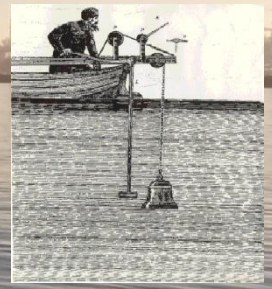
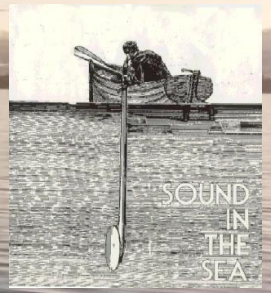
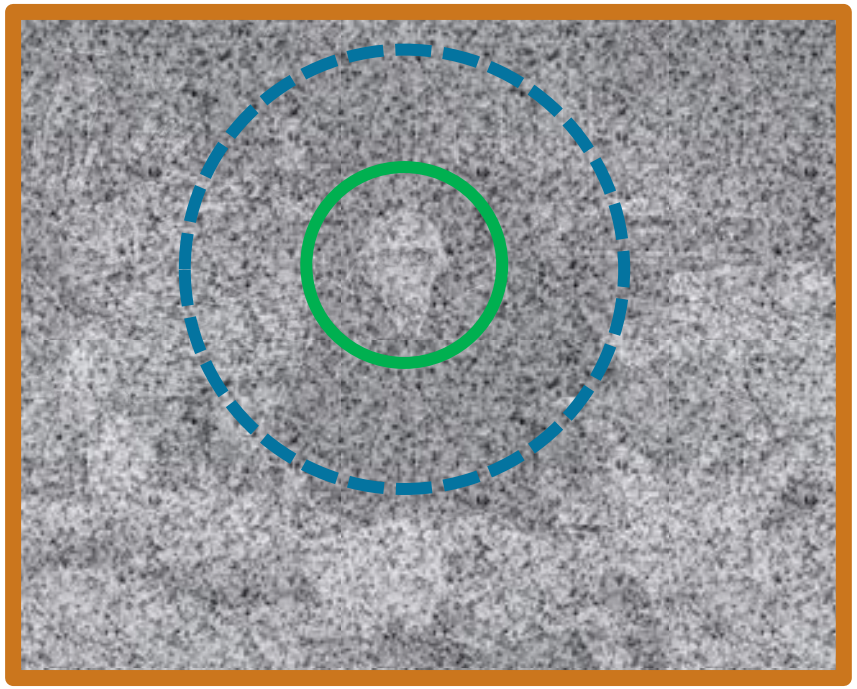
Fernerkundung und Modellierung von marinen Lebensräumen: Herausforderungen und Ergebnisse der Helgoland Expeditionen





Dr. Jens Schneider von Deimling, Merve Jensen
AG Marine Geophysik und Hydroakustik, CAU

Marine Habitats = marine Lebensräume



Scientist‘s Habitat? Jean Piaget

A specific Habitat has:

Environmental characteristics that support a species to live there (bio-geo-physico-chemical)

MAP – MINE - MODEL

- Direct detection of living species
- Indirect environmental characterization
- Habitat Modeling

Baltic Sea environmental assessments by innovative opto-acoustic remote sensing, mapping, and monitoring

SONAR

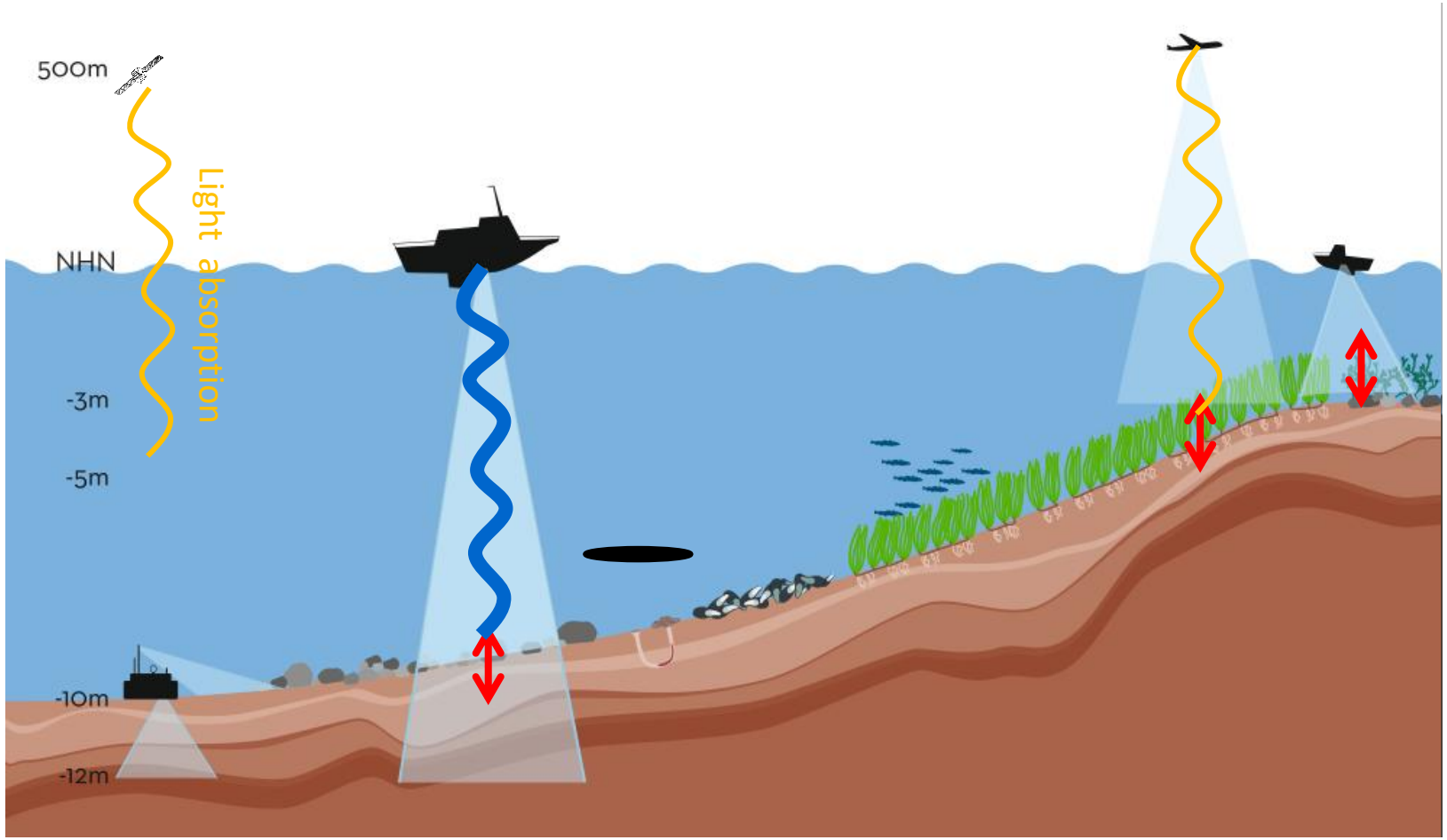
LiDAR

Imagery

Machine Learning

Projects 2017-2026

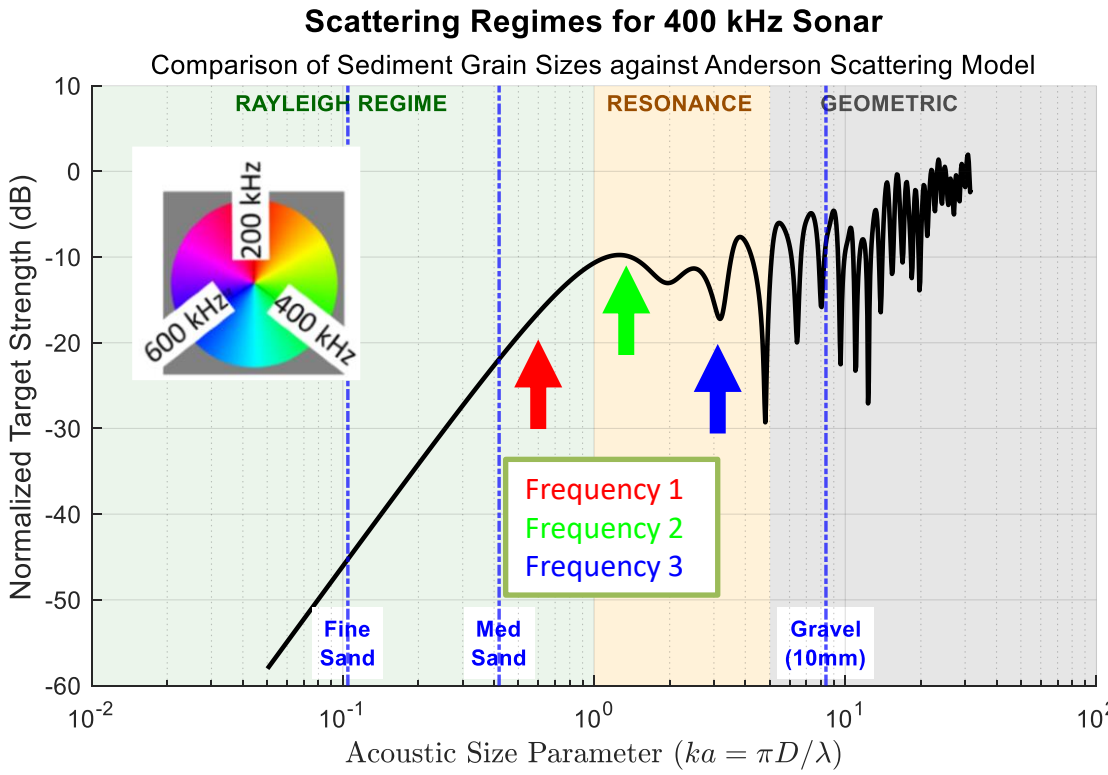
1. EU BONUS ECOMAP
2. sea4soCiety
3. EU Ocean Citizen
4. Marispace-X
5. BFN MMAP
6. ANK Labluc/Fubluc
7. ANK Zobluc
8. EU BETTER
9. Seascape
10. DFG Research UNIT AMCA



Dr. Jens Schneider von Deimling (Inst. f. Geowissenschaften)

Subtle acoustic signatures …

nonlinear behaviour of scatteres



$D = object\ diameter\ [mm]$

$\lambda_{400\ kHz\ @}$ 1500 m/s = 3.7 $[mm]$

- Frequency dependent penetration
- Penetration with 400 kHz in sand ca. 8 cm, expect much more in silt and mud (decimeters to meters)

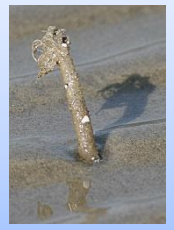
Experimental MBES

- **Multispectral**
- **Snippets Backscatter**
- **WCI**
- **Point Cloud**
- **Multidetect**

Microroughness Flora & Fauna

Bioturbation

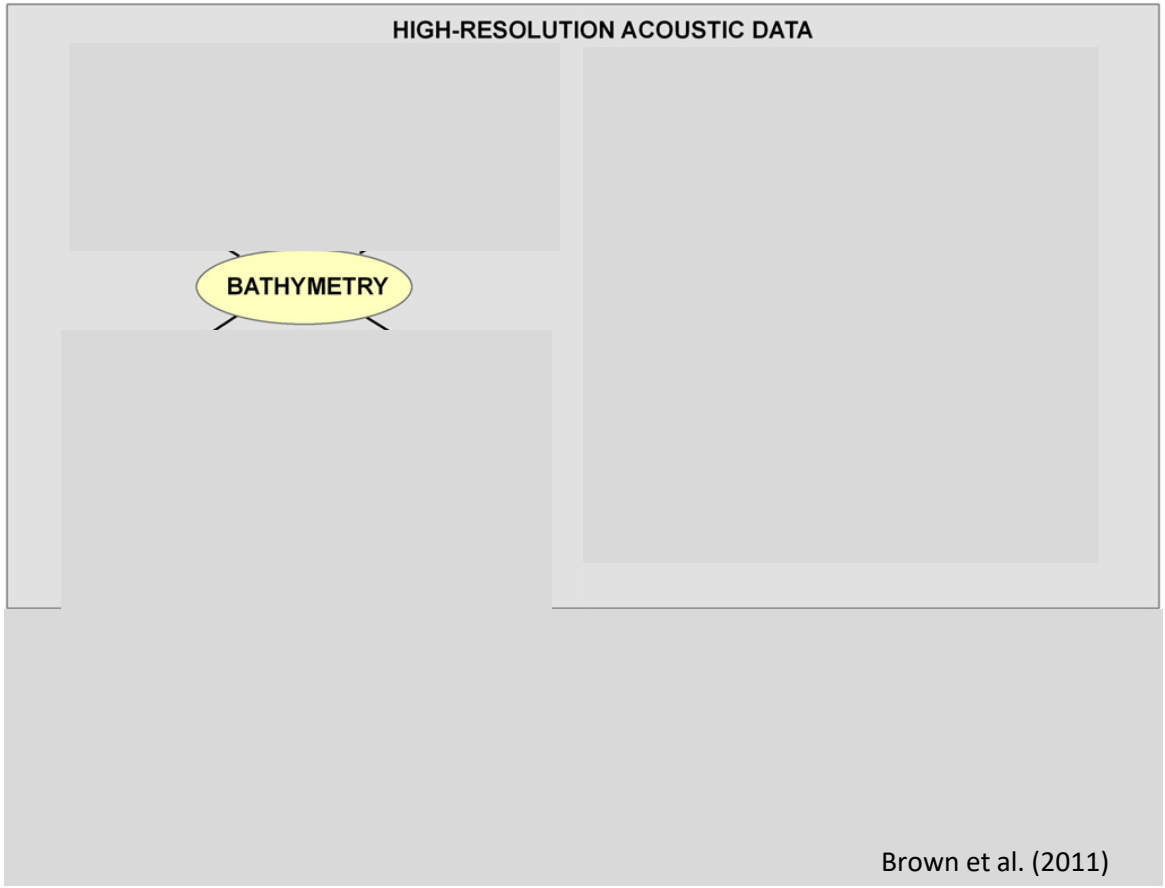
Biofilms? Buried fish?



https://britishseafishing.co.uk/greater-and-lesser-sandeel/

Habitat Mapping

Beyond bathymetry



Brown et al. (2011)

Backscatter Working Group

GEOHAB BSWG

- **Multispectral** Substrate
- **Water column** Fish, Seeps, Vegetation
- **Calibration**
- **Processing**
- **Acquisition**

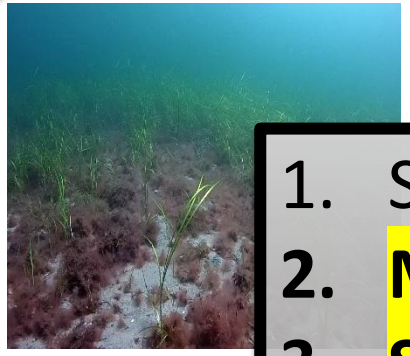
New MBES backscatter report under construction for 2027

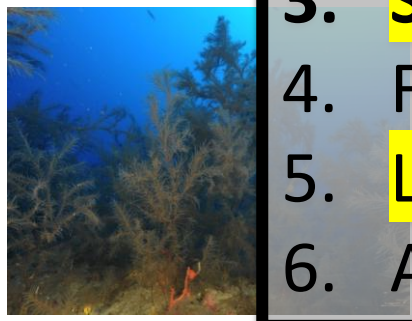
→ Highly dimensional, Terrabytes of Data

Dr. Jens Schneider von Deimling (Inst. f. Geowissenschaften)

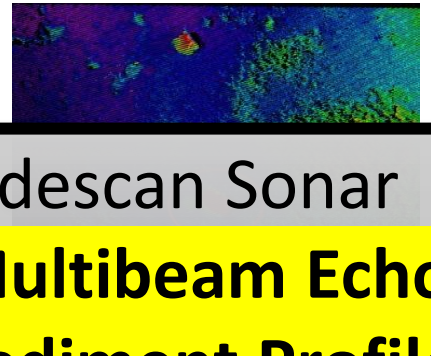
Experimental Hydroacoustics

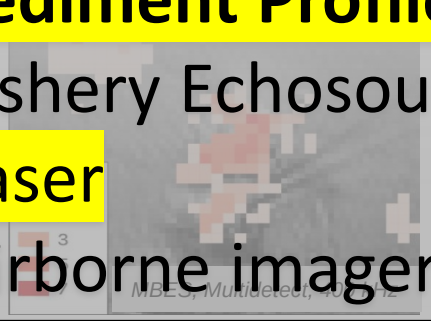
...tural



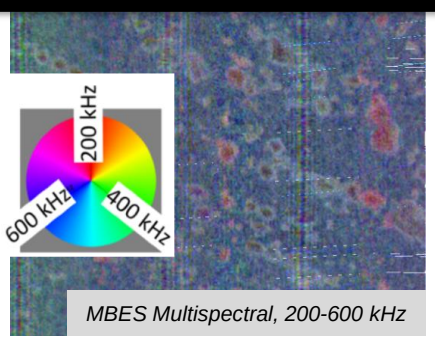


Acoustic imaging





Heinrich et al 2016



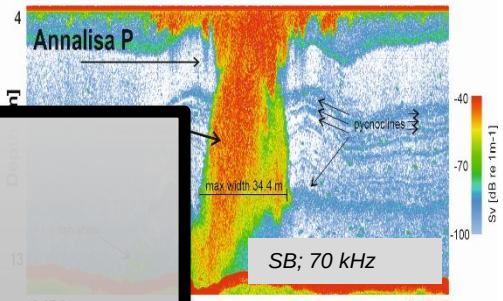
MBES Multispectral, 200-600 kHz

Anthropogenic

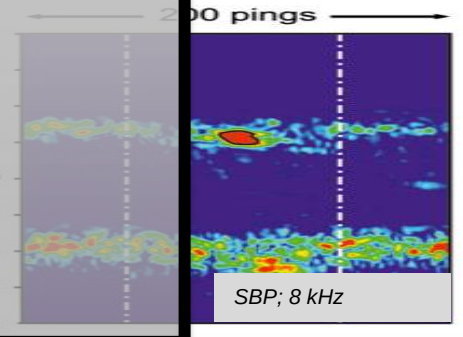
Wikipedia.org

MOBIL

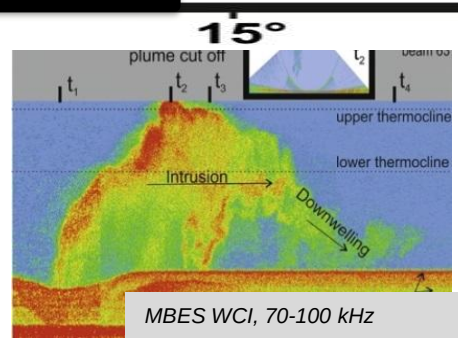
Acoustic imaging



SB; 70 kHz



SBP; 8 kHz

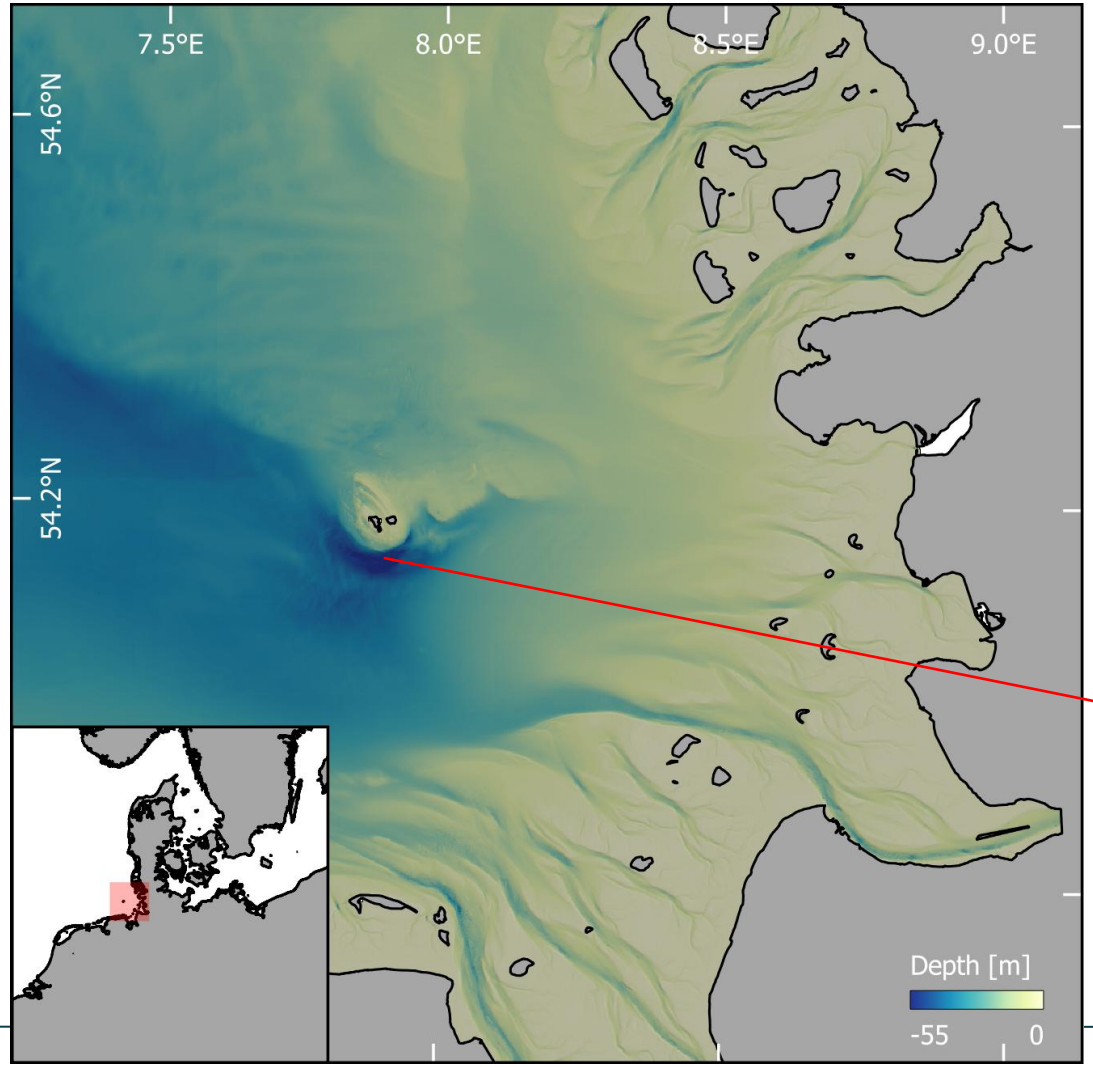


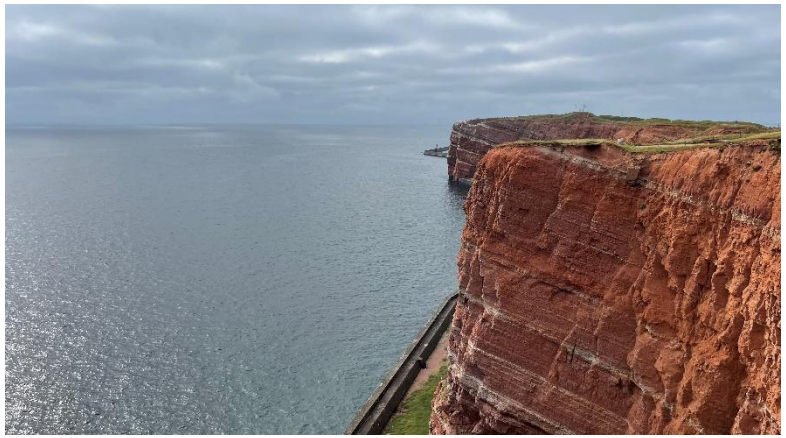
MBES WCI, 70-100 kHz

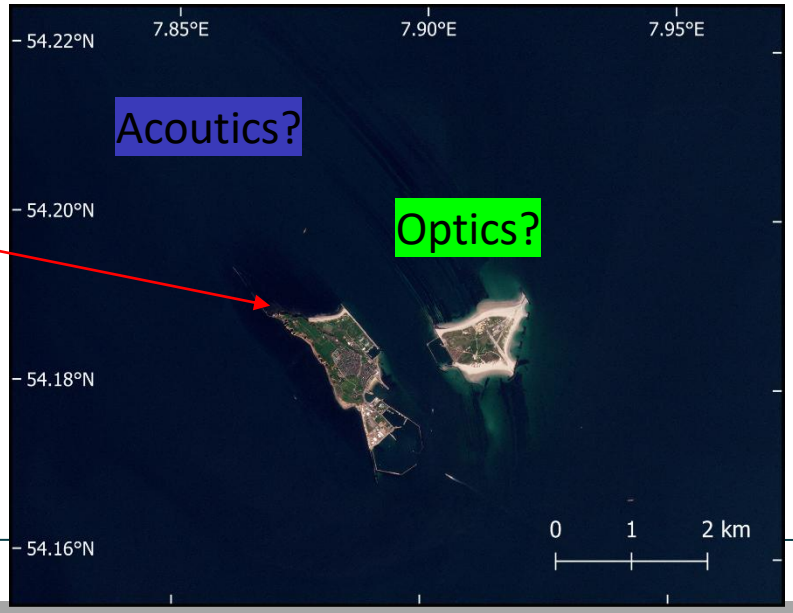
1. Sidescan Sonar
2. **Multibeam Echosounder**
3. **Sediment Profiler**
4. Fishery Echosounder
5. Laser
6. Airborne imagery

→ See publications on https://www.marinegeophysik.ifg.uni-kiel.de/

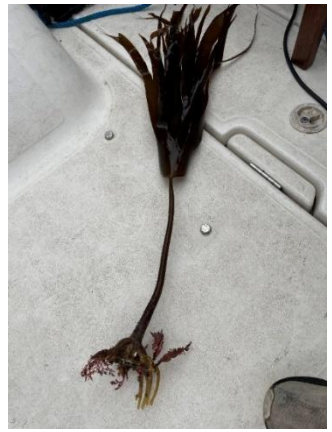
Helgoland – der Fels in der Brandung …





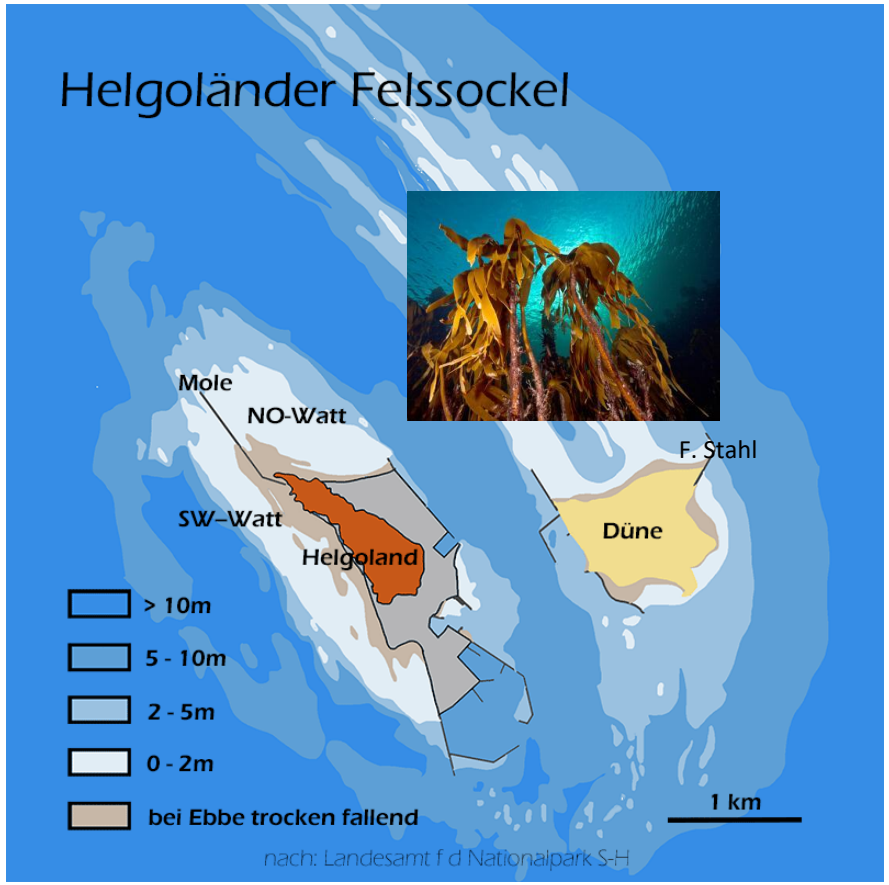


Der marine Biodiversitäts Hotspot Deutschlands

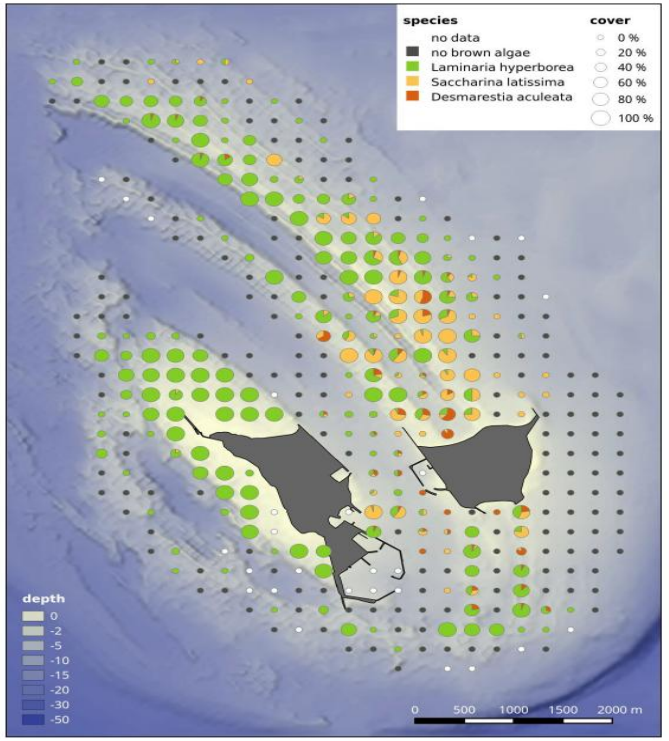


Laminaria hyperborea

Photo: Uli Kunz



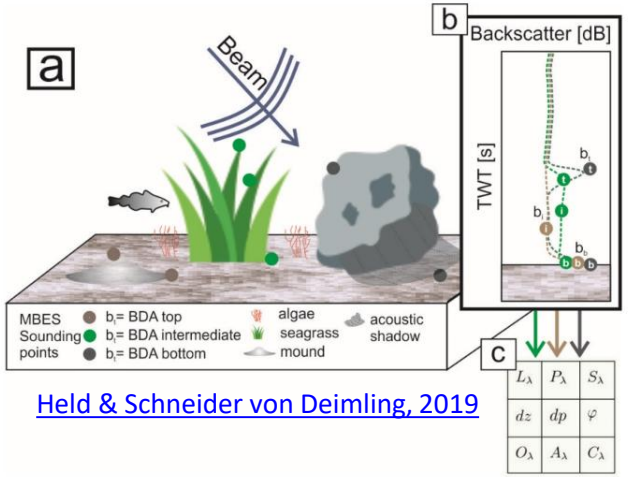
LKN.SH / BSH, basierend auf Singlebeam



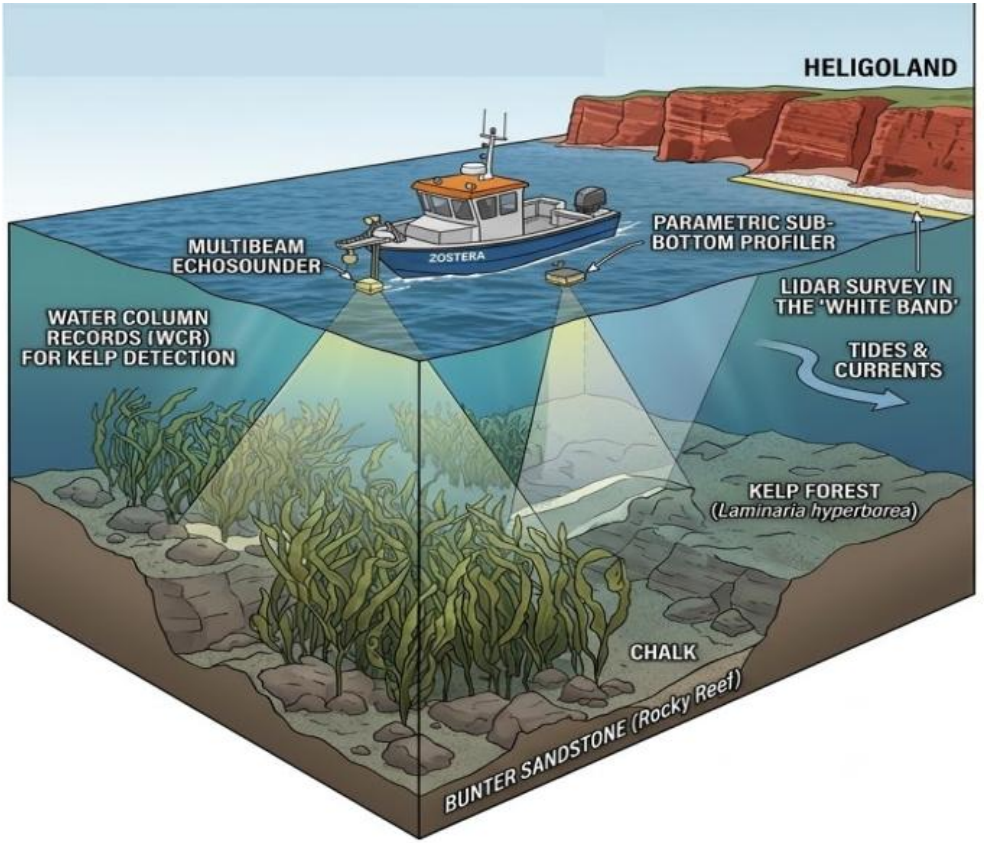
LFU Makrophytenanalyses
(Schubert, Wein, Bartsch, 2016)

Helgoland Herausforderungen

- Nautisch & Logistisch
  - Surveytiefe 0-5 m → kleines Boot
  - Exponiert
  - Untiefen + Felsuntergrund, Tidenhub
  - Kreuzsee, starke Tidenströmung
- Hydrographisch
  - 3 Wasserkörper
- Akustisch
  - Vegetation & Fehlechos



Held & Schneider von Deimling, 2019



Dr. Jens Schneider von Deimling (Inst. f. Geowissenschaften)

KIEL MARINE SCIENCE
CONNECTED RESEARCH
C | A | U

- **Survey Effort**

  7 scientific cruises

  1 airborne LiDAR s

- **Hydroacousti**

  ~4 TB raw hydroac

  Grid resolution: 0.2

  Accuracy: 2–4 cm

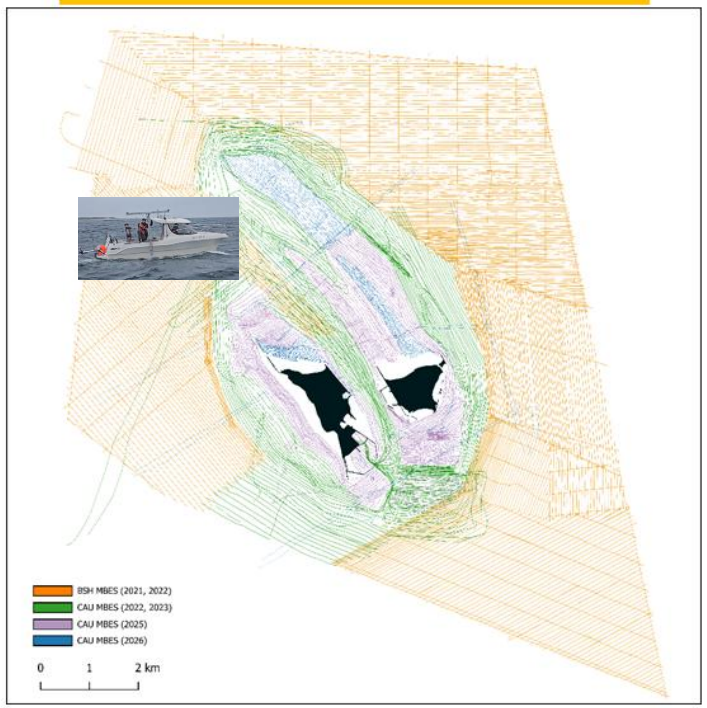
- **Ground-Truth**

  Underwater video

  CTD profiles

  Sediment samples

Mai 2026: we finished the last mile!



23-25.06.2026 38. Hydrographentag/DVW-Seminar, Lübeck-Travemünde
Dr. Jens Schneider von Deimling (Inst. f. Geowissenschaften)

Our Survey Boat FB Zostera

1. High-resolution mapping of bathymetry and backscatter
2. Geological reinterpretation of the Heligoland Complex
3. Acoustic detection and characterisation of submerged vegetation
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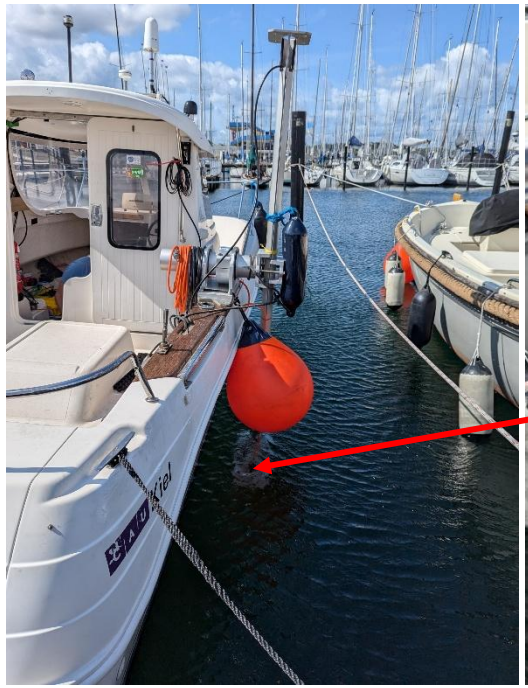
FB Zostera since 2018

- MBES NORBIT
- Applanix Wavemaster II
- SBP INNOMAR
- Sidescan Sonar
- Airgun Seismic
- SB Kongsberg EK80
- Video
- CTD AML X-probe and winch
- van-Veen Grab
- Onbord Survey computer
- DCT, very bright Monitors
- ENC plotter
- AIS transponder
- LTE Modem
- Diesel and elektric propulsion
- C4Rpole, elliptic pole

Data Acquisition

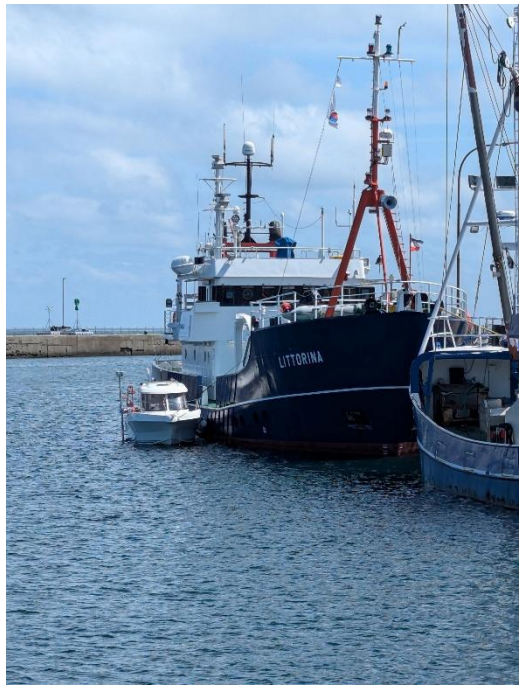
FB Zostera (0- 5 m)

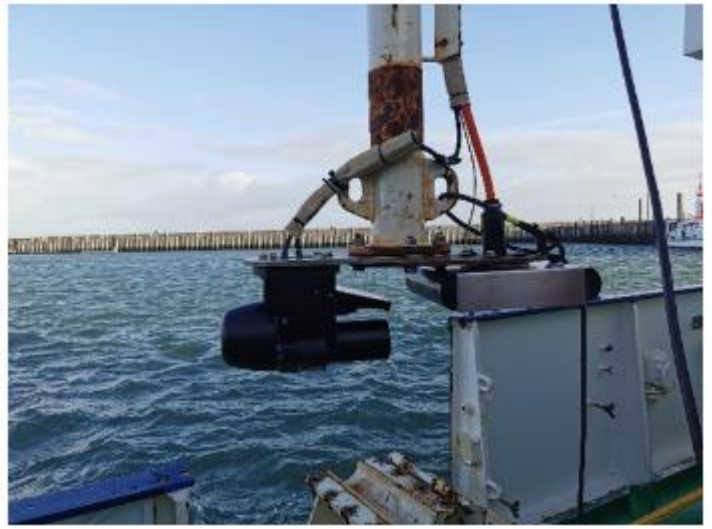


NORBIT shallow water iWBMS
Applanix Wavemaster II, full RTK
Chirp signal 400 kHz

INNOMAR smart
Frequencies: 100 kHz (HF) / 10 kHz (LF)

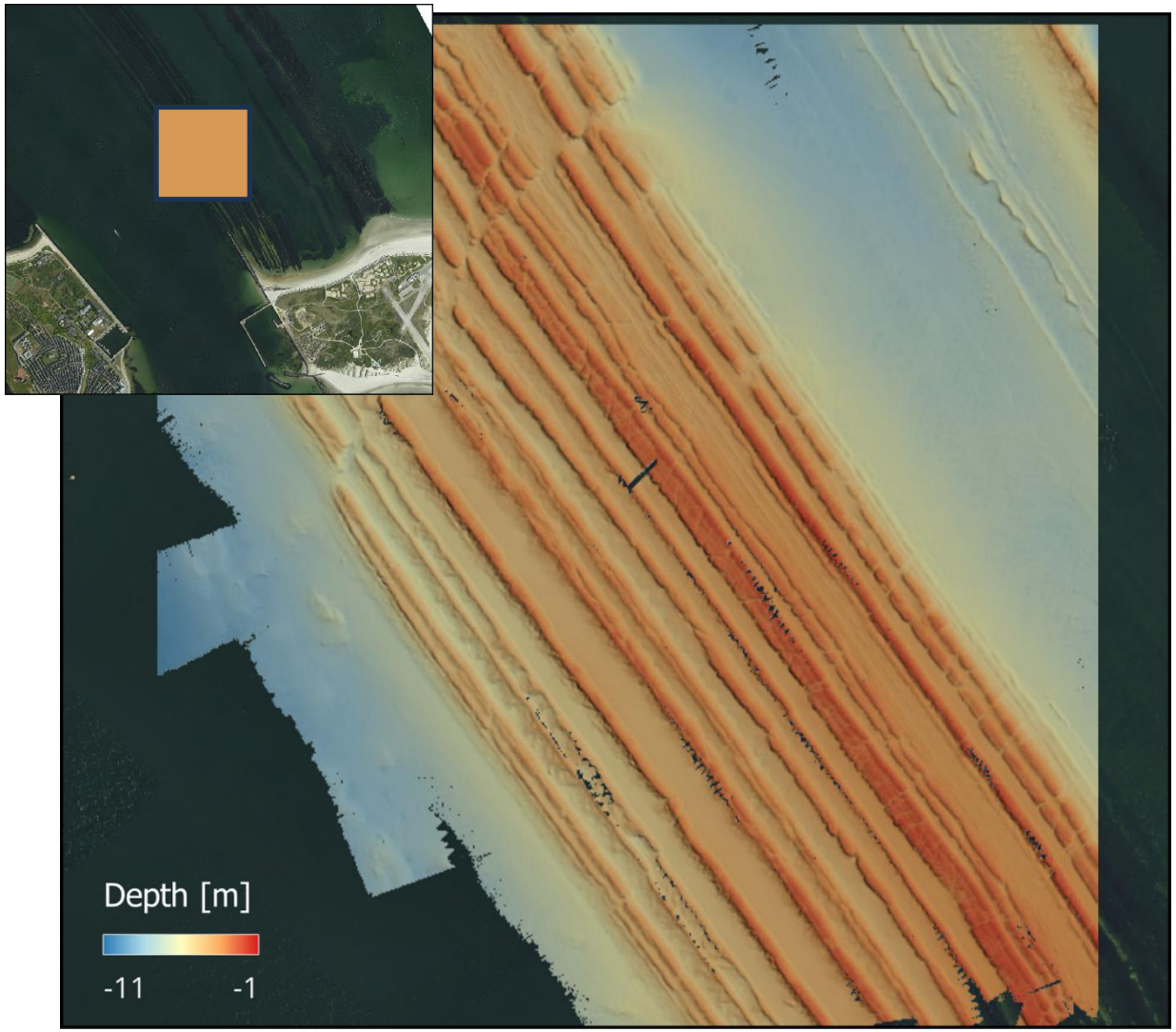
R/V Littorina (5-10 m)





INNOMAR SES2000 standard
Frequencies: 100 kHz (HF) / 15 kHz (LF)

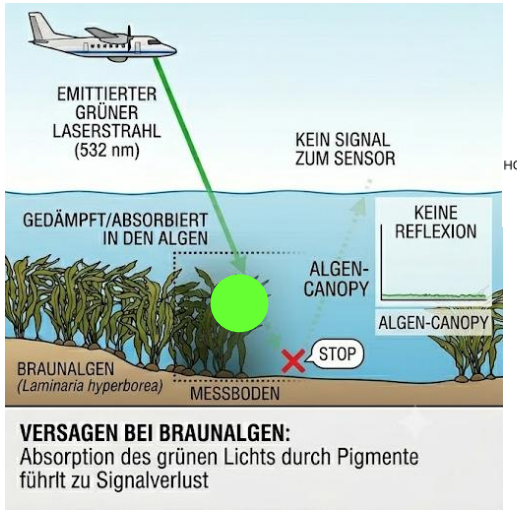
MBES – SBP Synchronization with Triggerbox



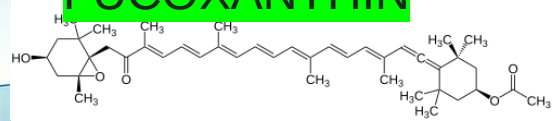
Satellite Image

LIDAR Riegl VQ880 (532 nm)

MBES NORBIT 400 kHz



FUCOXANTHIN



Absorptions Maximum
450 bis 540 nm

LIDAR Eindringtiefe:

4.5 m auf Sand

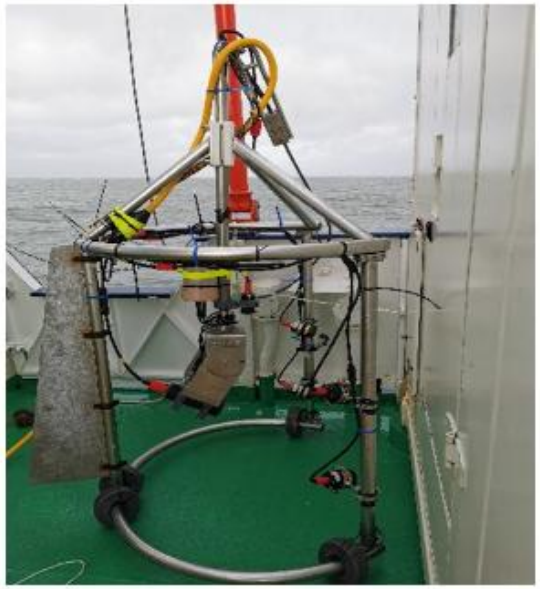
0 m bei Vegetation

→ Full Waveform Analyse ?

Dr. Jens Schneider von Deimling (Inst. f. Geowissenschaften)


BSH
LKN.SH
C A U
Christian-Albrechts-Universität zu Kiel
Mathematisch-Naturwissenschaftliche Fakultät

Validierung mit Kamera (Biologie) & Greifer (Geologie)



First results

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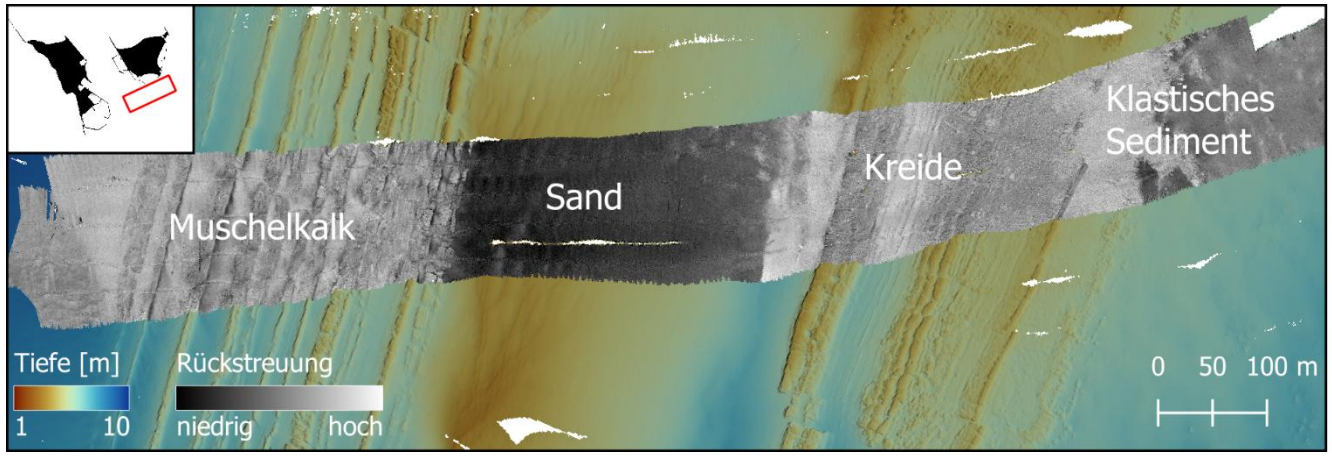
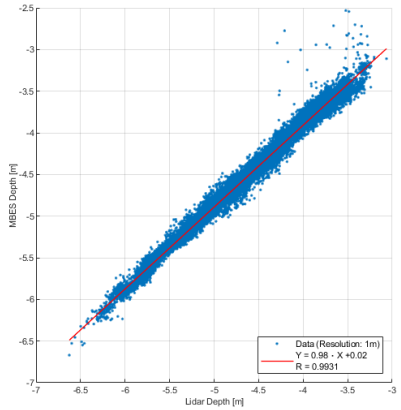
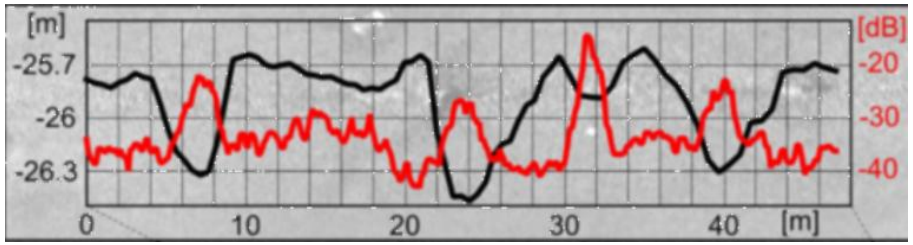


Schneider von Deimling & Jensen, 2026 HN133

0.25 m Grid
MBES – LiDAR (r=0.993)
Snippet Backscatter (5 cm Auflösung)
BS Kompensiert
BS Unkalibriert





MBES **bathymetry** / **backscatter**

First results

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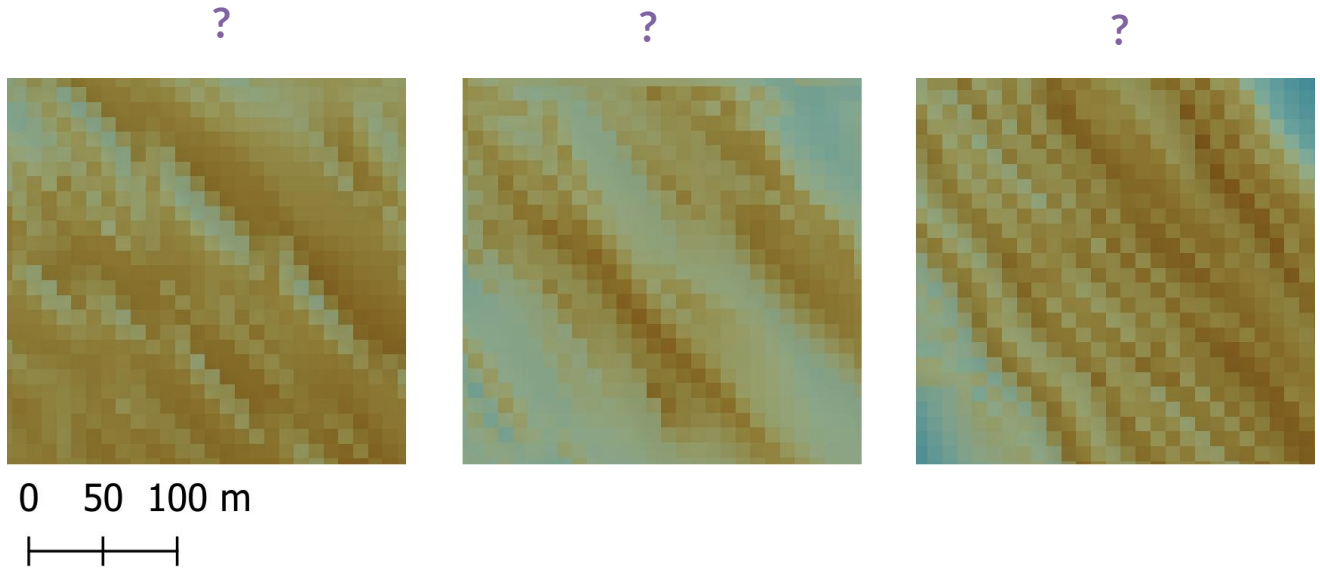
Deriving geology from microbathymetry?



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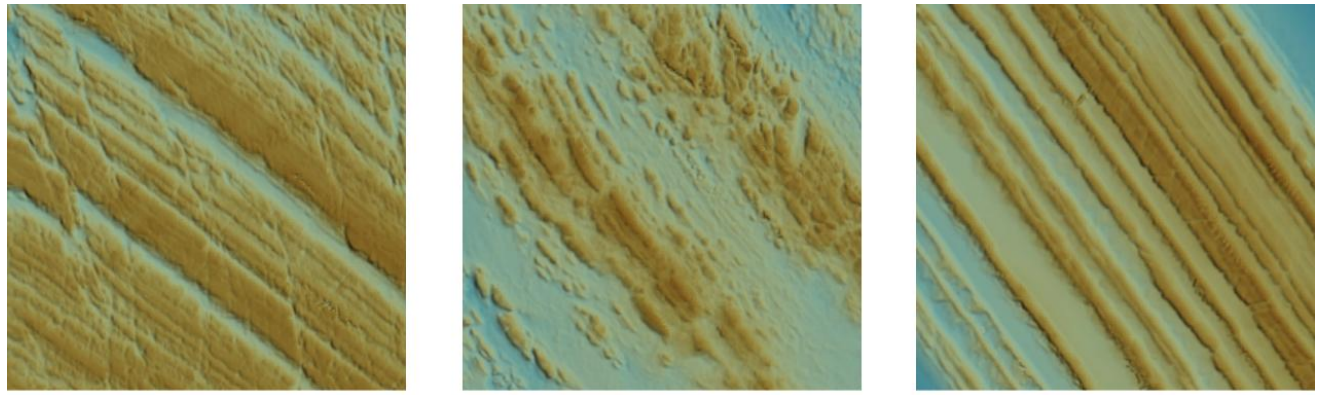
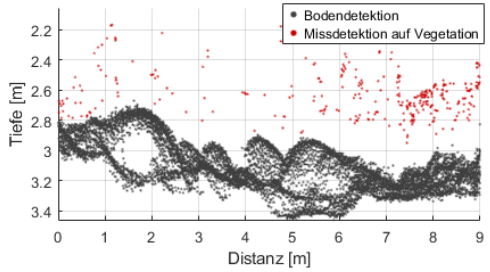
Deriving geology from microbathymetry?

Buntsandstein | Kreide | Muschelkalk





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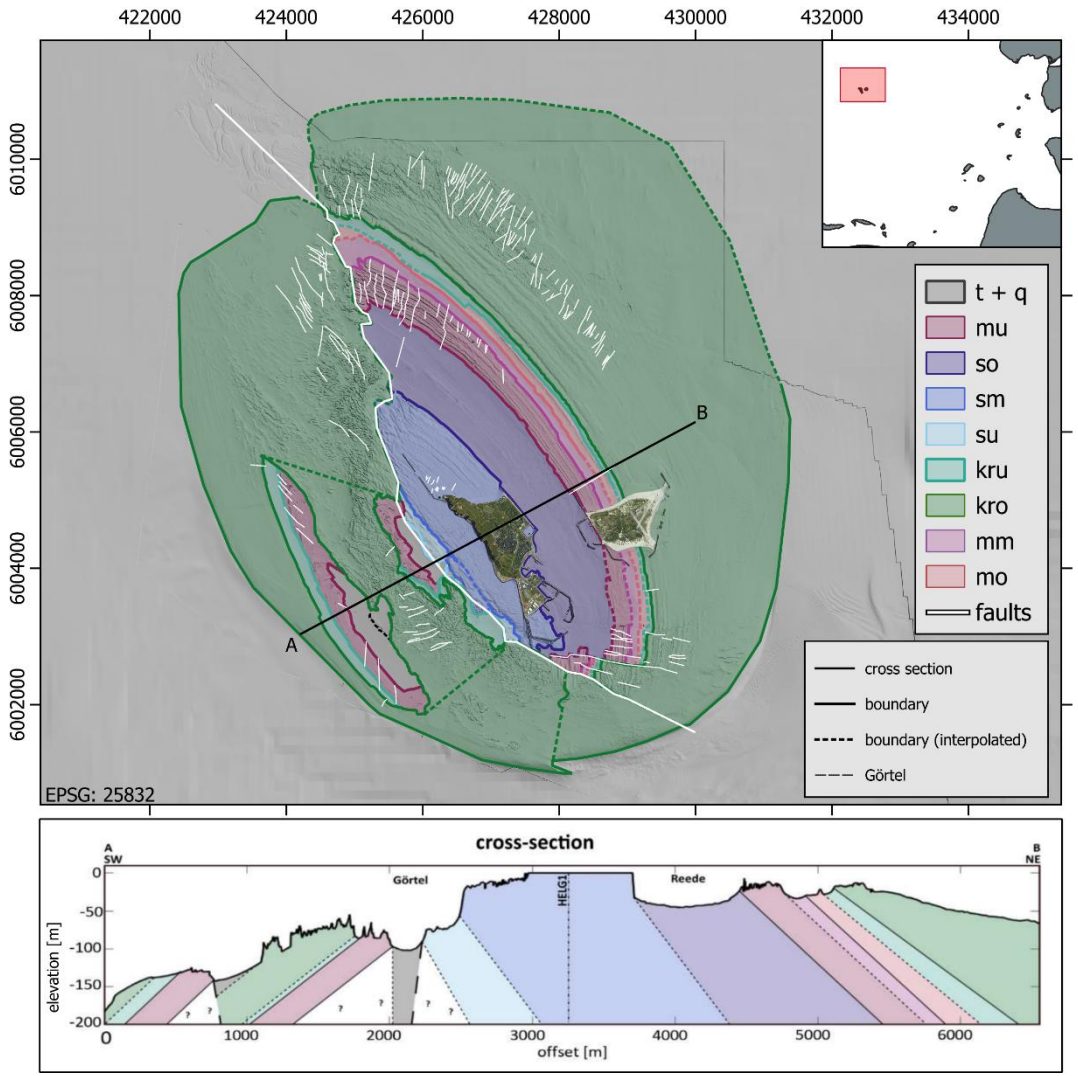

Apdapted from Anna Ziehl, 2024

First results

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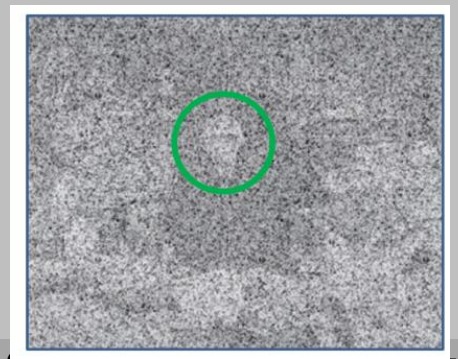

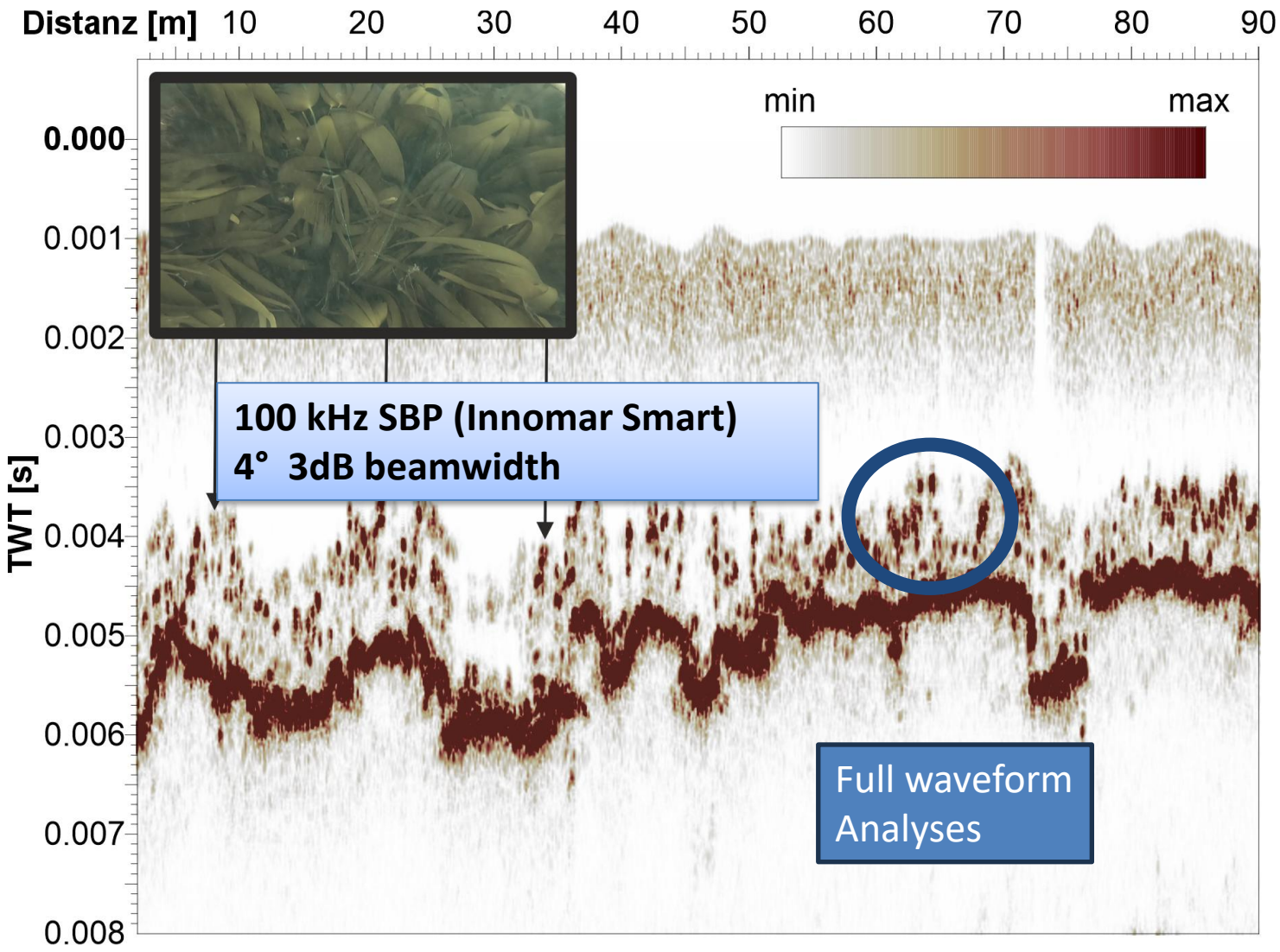

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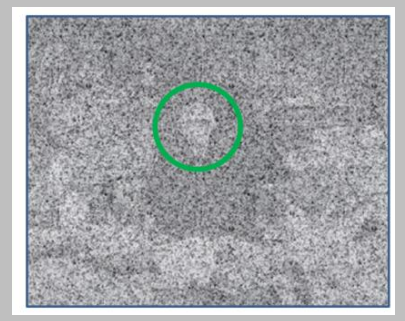
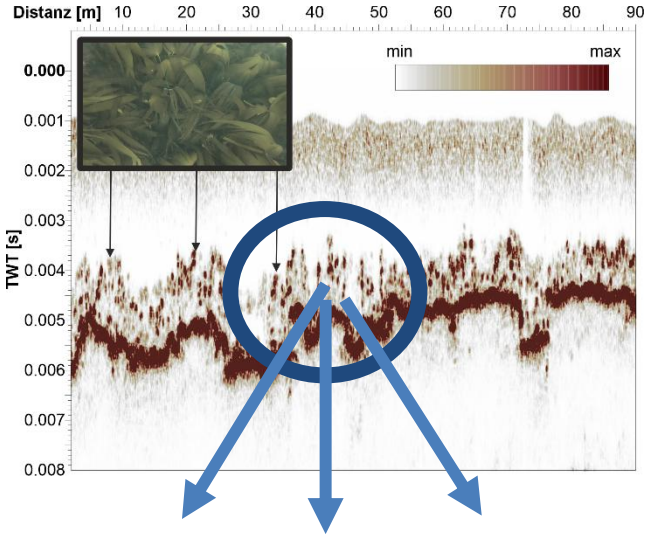
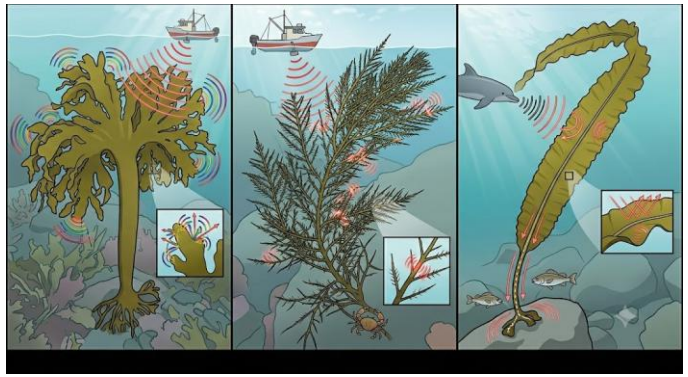




100 kHz SBP (Innomar Smart)
4° 3dB beamwidth

Full waveform analyses
- Wavelets
- Seismic attributes
- ML



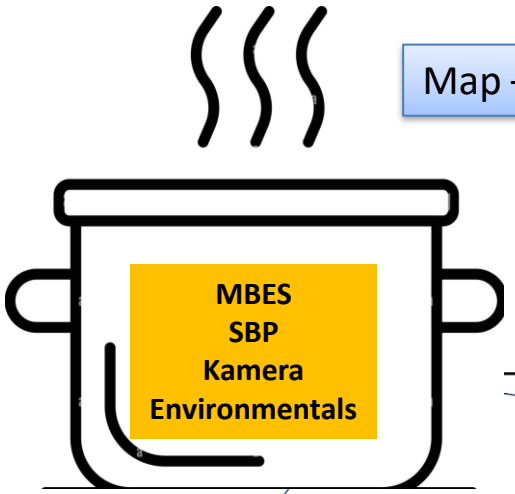
Eiche? *L. hyperborea*

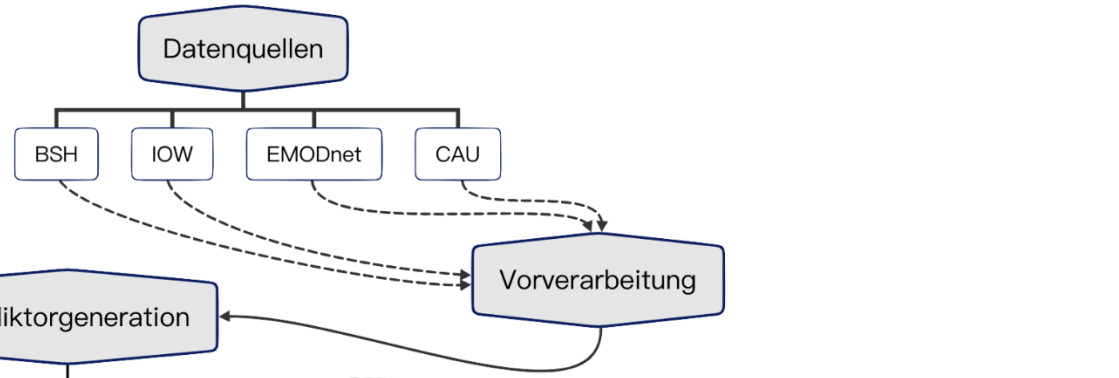
Tanne? *D. aculeata*

Bambus? *S. latissima*

Nano Banana 2

Map – Mine – Model



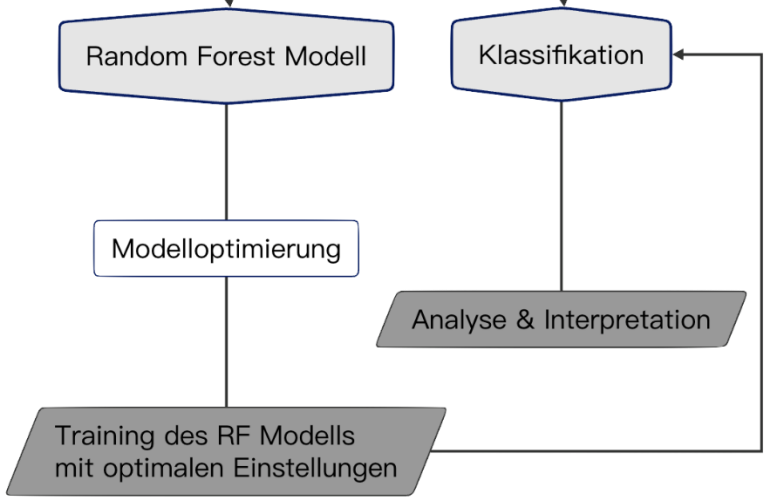


Feature_DEM
(Pythonprogramm)

- 10x10m Bathymetrie Ableitung von:
  - Tiefe
  - Slope
  - Aspect
  - Topographic position index (TPI)
  - Topograpic roughness index (TRI)
  - Topographic wetness index (TWI)
  - maximaler lokaler Slope
  - Profilkrümmung
  - Querschnittskrümmung
- 50x50m Bathymetrie:
  - Aspect
  - Slope
  - TPI
  - TRI
- Erstellung von ASCII hochdimensionalen Datenwürfel mit 10x10m Auflösung

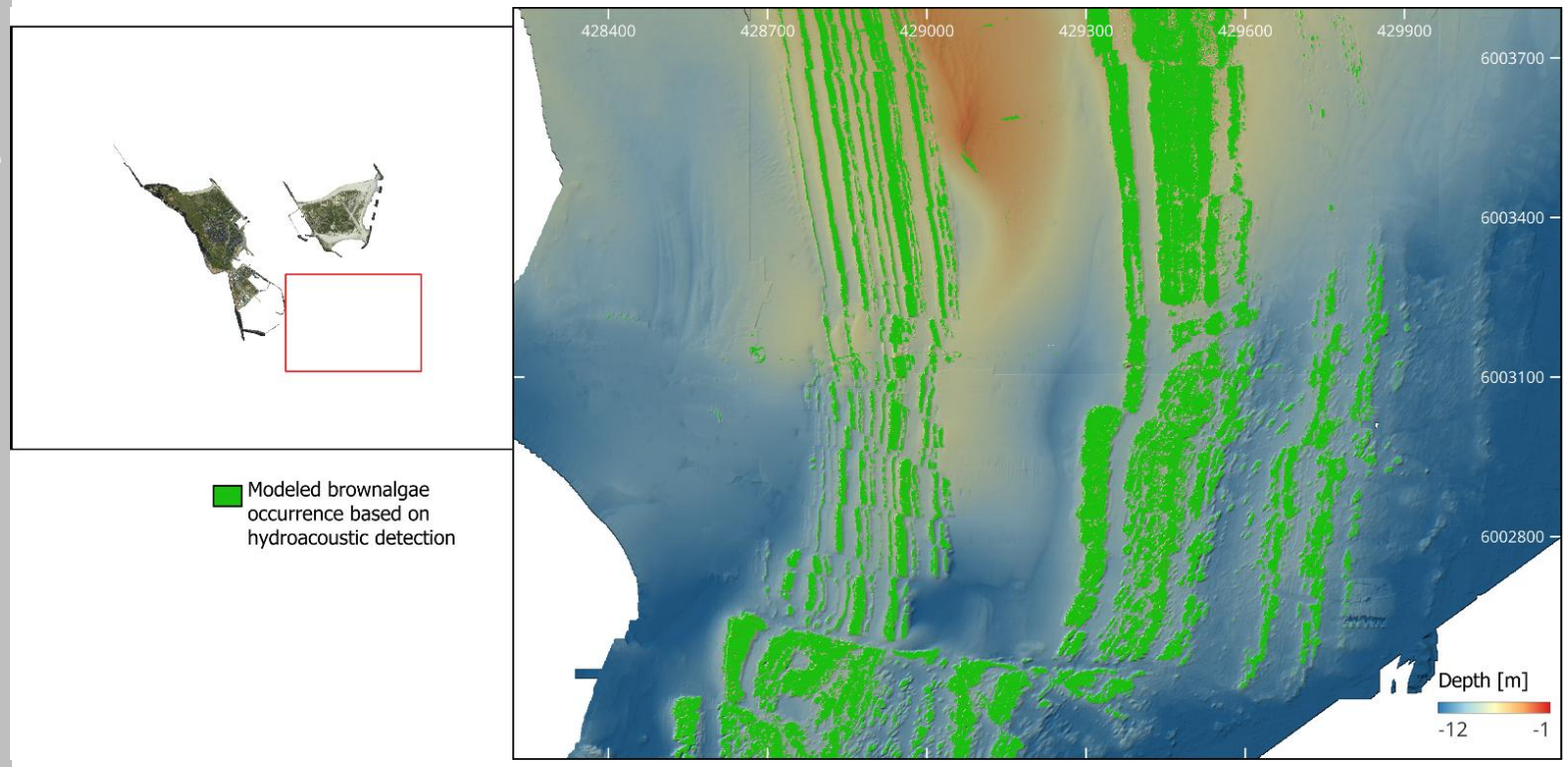
Extraktion
(Qgis)

- Erweiterung des Datenwürfels mit:
  - Temperatur
  - minimaler Salzgehalt
  - Bodenschubspannung
  - Strömungsgeschwindigkeit
  - signifikante Wellenhöhe
  - Lichtverfügbarkeit am Boden
  - Sediment
  - Tiefenabstand zur Ausgleichsebene
  - maximaler Fetch
  - durchschnittlicher Fetch
  - Fetch aus östlicher Richting
  - Fetch aus westlicher Richtung
- Export zu ASCII



First results

1. High-resolution mapping of bathymetry and backscatter
2. Geological reinterpretation of the Heligoland Complex
3. Acoustic detection and characterisation of submerged vegetation
4. Predictive habitat modelling and carbon budget estimation



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Wozu eignet sich das am Ende?

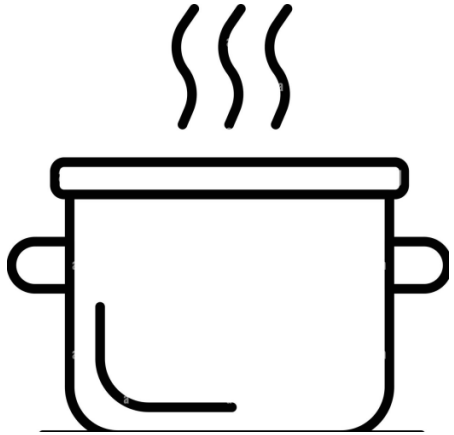
Map & Mine

MBES (Fächerecholot):

- Neue geologische Karte Helgolands
- Morphometrie und Substrat als Prädiktor für Habitate

SBP (Sedimentecholot):

- Nachweis und Quantifizierung von Biomasse (Kelp)



Model & Predict

- Identifikation von ökologischen Stressoren
- Flächenhafte Biomasse-Extrapolation und Bilanzierung (CO2)
- effizienteres Monitoring und optimierte Schutzstrategien

I. Hardware | II. Data acquisition | III. Processing | IV. Calculation of bathymetry and backscatter | V. Models

MBES (≤50Hz per beam)
- Traveltime
- Angle
- Beam backscatter
- Calibrated backscatter
- Sidescan
- Snippet sidescan
- Water column imagery

Keel sound velocity probe
- Velocity

MotionReference Unit* (200Hz)

Gyro*
- Heading

GNSS* (200Hz)
- Position
- Phase
- Real time kinematic

Vessel
- Draft
- Squat

CTD
- Conductivity
- Temperature
- Depth

*Inertial navigation system (INS)

Correcting position/depth of sounding
Correcting backscatter value of sounding
Correcting bottom detection algorithm)

Bathymetry:
Correction of tide, raytracing, offsets: roll+pitch+yaw+latency (patch test⁺) and draft, squat

Raytracing
Cleaning
Filtering
CUBE

CAT A --> cm accuracy

IHO

CAT E (environmental) 0.3 dB

GEOHAB BSWG

Jackson
AB

MBES experimental
- Snippets
- Multispectral
- Point Cloud
- Multidetect
- WCI

S-44 Edition 6.2.0

9

3.8 Nature of the Botton

Characterisation Methods

The nature of the bottom should be determined in potential anchorage areas, other critical areas, and in areas where bottom conditions are suspected to have significant influence on required feature detection. Components of bottom characterisation techniques include: physical sampling (PHY), visual/optical analysis (VIS), laboratory analysis (LAB), and inference technique (INF) from sensors data (e.g. backscatter).

Mophometry nein
Unsupervised classification
Supervised classification
Groundtruthing

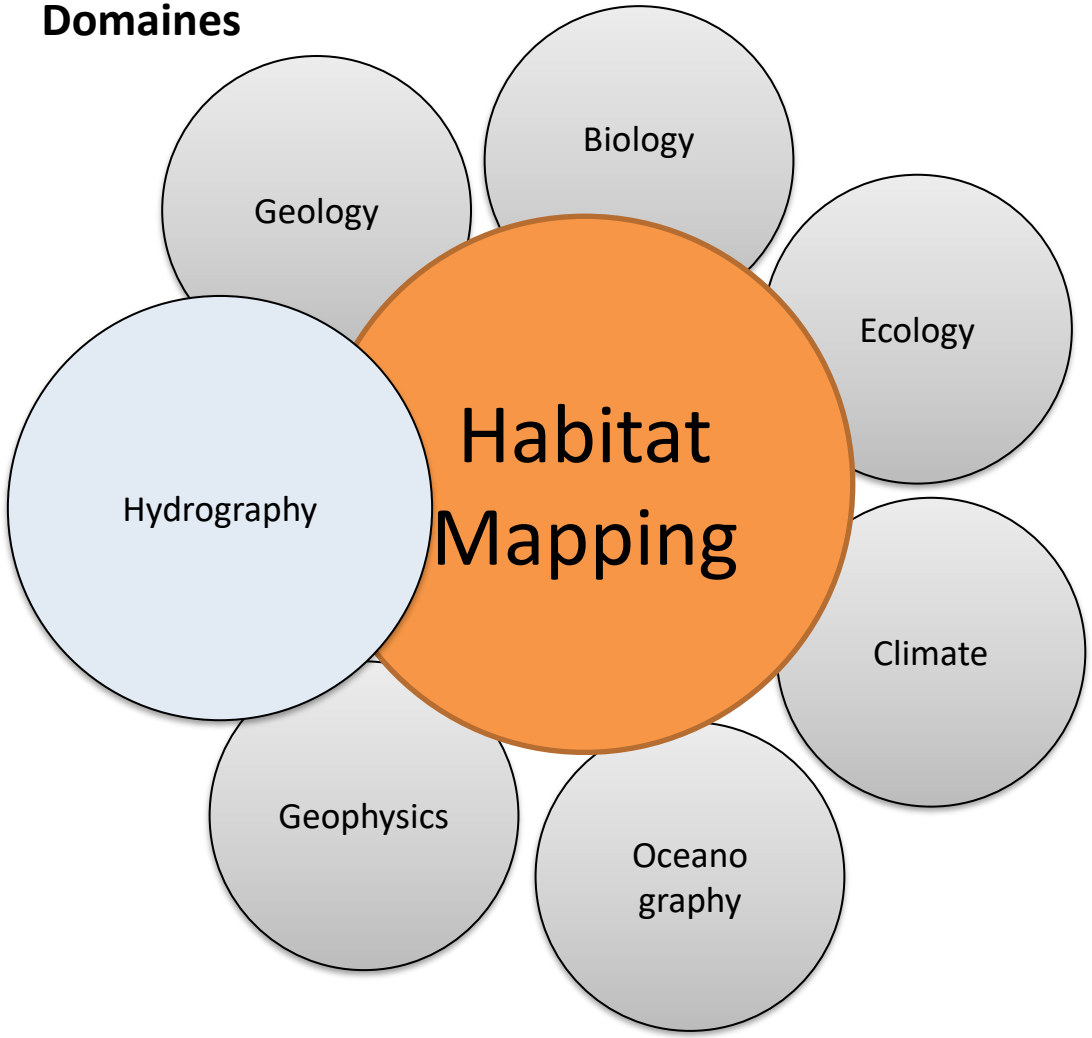
⁺ correcting static offsets of hardware:
x, y, z [m] – distance between components
α, β, γ [°] – angle offsets in orientation

Habitat Mapping… truly cross-disciplinary

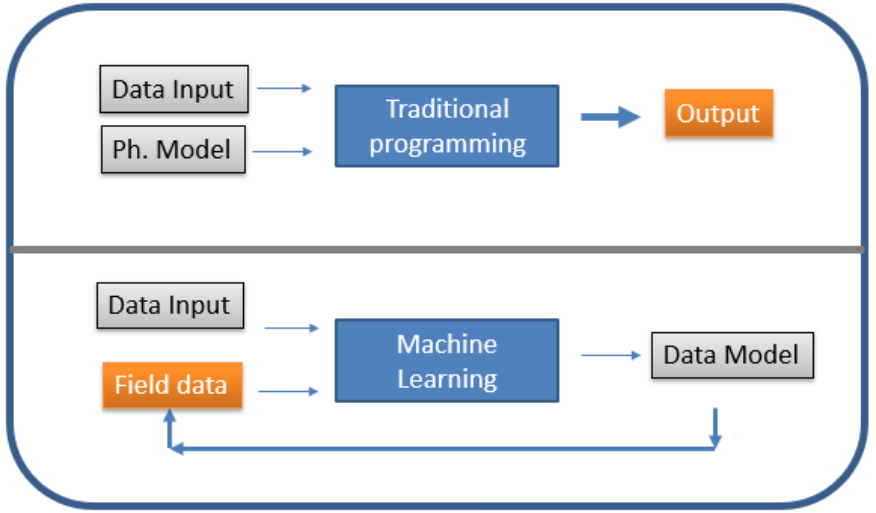
Acquisition
Processing

- Acoustics
- Engineering
- Data Science

Domaines



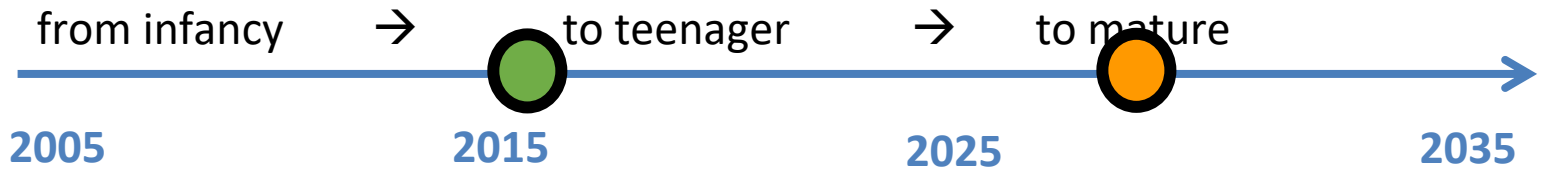
Model Output



Coastal habitat mapping using modern MBES systems: **where are we?**

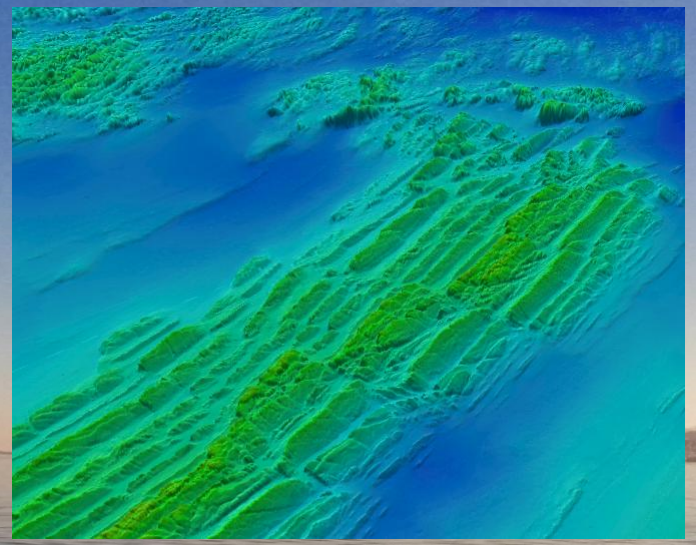
Task	Challenge	Solution
Remote sensing reliability	Mixed habitats	Feature / Spectral libraries Indices R&D
Map Large Areas	Data rates: 1h →50 Mio. data points	Data scientists Super Computers
Seafloor Classification and Habitat Modeling	High data dimensionality: Bathy, Multispectral backscatter, Derivatives…	Machine learning R&D
Calibration	Sensor drift	Manufacturors R&D
.....	.....	.....

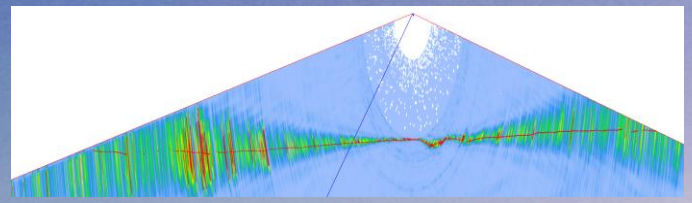
Emerging Market driven e.g. by MSFD

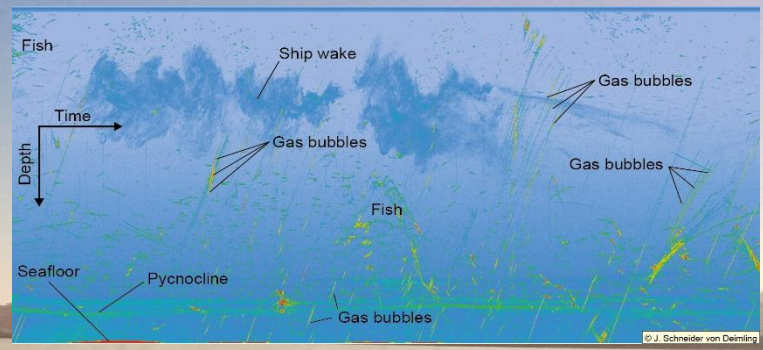


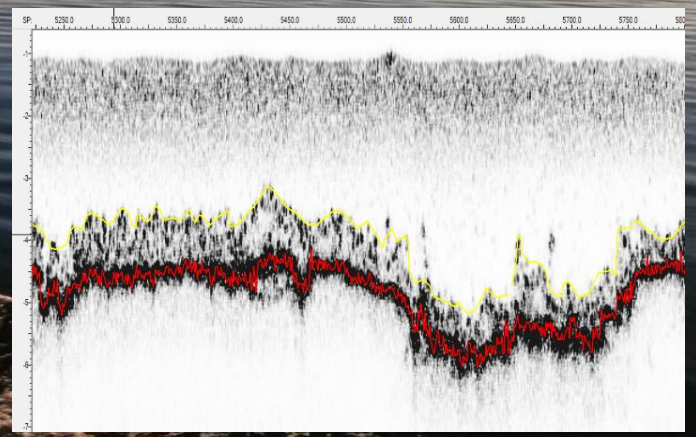
Vielen Dank für Ihre Aufmerksamkeit!

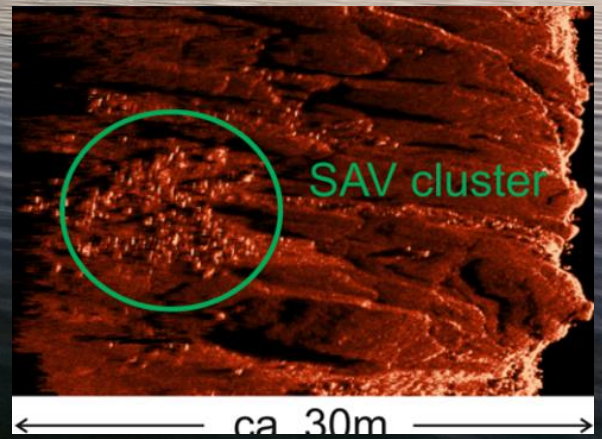
https://www.marinegeophysik.ifg.uni-kiel.de











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