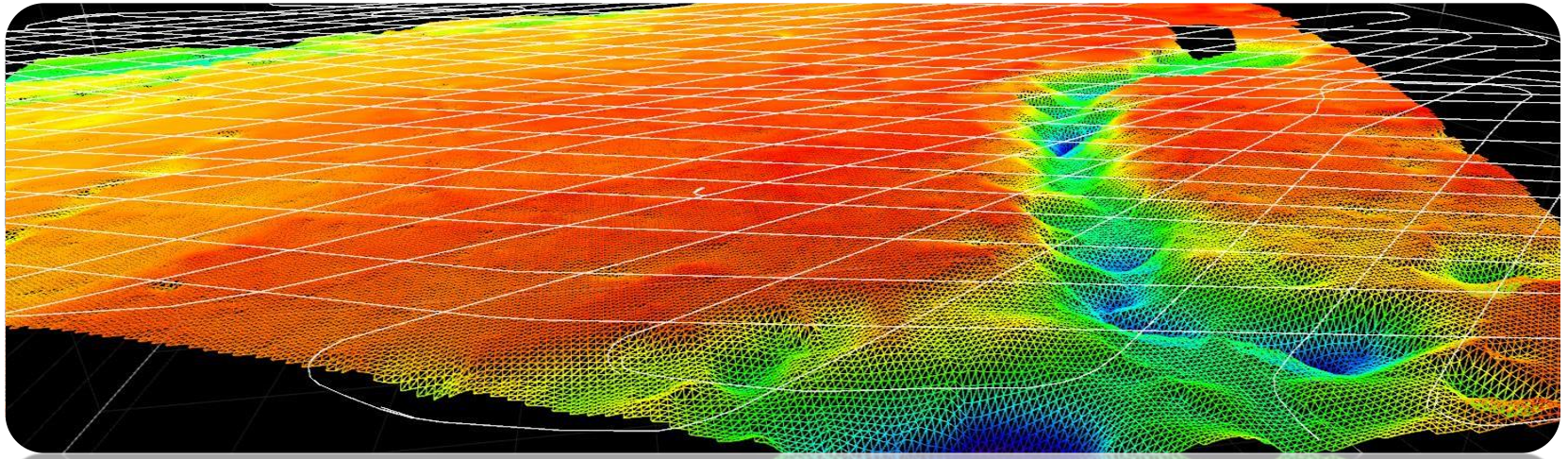

Site characterisation and installation techniques to mitigate geological hazards: latest advancements in design methodologies, de-risking and cost-reduction

Florian Meier, Fraunhofer IWES

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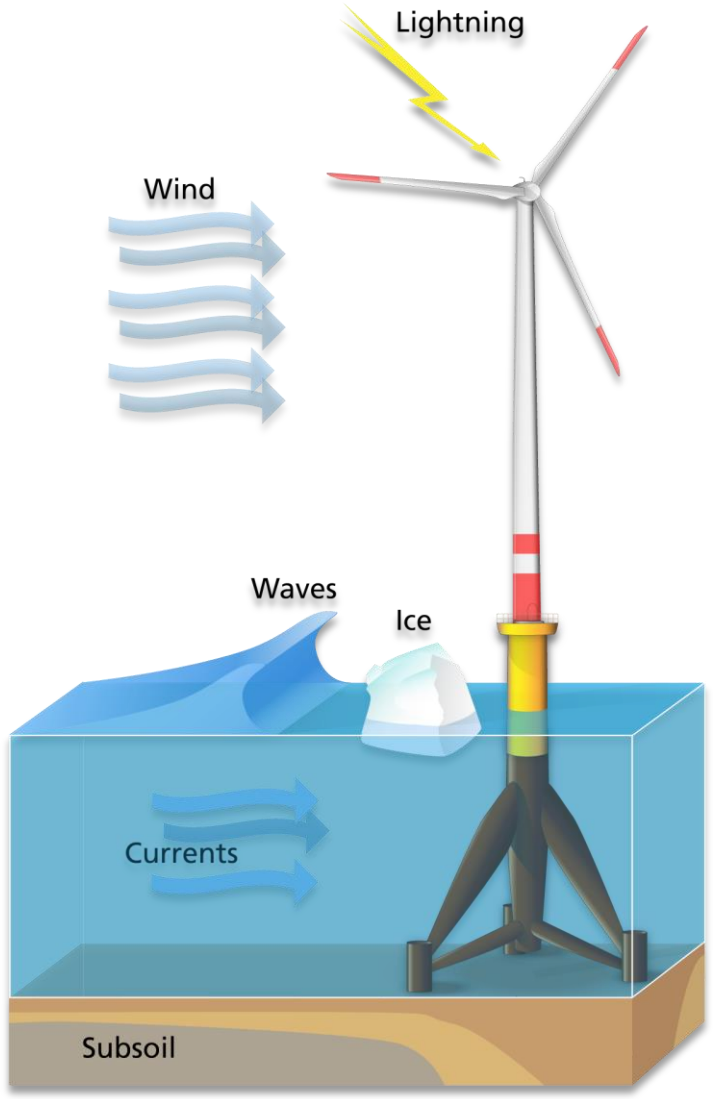
Institute for Wind Energy and Energy System Technology

Research topics, offshore site assessment, overview:

- Wind
- Waves
- Currents
- Ice
- Lightning
- Weathering
- Subsoil



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Research topics, offshore site assessment, overview:

- Wind
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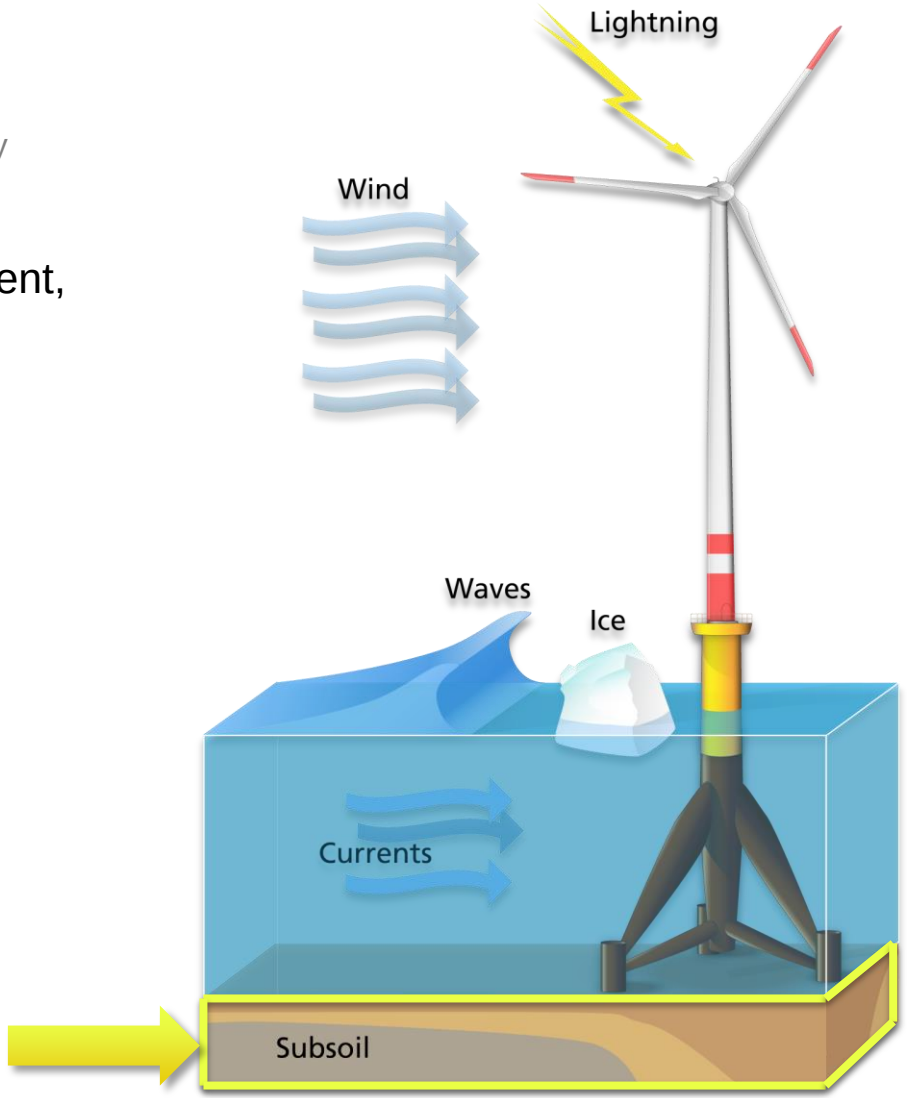
- Weathering
- **Subsoil**



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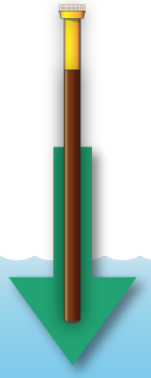
Subsoil assessment



<u>Offshore</u> of particular importance!

- Effective and focussed foundation assessment
- Risk mitigation
- Reliability of wind turbines throughout whole lifetime
- Enhanced planning flexibility as early as possible

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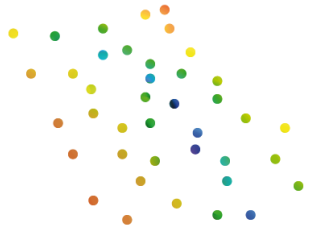
Subsoil assessment – available techniques

Geology (corings)

- Geological information, geotechnical parameters

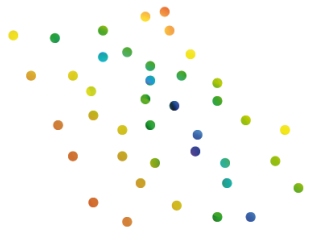
1D



Geotechnics (cone penetration tests (CPT))

- Geotechnical parameters

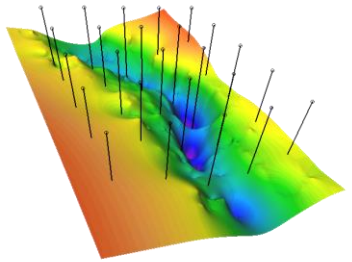
1D



Geophysics (remote sensing: magnetics, bathymetry, sidescan sonar, seismics)

- Spatial overview
- Joining all available data -> the whole picture

3D



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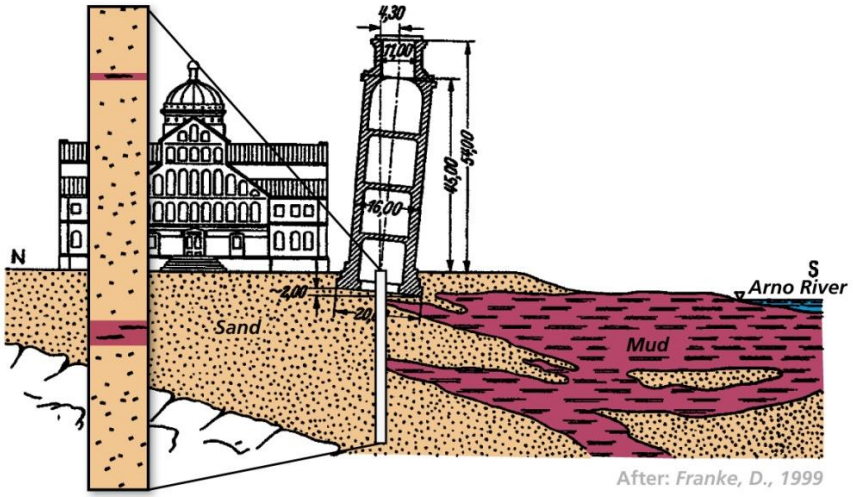
Deficiency of 1D information

Geological and geotechnical investigations are of high importance and deliver crucial information, but are only 1D

- This can lead to wrong assumptions!



After: *Franke, D., 1999*

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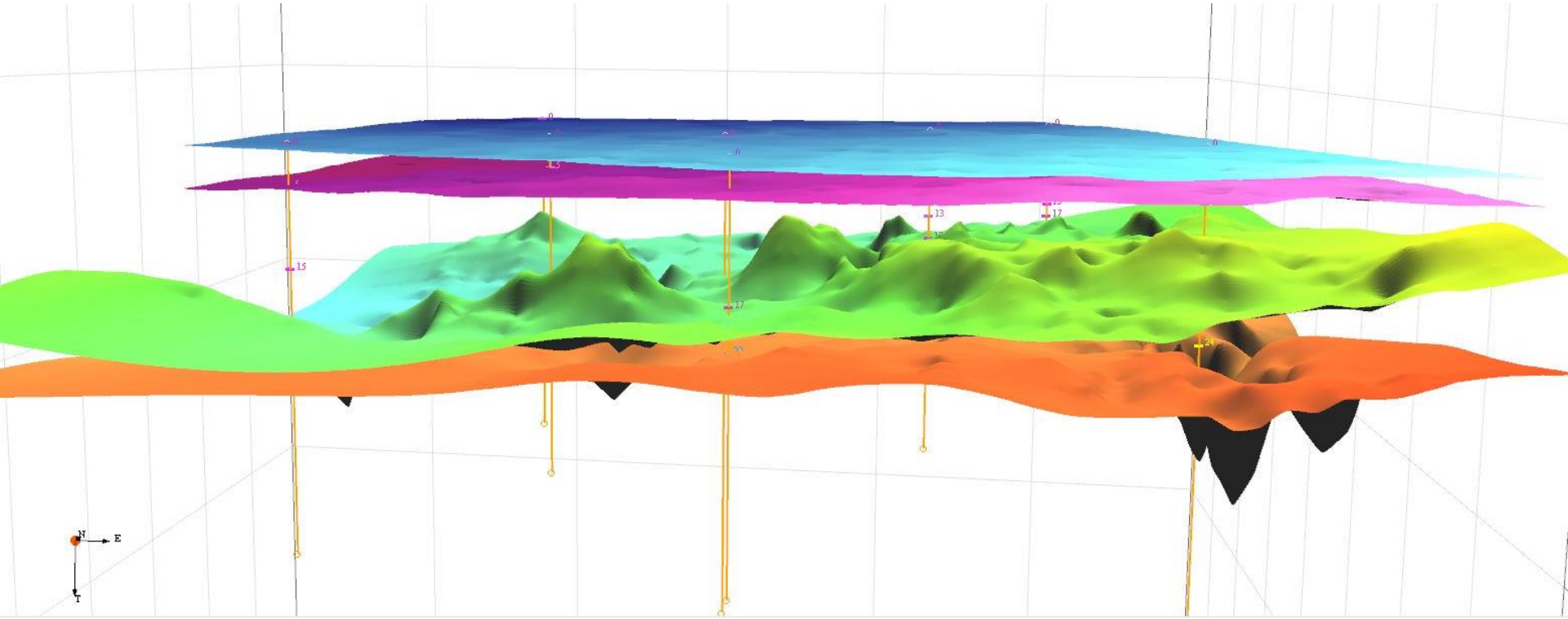
Recommended procedure

Join all information in a comprehensive 3D model



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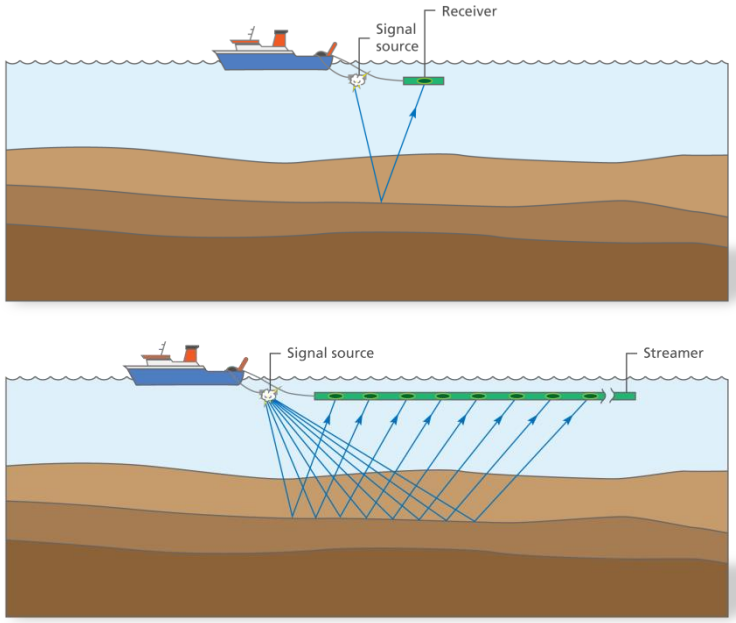
Acquisition of seismic data

Important decisions:

- Acquisition mode: single channel vs. multichannel
- Choice of signal source: Frequency range, signal shape



Comparison of single-channel and multichannel seismics

Different signal sources

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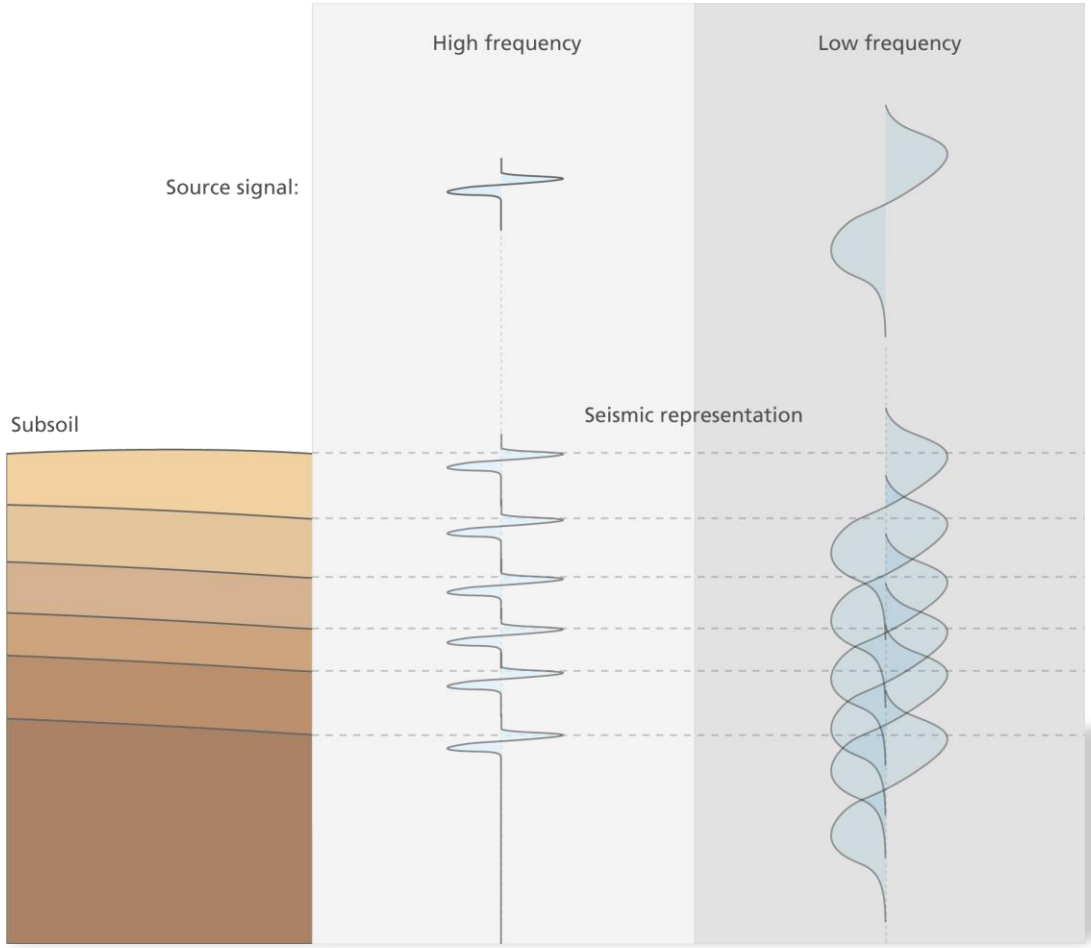
Influence of the seismic signal source: ***resolution***

Signal source

Frequency

Wavelength

Resolution



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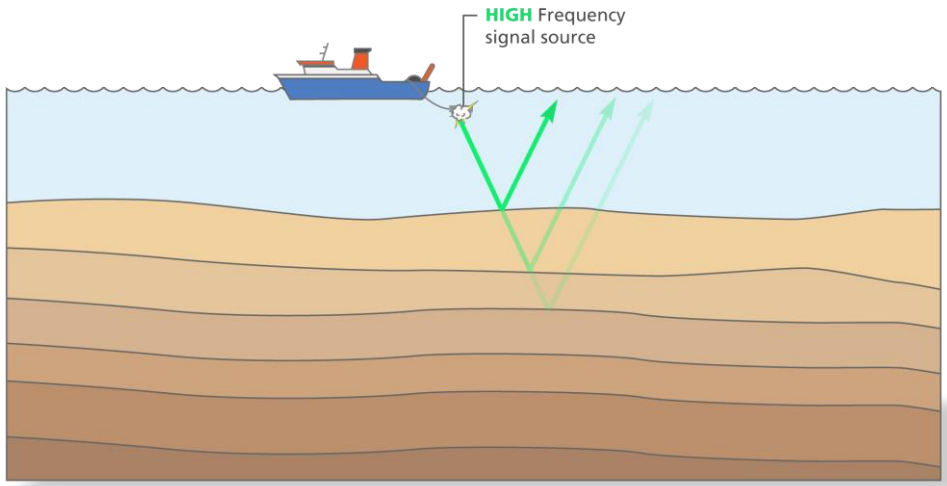
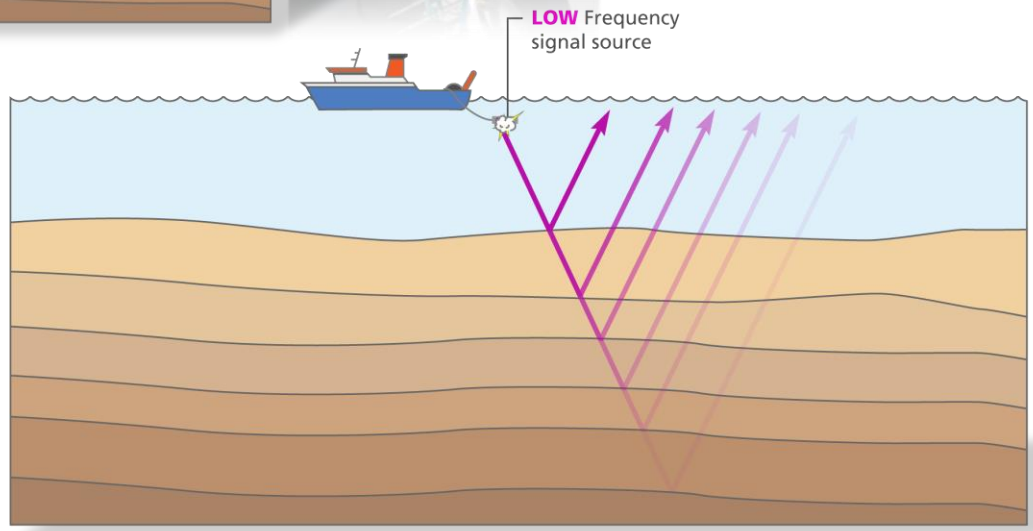
Influence of the seismic signal source: *penetration depth*



High frequency seismics – **Low** penetration



Low frequency seismics – **High** penetration

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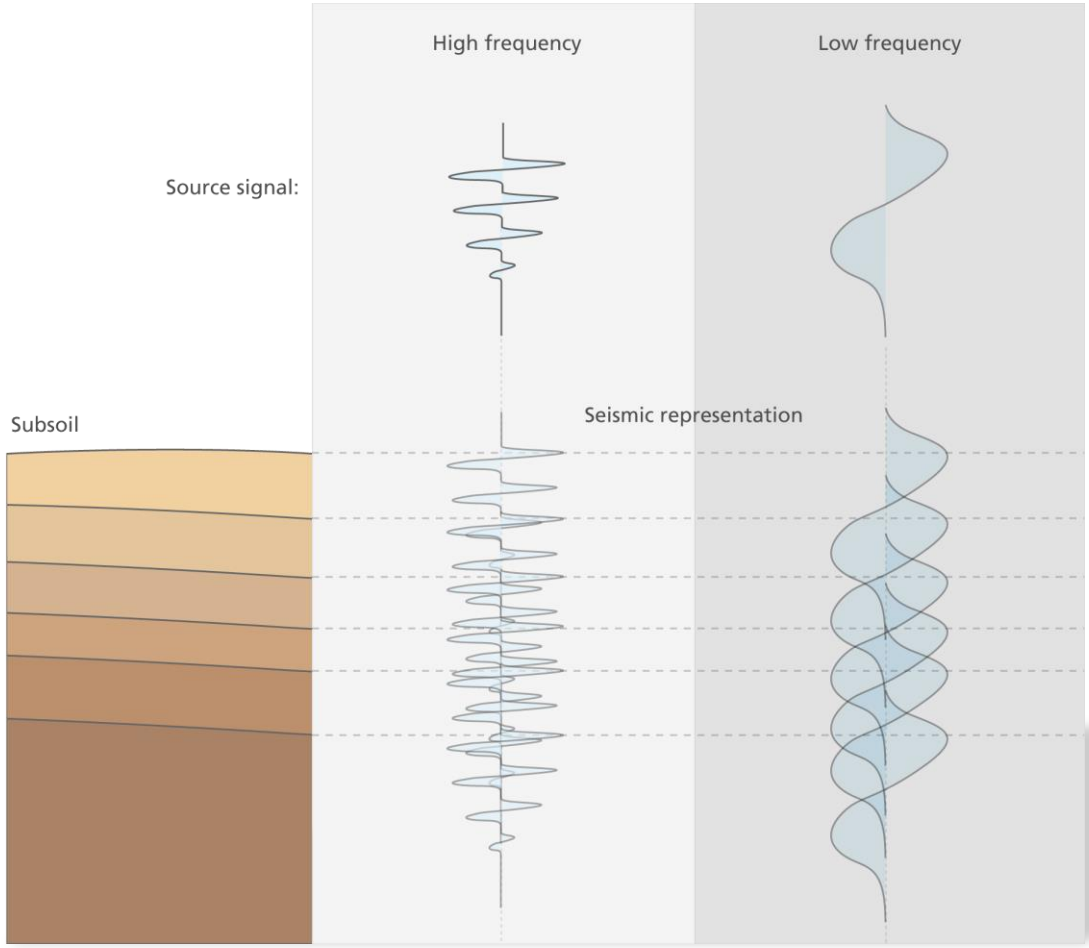
Influence of the seismic signal source: ***signal shape***

It’s not only the frequency -

also very important:

Signal shape!



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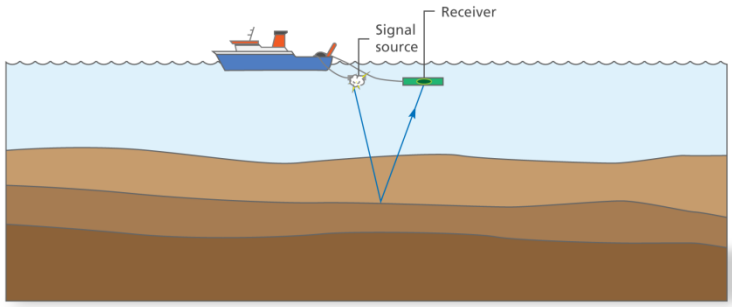
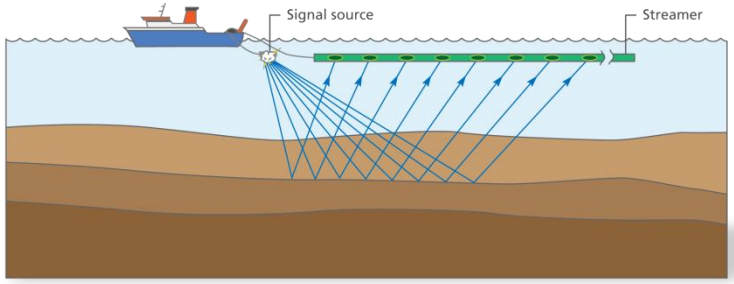
Single channel- vs. multichannel seismics



Single channel seismics

vs.



Multi channel seismics

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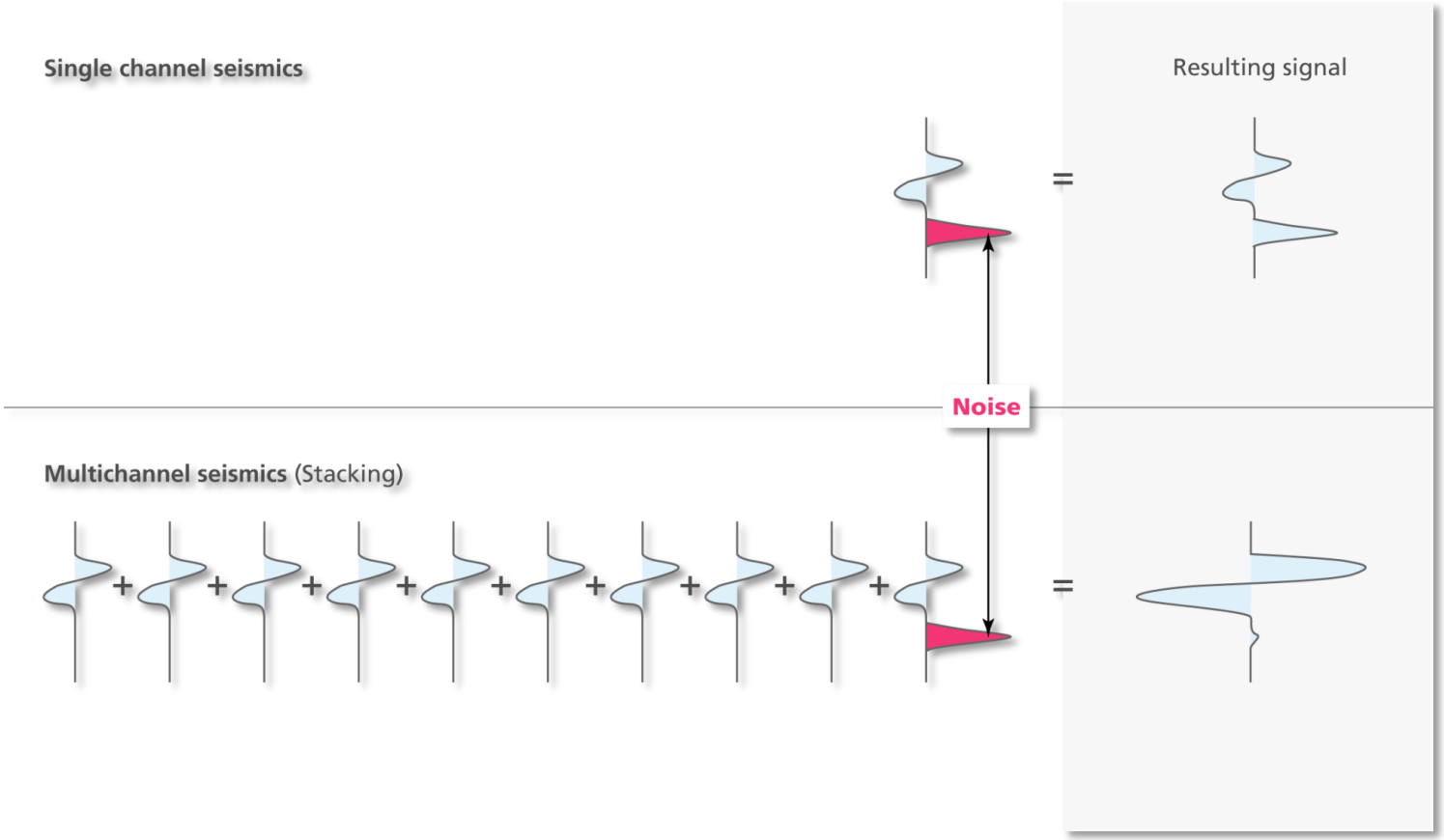
Single channel- vs. multichannel seismics

Advantage of stacking – signal to noise ratio



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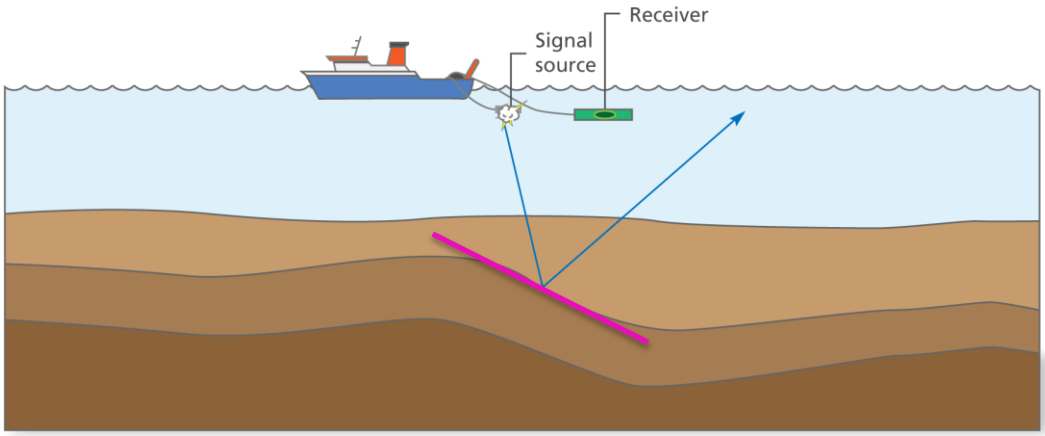
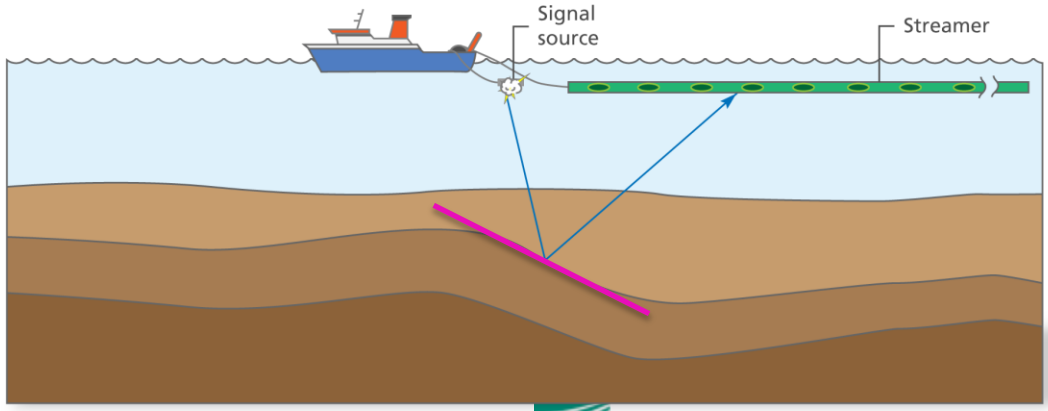
Single channel- vs. multichannel seismics

Detection of inclined layers



Single channel seismics

Multi channel seismics



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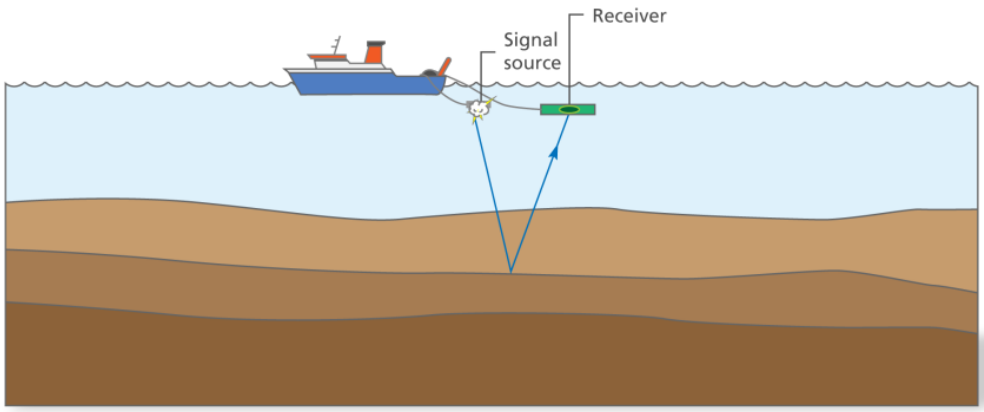
Seismics for the offshore wind industry: standard method

Boomer single-channel seismics:

- Cheap
- Easy to apply
- Fast
- No profound knowledge necessary



Single-channel seismics

Boomer

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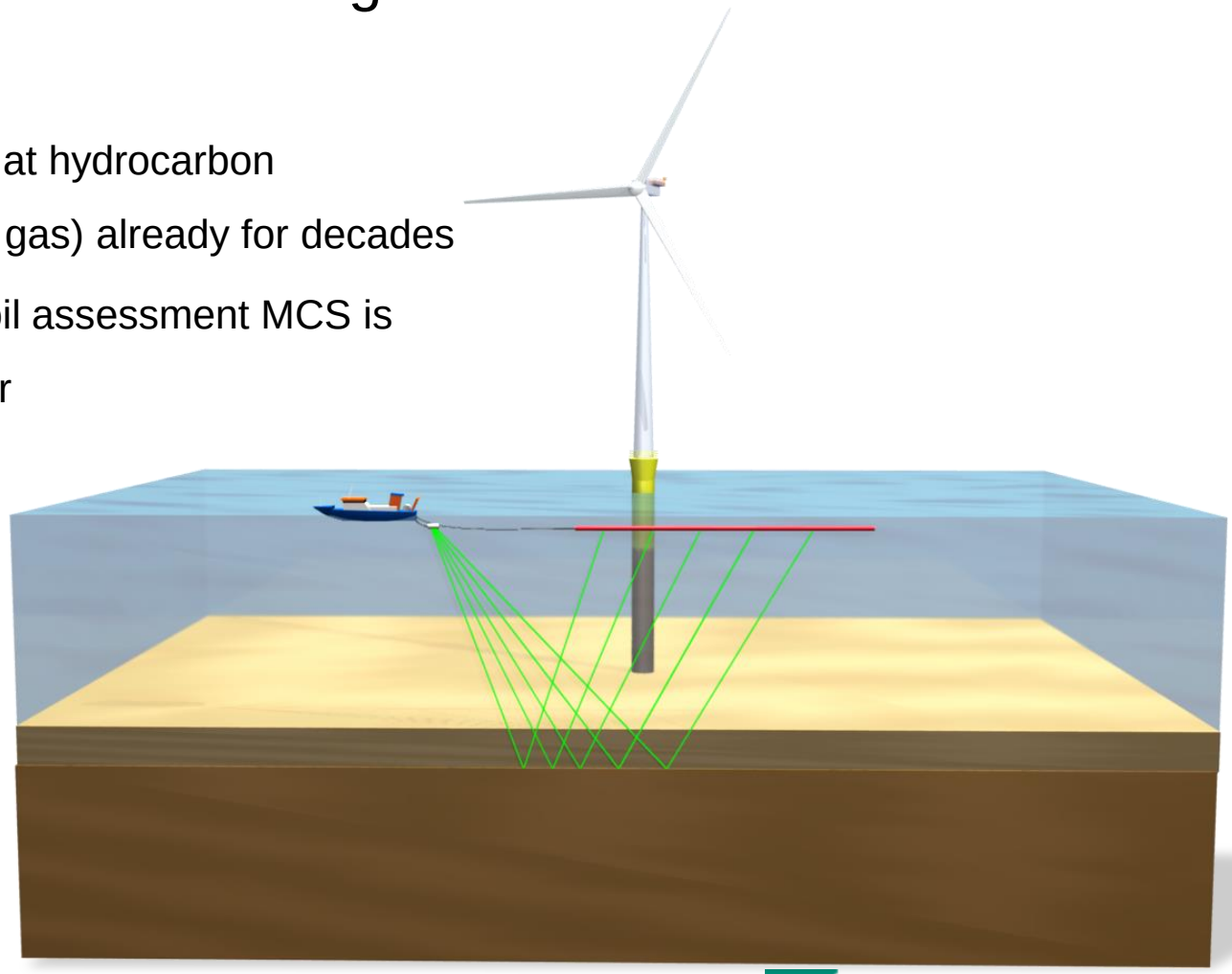
Sophisticated subsoil investigation with multichannel seismics (MCS)

- MCS is standard at hydrocarbon exploration (oil & gas) already for decades
- In offshore subsoil assessment MCS is technology leader



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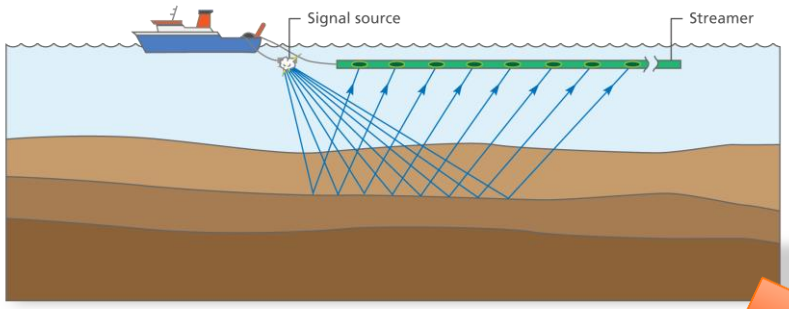
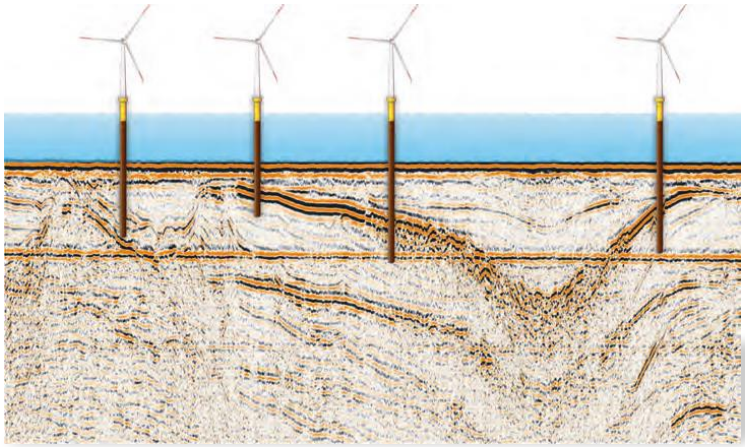
Multichannel seismics

- MCS is able to deliver high resolution images of subsoil conditions, reaching depths of up to several hundred meters





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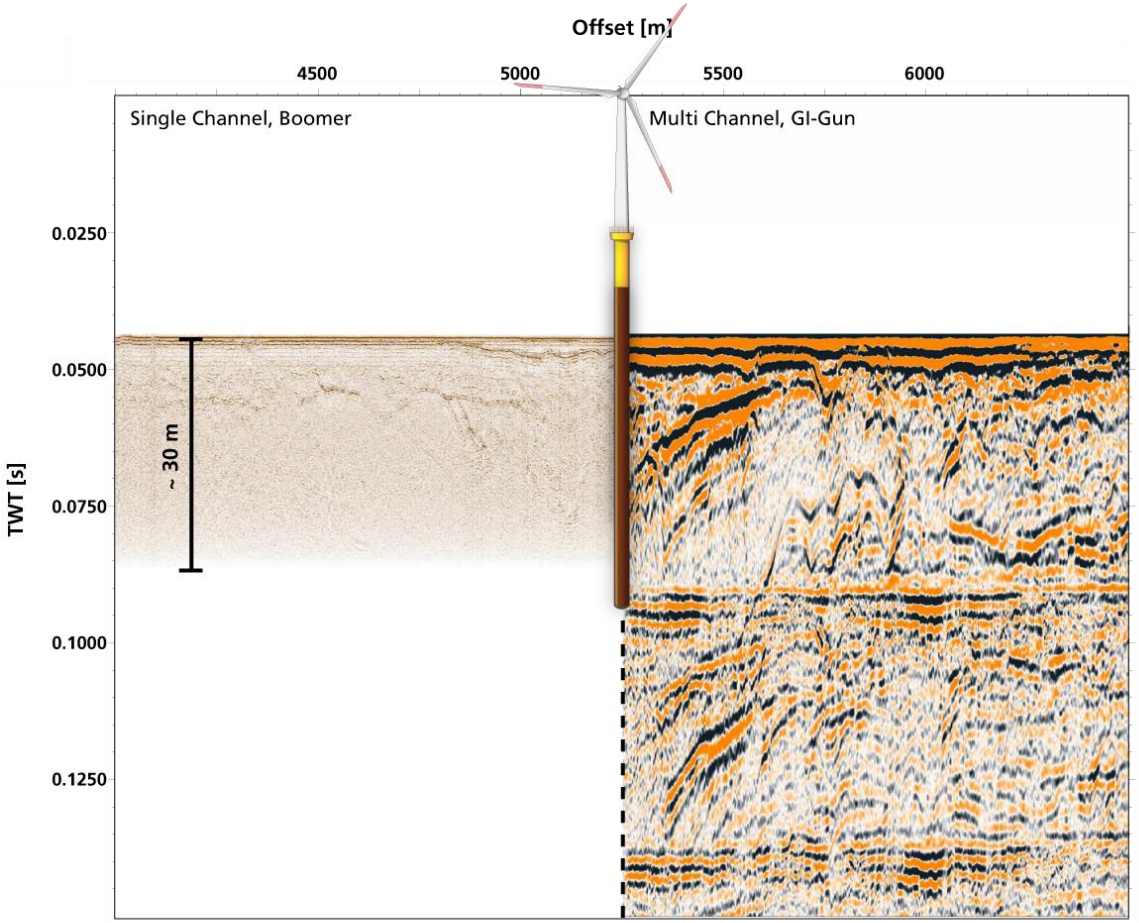
Standard method vs. multichannel seismics

BSH Standard:
‚Mandatory:
Signal penetration
***at least** to the depth of*
the foundation base‘ !



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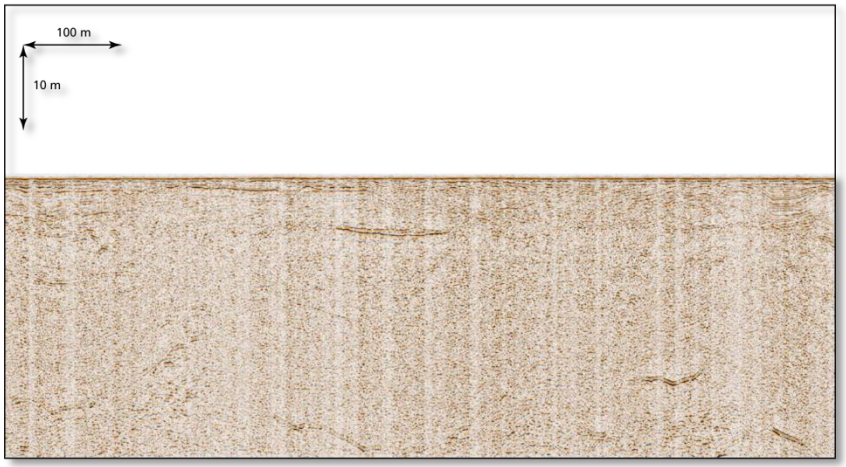
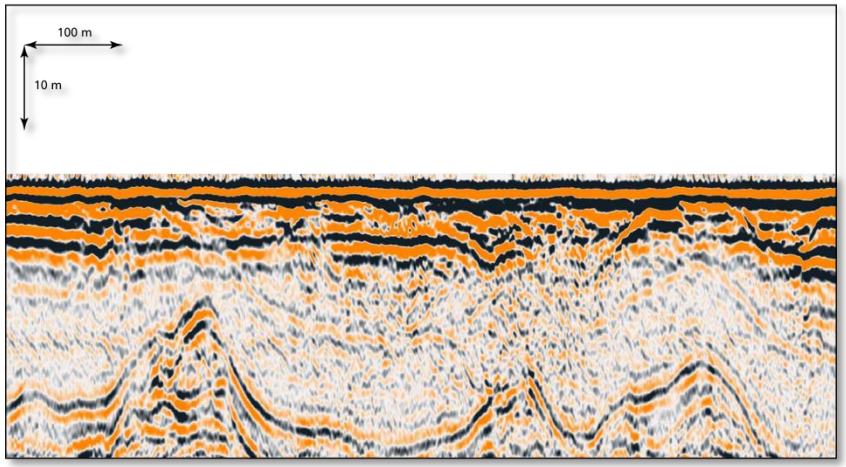
Standard method vs. multichannel seismics

- Same profile, different method, North Sea



Boomer single-channel seismics



IWES multichannel seismics

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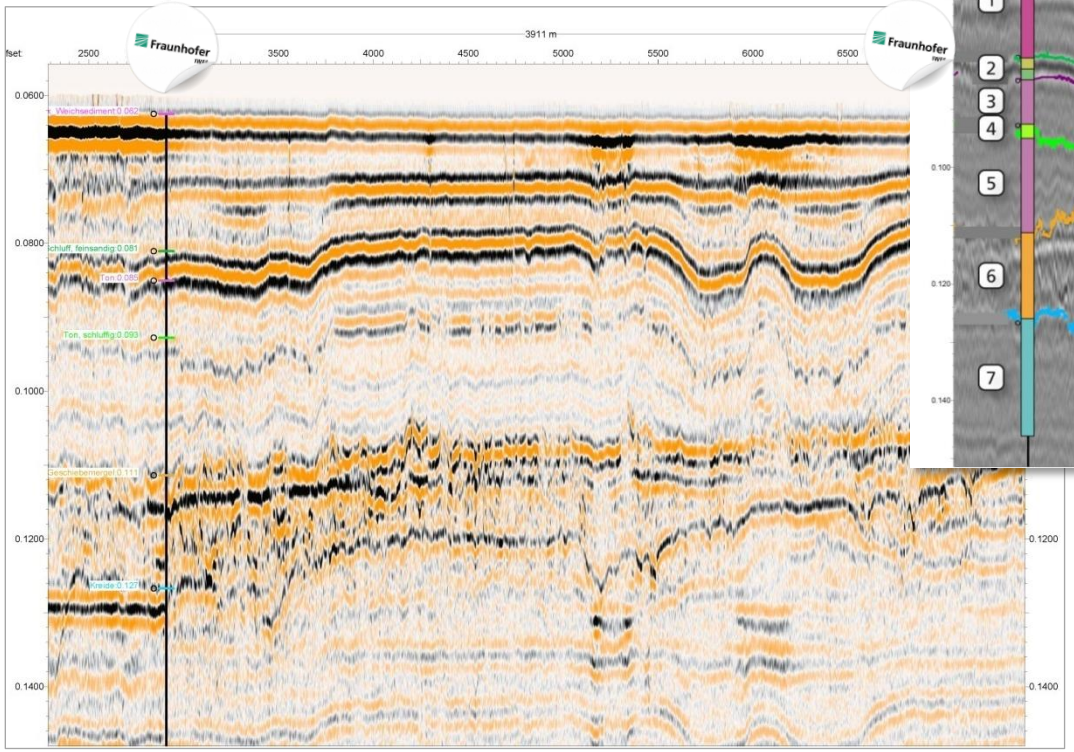
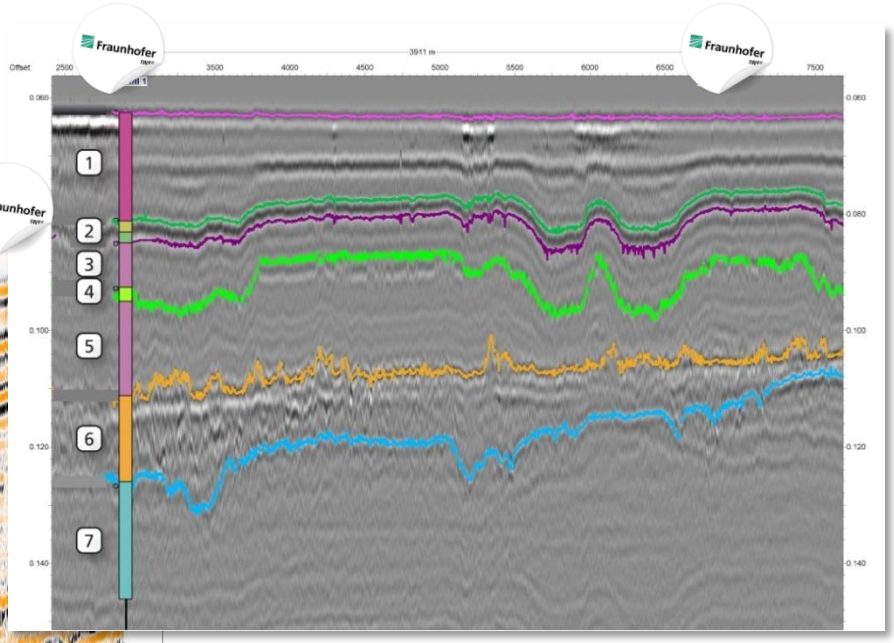
Case study

- Windfarm, Baltic Sea



GI-Gun multichannel seismics



GI-Gun multichannel seismics

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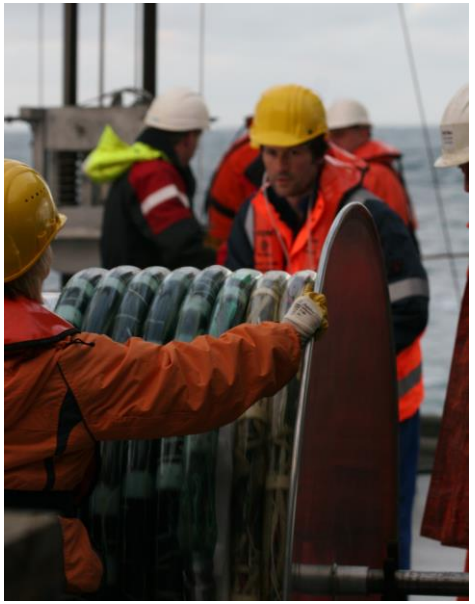
IWES multichannel seismics

Fraunhofer Multi-Channel System

- Especially designed for shallow water conditions (< 100m)
- Fully digital (low noise)
- 96 channels - high fold
- High sample rate (125 µs / 8 kHz)
- Specialized signal source (Micro! GI-Gun)

Compared to standard system (single channel seismics)

- Enhanced signal penetration (several 100m poss.);
  guarantee to reach foundation depth!
- High resolution (approx. 1m)
- High signal/noise ratio
- Visualization of steeper structures/inclined layers possible



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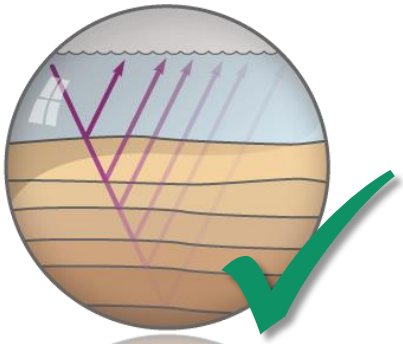
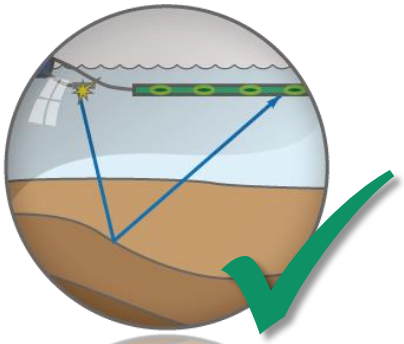
Multichannel seismics

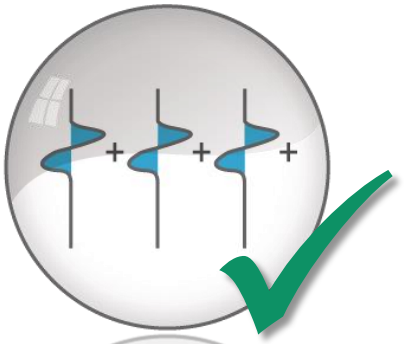


Penetration depth

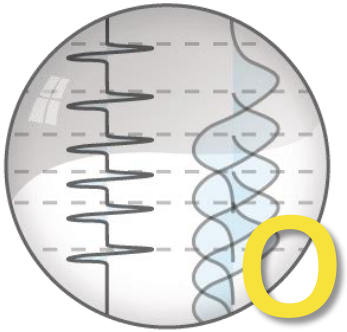
Signal shape



Inclined layers



Stacking /
Signal-Noise ratio



Vertical resolution

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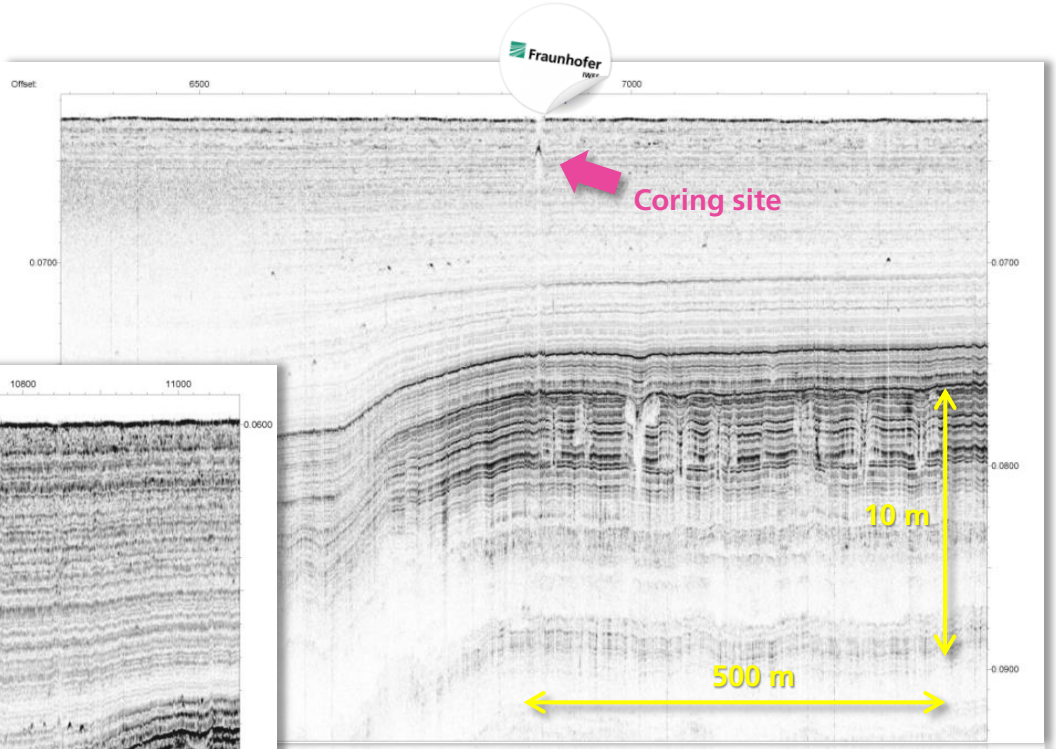
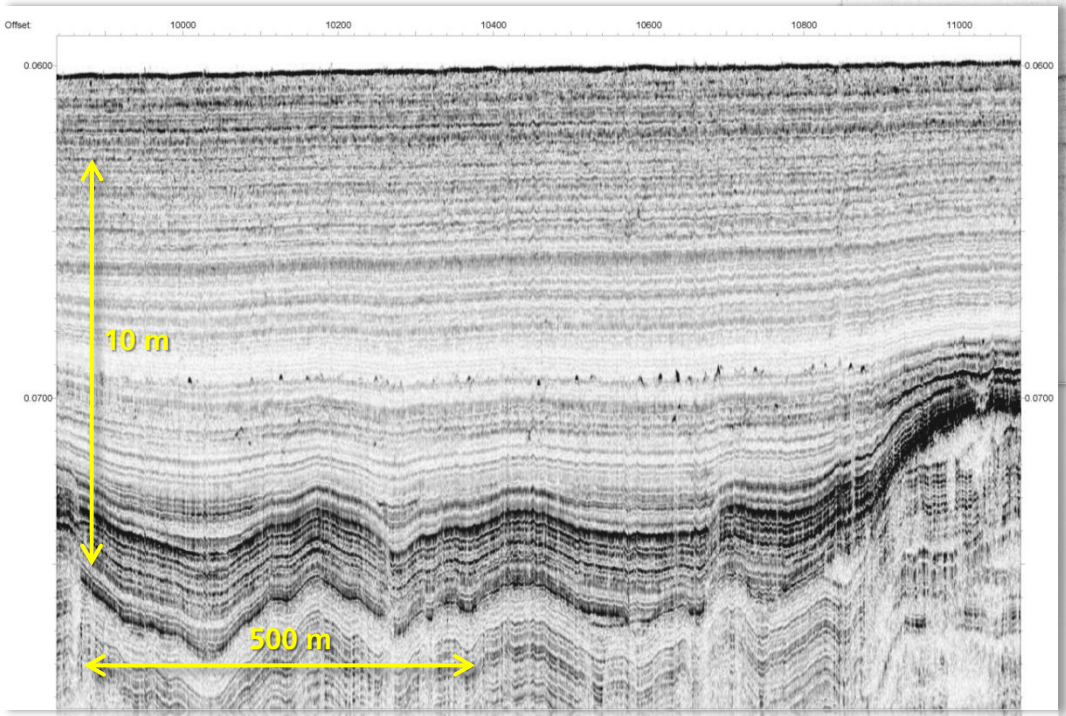
Imaging the upper layers

- Sediment echosounder; windfarm area; Baltic Sea



Sediment echosounder (12 kHz)



Sediment echosounder (12 kHz)

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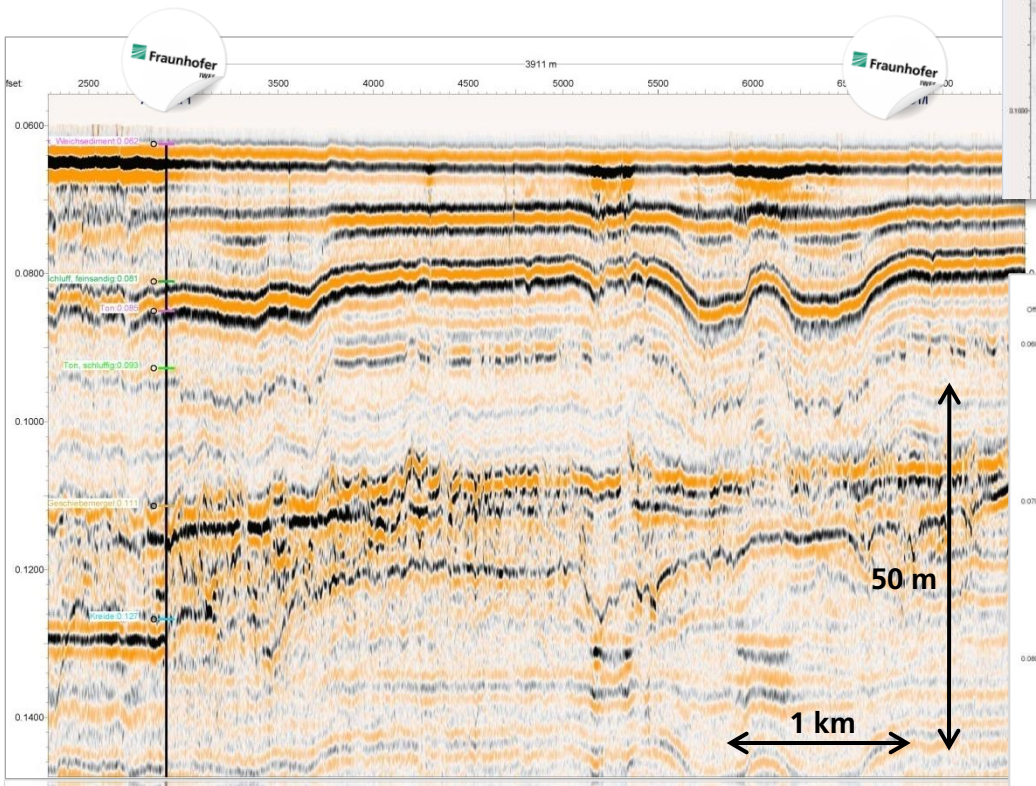
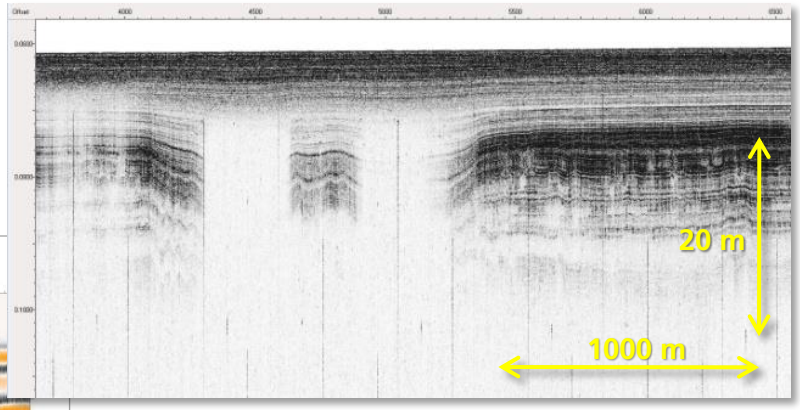
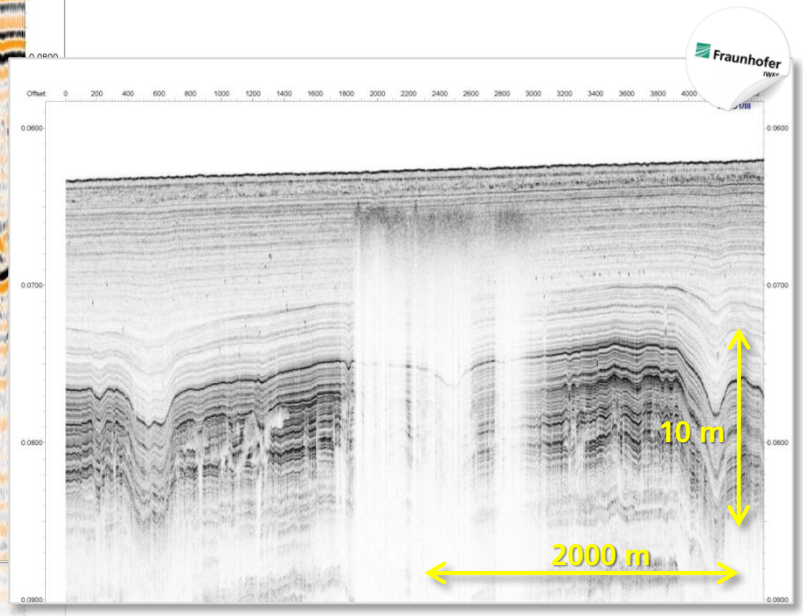
Case study – shallow gas

- Frequency dependent penetration capability







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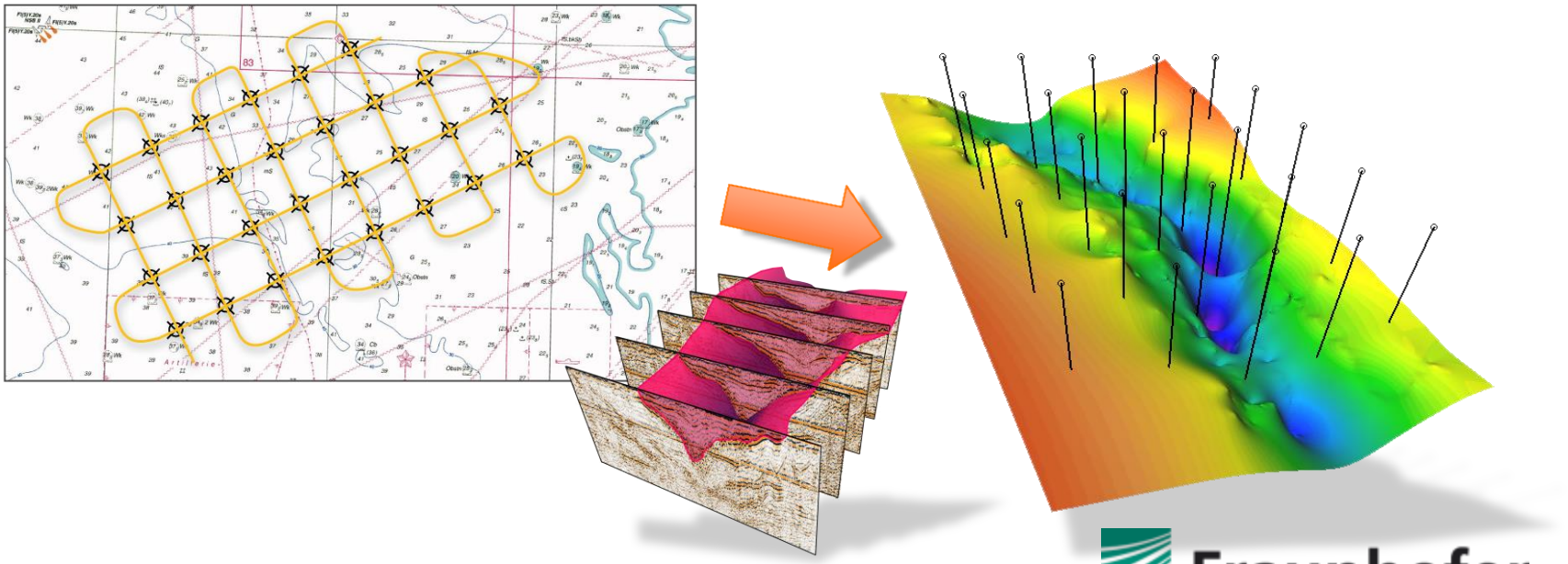
From 2D to 3D

- Combination of multiple seismic 2D profiles, together with geological information allows generation of 3D subsoil models
- This allows to easily display the spatial location of different soil layers at any position



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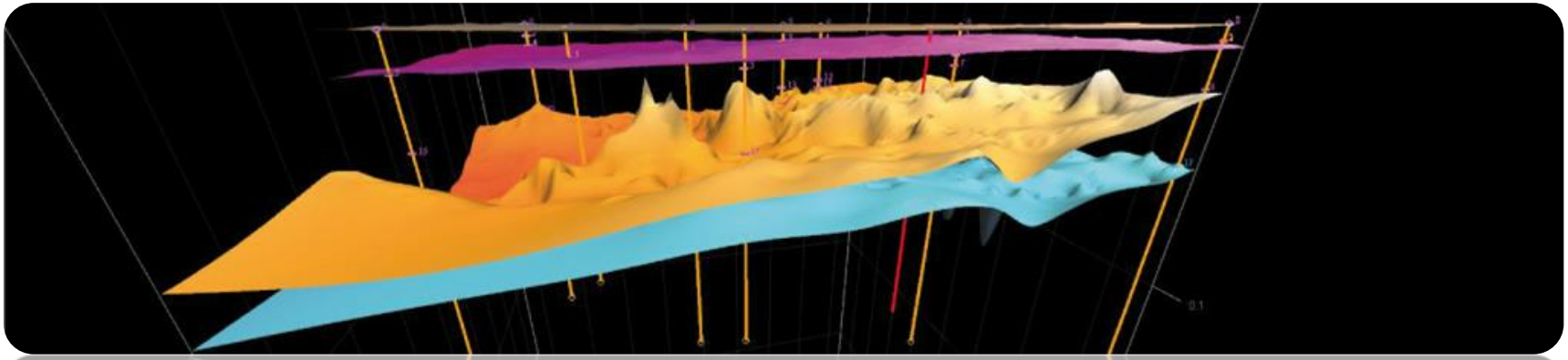
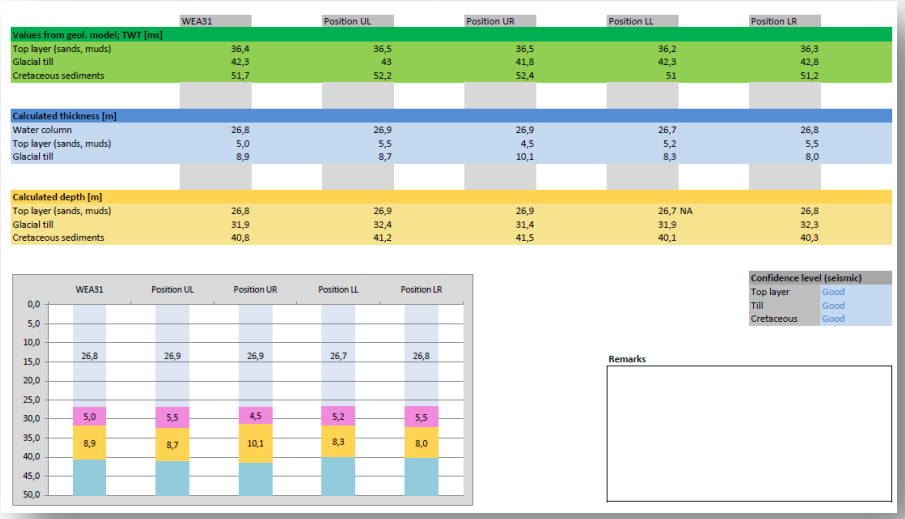


Comprehensive geolgocial subsoil model allows the generation of **interpolated soil profiles**:

- At any desired location
- Fast
- Cheap (possibility to reduce number of expensive corings)
- Flexible
- Always available
- No additional surveys needed



	WEA31	Position UL	Position UR	Position LL	Position LR
Values from geol. model; TWT [ms]					
Top layer (sands, muds)	36,4	36,5	36,5	36,2	36,3
Glacial till	42,3	43	41,8	42,3	42,8
Cretaceous sediments	51,7	52,2	52,4	51	51,2
Calculated thickness [m]					
Water column	26,8	26,9	26,9	26,7	26,8
Top layer (sands, muds)	5,0	5,5	4,5	5,2	5,5
Glacial till	8,9	8,7	10,1	8,3	8,0
Calculated depth [m]					
Top layer (sands, muds)	26,8	26,9	26,9	26,7 NA	26,8
Glacial till	31,9	32,4	31,4	31,9	32,3
Cretaceous sediments	40,8	41,2	41,5	40,1	40,3

Confidence level (seismic)	
Top layer	Good
Till	Good
Cretaceous	Good

Remarks

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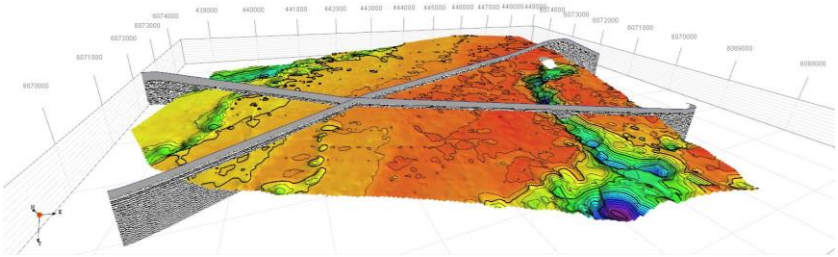
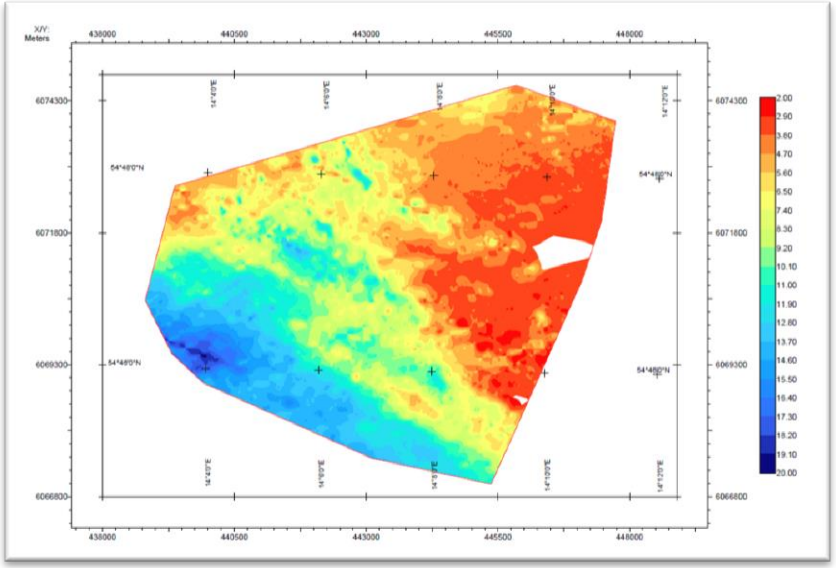
Benefit



3D subsoil model based on a high-quality seismic survey allows:

- Fast, comprehensive overview
- Focussed planning of sites (Site optimization on basis of geological conditions (at an early stage))
- Optimized planning and/or reduction of expensive corings/CPT
- High flexibility throughout the whole planning phase, e.g. in case OWT locations are changed at later stages
- Avoidance of unpleasant surprises (risk mitigation)
- No further additional geophysical surveys needed at later project phases
- Easy and instantaneous generation of subsoil profiles at any position in the park



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Future activities

Research project ‘Seismik NordOst’ (BMWi)

- Systematic research on the question: “How to use seismic investigations in a most effective way to address the needs of the offshore wind industry”
- Research areas: North Sea and Baltic Sea
- Cooperation partner: E.ON Climate and Renewables GmbH

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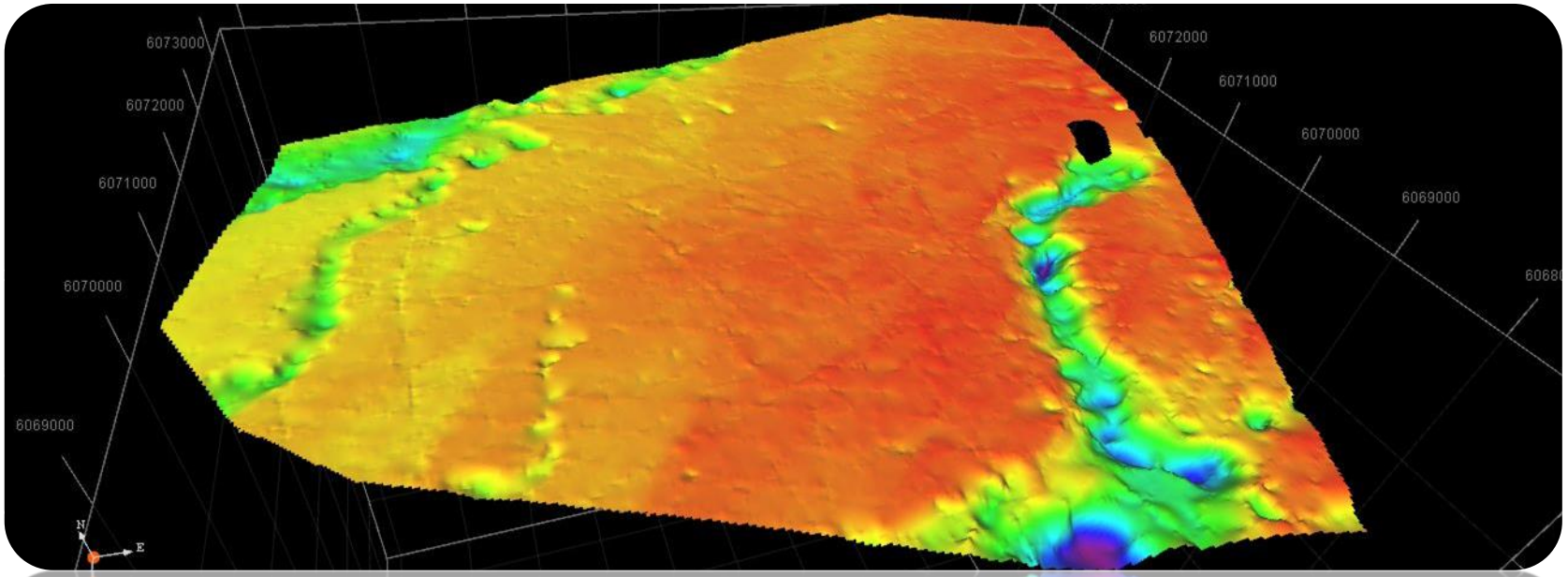

Summary: why does it pay off to put effort into geophysics?

- Reduce risks
- Safe money (very cheap, compared to corings)
- Know as much, and as early as possible:
  - Full overview of whole windfarm gives **great flexibility** throughout the whole development process
  - Spatial knowledge allows **detailed planning** of OWT sites and **optimization** of expensive geological and geotechnical examinations

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