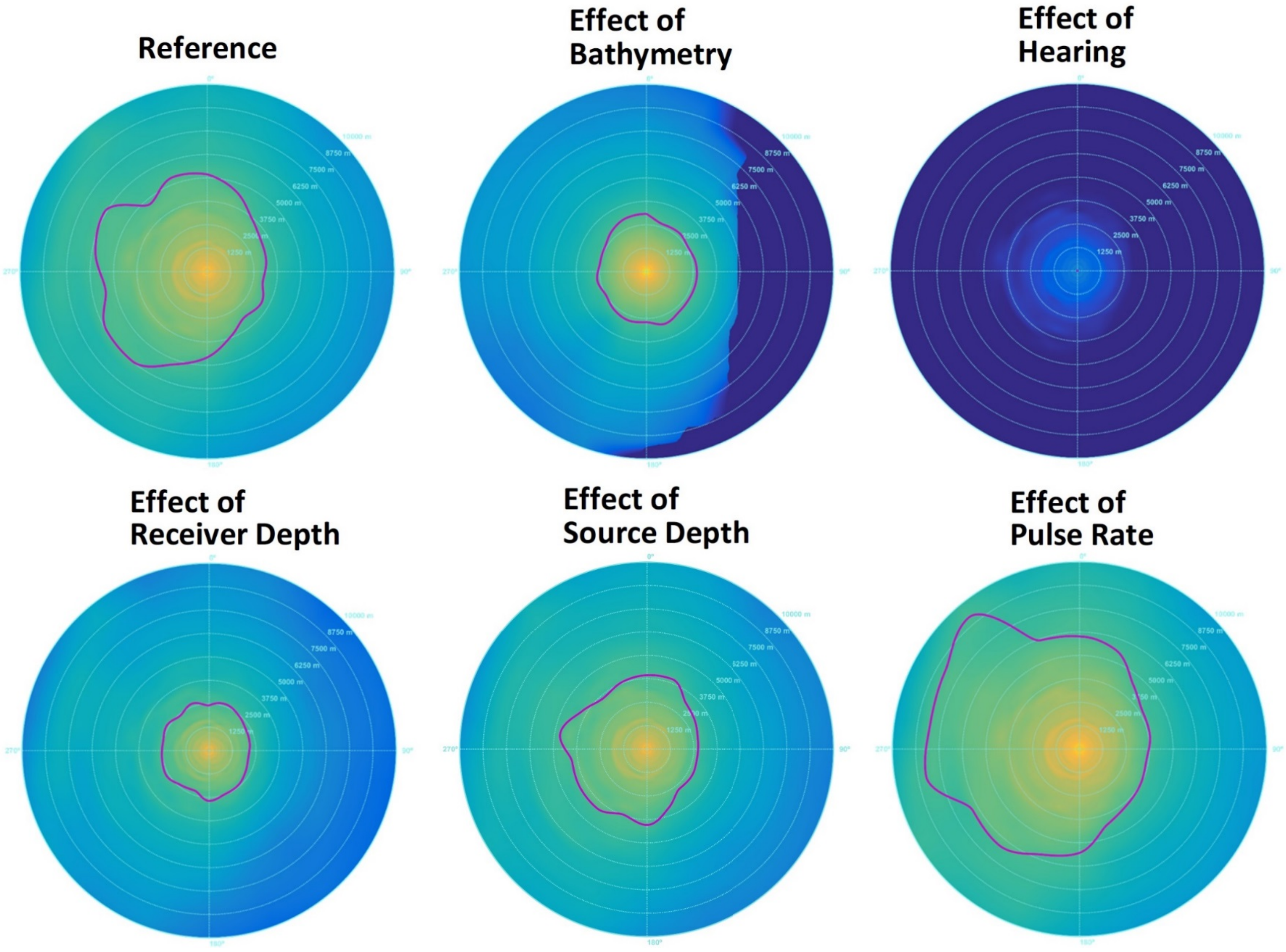
Where does it exceed protection guidelines?

Evidence-base
where can we get the most representative measurements?
(sparse sampling problem)

KTP project with C. Budd (Maths) and Seiche Ltd.
(2014-2017)

Joint PhD studentship (2015-2021)

Mitigation zones



Complex in shallow water

Effects of shores (e.g. freshwater from rivers) and weather (e.g. sun, waves)

Very high variability overall

Blondel et al., 2016

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Seismic mitigation

Can we use seismic sources to detect silent animals?

Looking from above

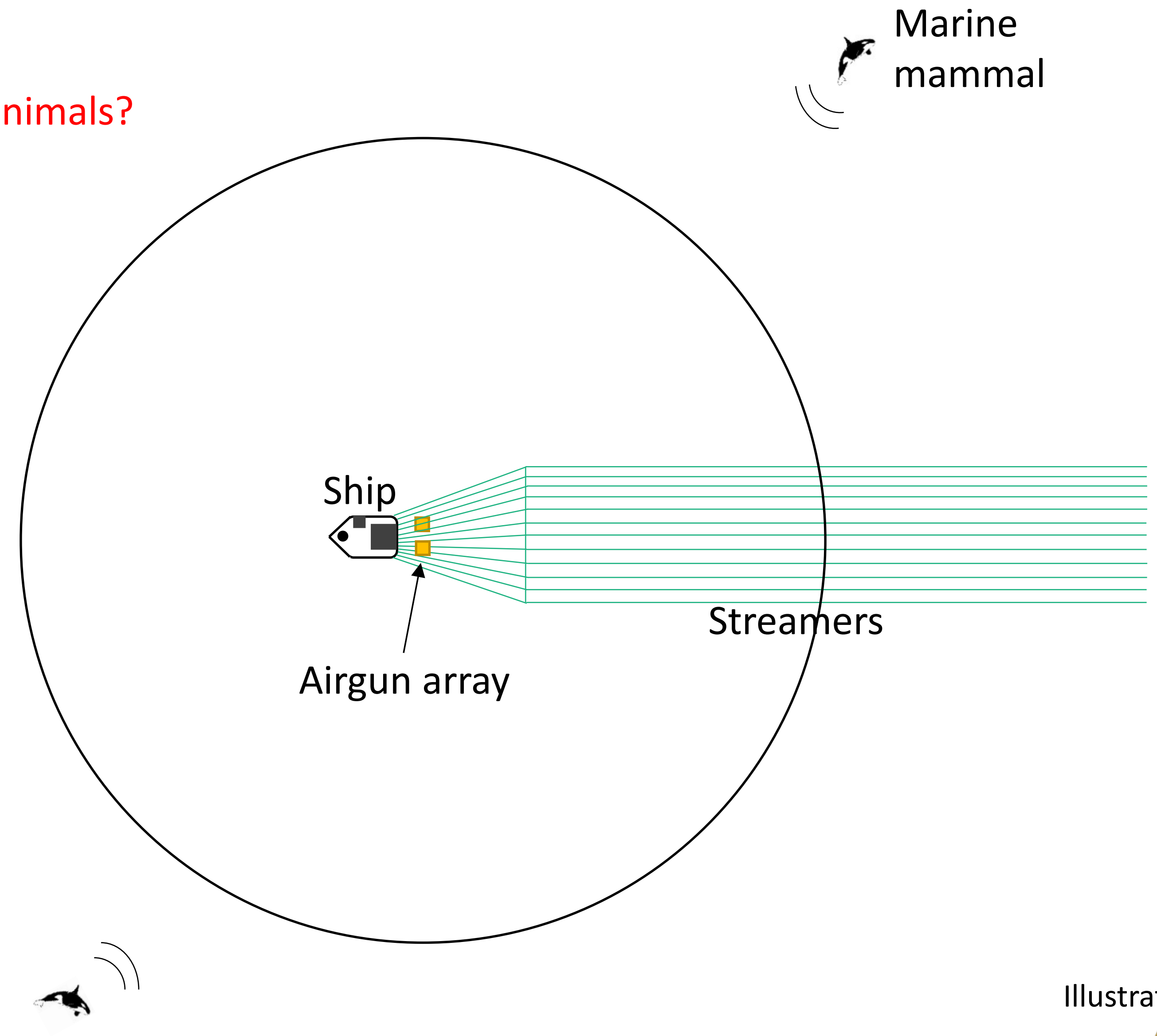
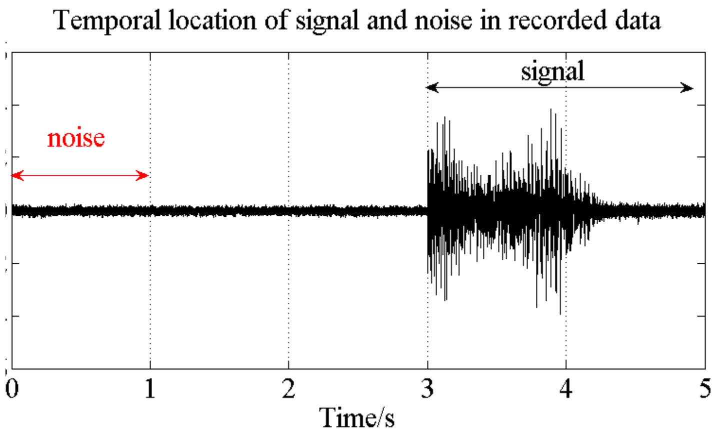
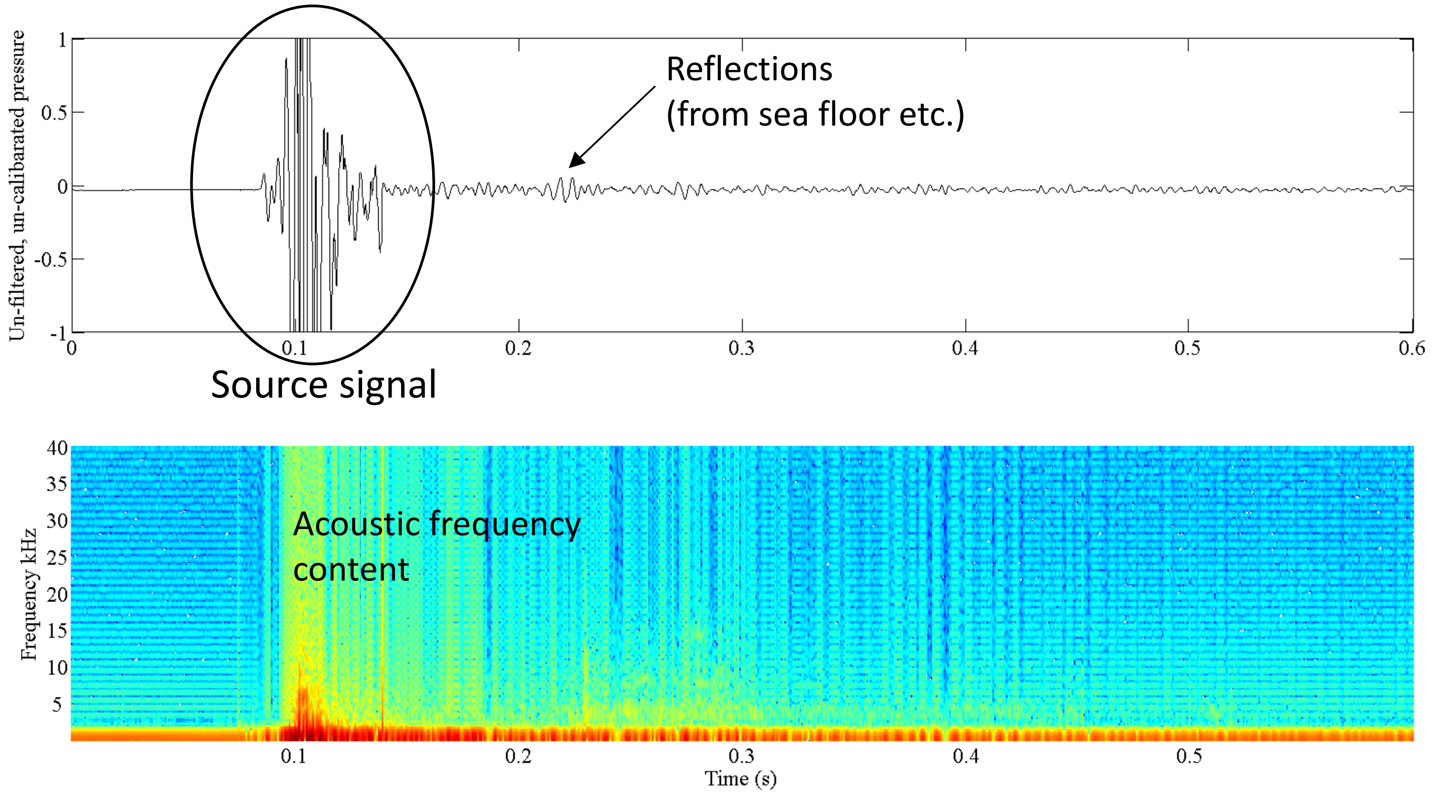


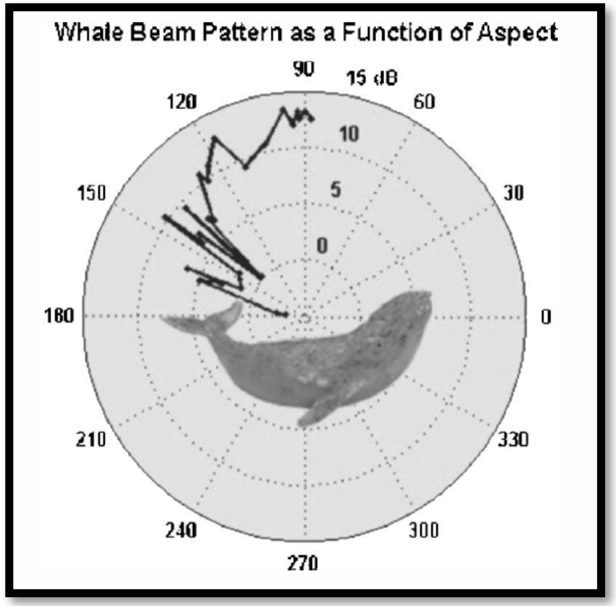
Illustration not to scale

Seismic signals

Loud and rather regular – But many reflections (sea surface, sea bed, …)

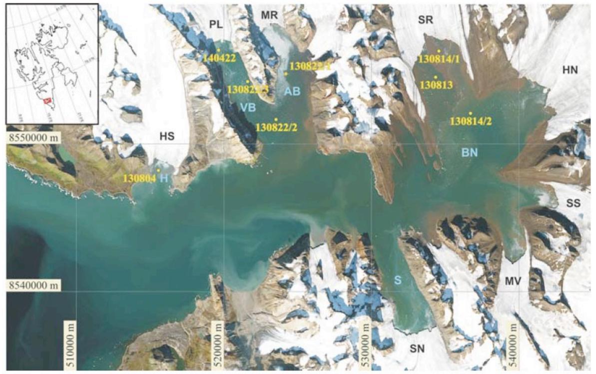


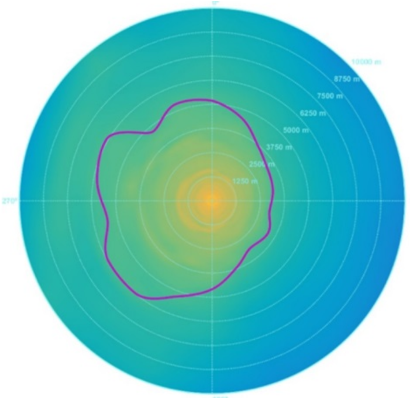




Typical seismic signal

Conclusions





- ✓ Acoustics is the only tool to explore/understand/protect the ocean environments
- ✓ **Everybody needs Physicists ☺**

- ✓ Very large amounts of data: which bits make sense? How far should we trust them?
- ✓ The oceans are very large and vary a lot: where should we measure? how can mathematical models help?
- ✓ **Everybody needs Mathematicians ☺**

- ✓ Interacting with end-users and using our scientific results: need for **full interdisciplinarity**

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