Geo-acoustic modelling of late and postglacial sedimentary sequences in the Baltic Sea and their acoustic visibility

Michael Endler, et al.
Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany

Contact

Address Leibniz-Institut für Ostseeforschung Warnemünde (IOW)
Seestraße 15
18119 Rostock
GERMANY

Email michael.endler@io-warnemuende.de

Website www.io-warnemuende.de

7th Workshop
Seabed Acoustics
Rostock, November 19 - 20, 2015

Geo-acoustic modelling of late and postglacial sedimentary sequences in the Baltic Sea and their acoustic visibility.

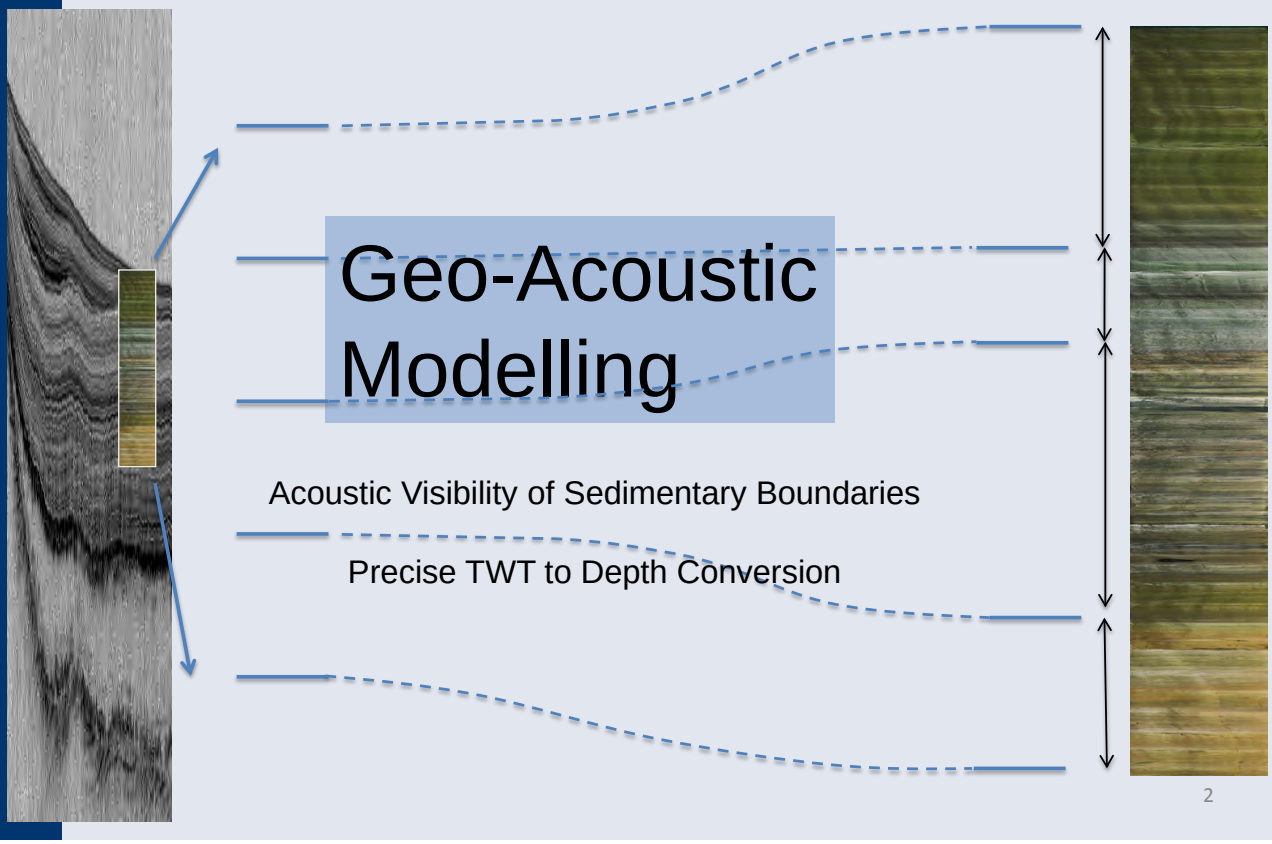
Michael Endler[1], Rudolf Endler[1], Jens Wunderlich[2], Matthias Moros[1], Jørn Bo Jensen[3], Helge W. Arz[1]

1 Leibniz Institute for Baltic Sea Research Warnemünde (IOW)
2 Innomar Technologie GmbH
3 Geological Survey of Denmark and Greenland (GEUS)

BMBF – joint research project
Innomar Technologie GmbH & IOW

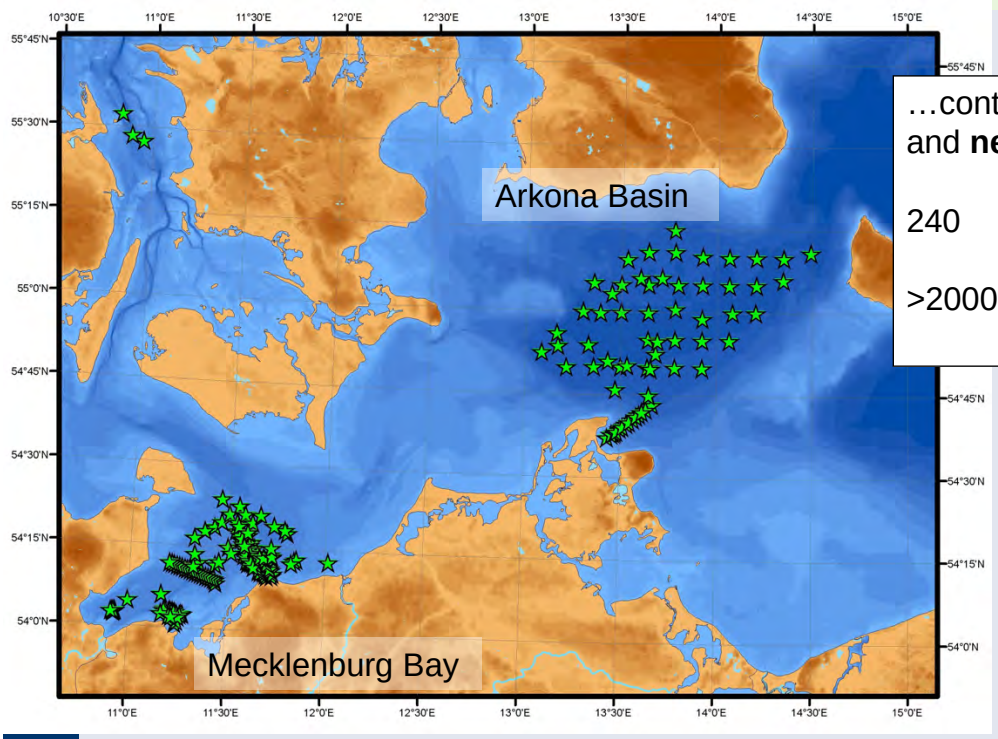
Motivation

7th Workshop
Seabed Acoustics
Rostock, November 19 - 20, 2015



Working Areas

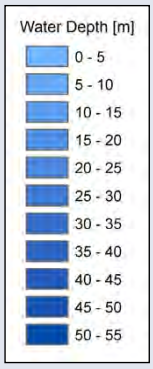
The data base…



…contains data from **old** and **new** sampling stations

240 sampling stations

>2000 sub samples



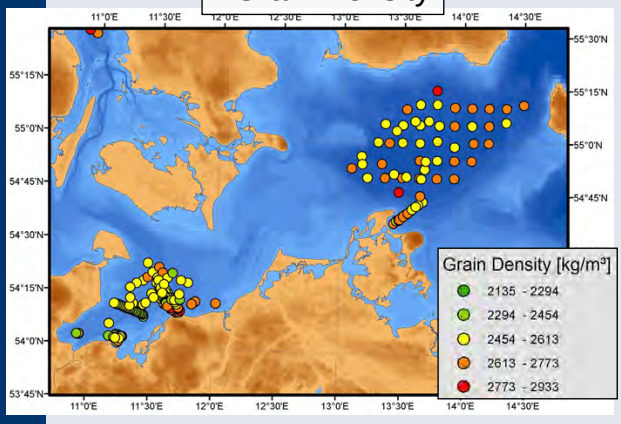
- surface data => no influence of compaction
- long core data for depth model

3

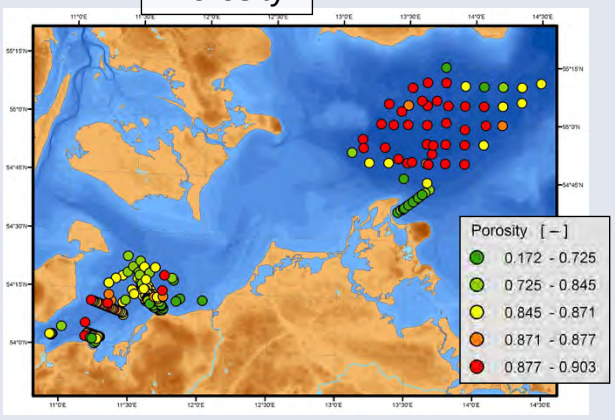
Results: key parameters for calculating acoustic properties

surface data

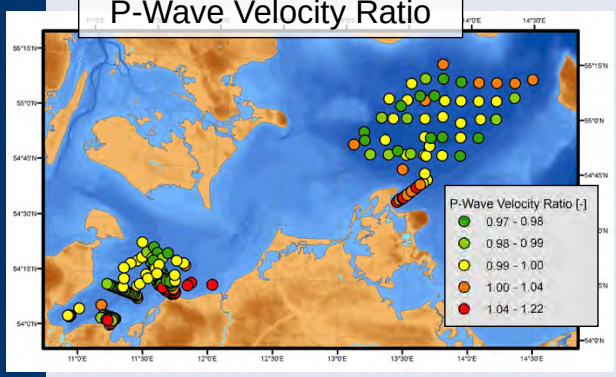
Grain Density



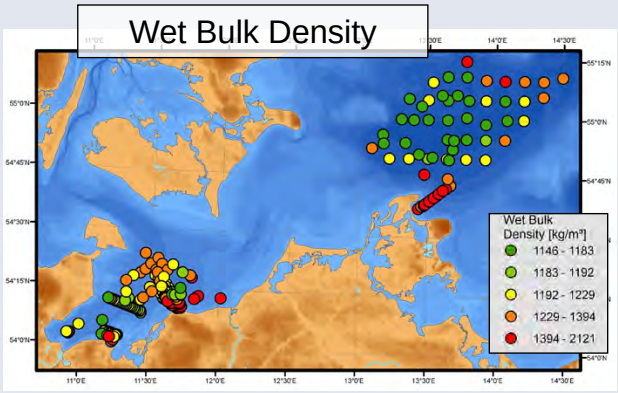
Porosity



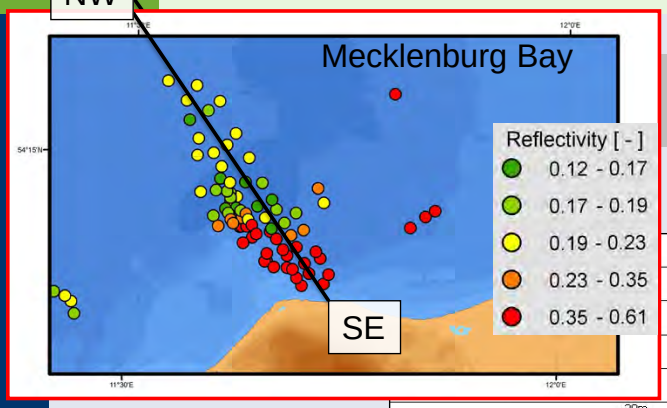
P-Wave Velocity Ratio



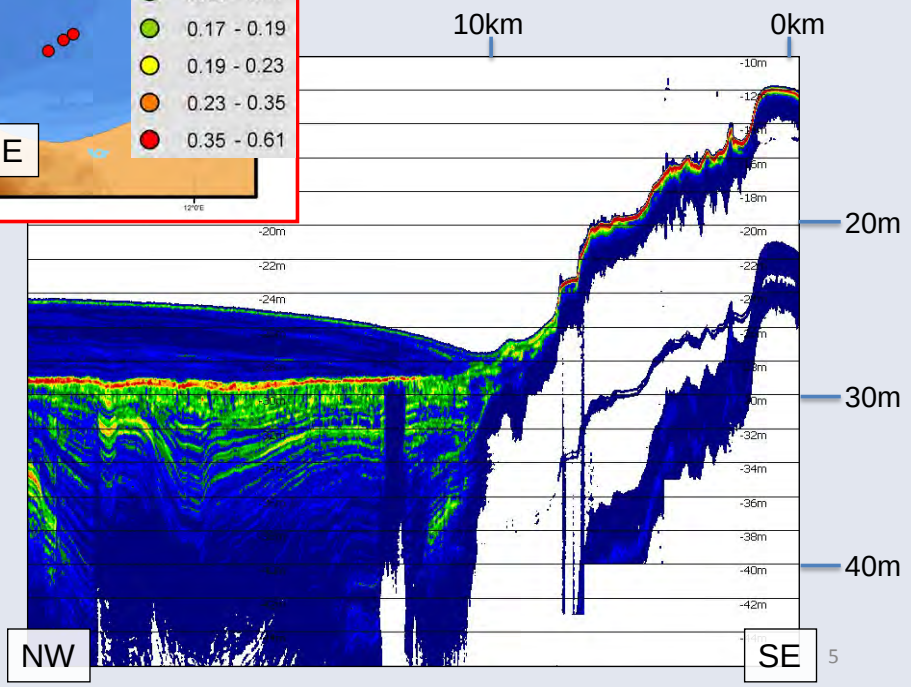
Wet Bulk Density



Comparision of the calculated Acoustic Reflectivity of the Seafloor Sediments with Sediment Echosounder Profiles



=> The compiled data set is a valuable base for Acoustic Seafloor Classification.



5

Methodology

Defining Key Parameters

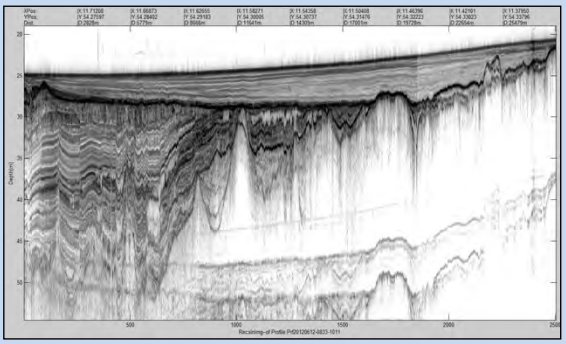
What makes an acoustic reflector?

$$R_x = \frac{(Zac2 - Zac1)}{(Zac2 + Zac1)}$$

(normal incidence)

$$Zac = wbd \cdot Vp$$

acoustic impedance = wet bulk density * sound velocity



In Situ measurements
=> Vp

Core logging
=> Vp, wbd

Empirical Relationships
=> Vp=*f*(por, …), wbd=*f*(gs-mean, …)

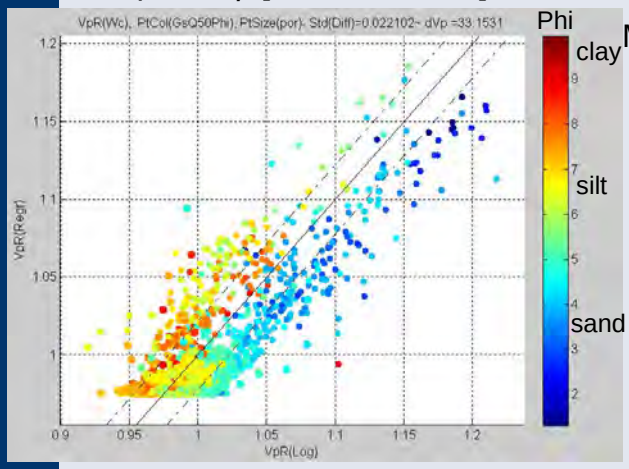
Geoacoustic Modelling
=> Vp=*f*(por, ds, LOI, S, T, P, …)

=> synthetic seismograms ; TWT – depth conversion

6

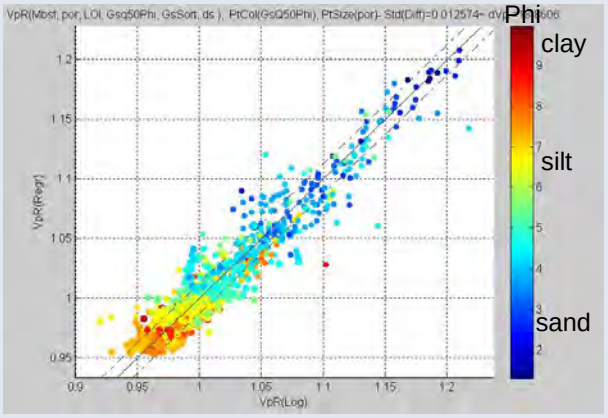
Results: Empirical Regressions

VpR = ƒ [Water Content]



Modeled vs. measured: ±34.6m/s

$$\mathbf{VpR}=\frac{\text{VpSediment(STP)}}{\text{VpPoreFluid(STP)}}$$



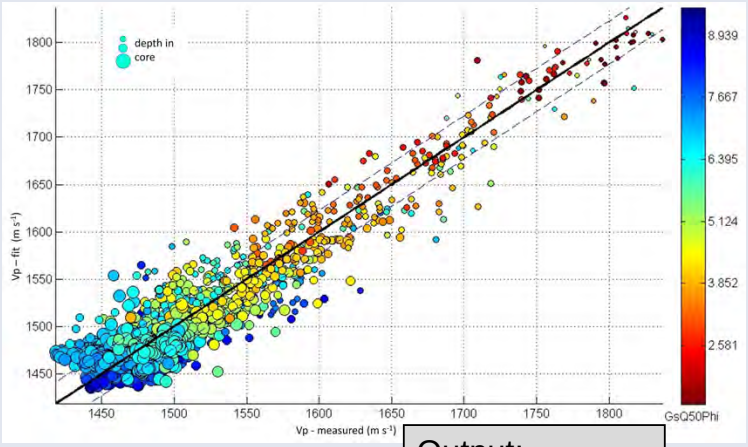
Modeled vs. measured: ±18.9m/s

VpR = ƒ [CoreDepth, GrainSize-Median, GrainSize-Sorting, Porosity, LOI, Grain Density]

7

Results: Biot - Stoll model

Modeled vs. measured: ±22.9 m/s



Input:

Environmental parameters
Salinity, temperature of the pore fluid, depth (density, bulk modulus , viscosity of pore fluid)

Sediment parameters:
Grain density
Bulk modulus of Sediment grains
Porosity
Permeability
Pore size parameter
Structure factor
Shear modulus of frame
Bulk modulus of frame
Modulus of the pore fluid *(in situ conditions!)*
Desired acoustic wave frequency

Biot-Stoll Model admits fluid motion relative to the solid frame

Output:

Phase and velocity

of

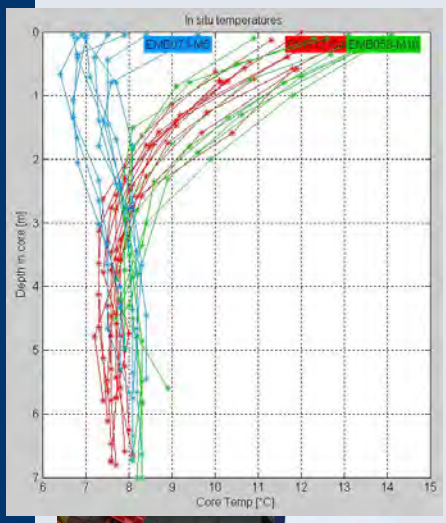
pressure - and

shear - waves

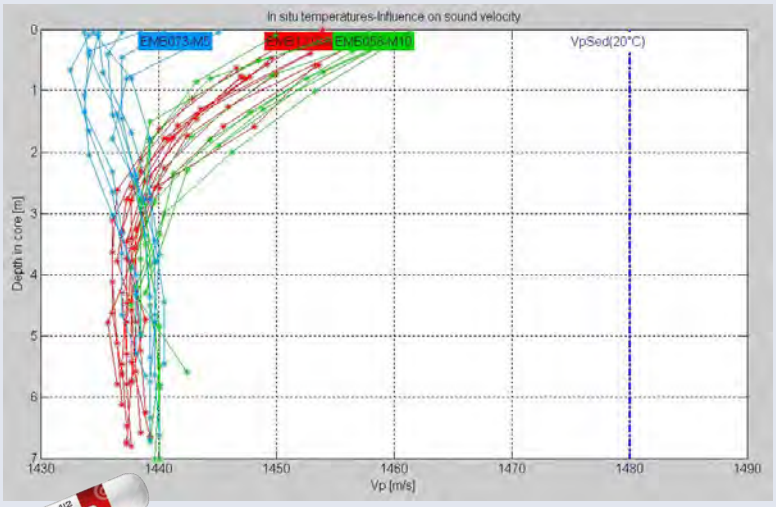
8

In Situ Correction

Temperature



spring autumn



Vp-shift of **40m/s** compared to laboratory conditions!

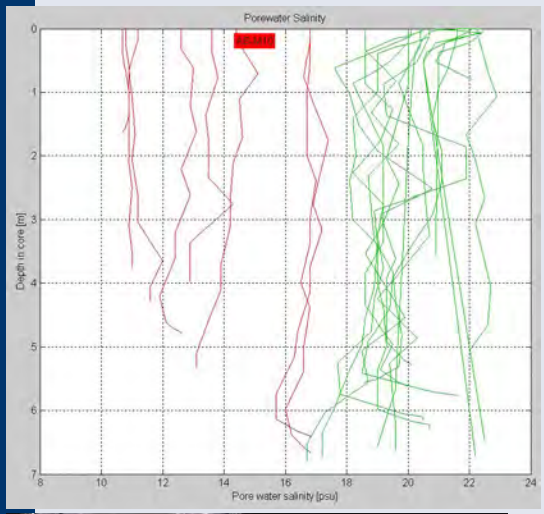
Seasonal Variance!

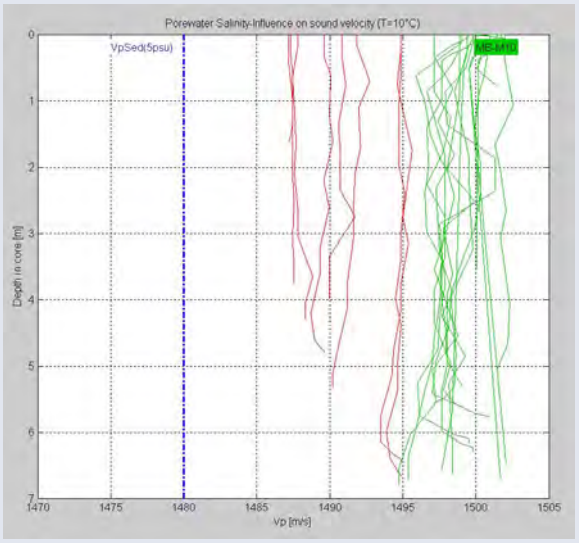
9

In Situ Correction

Salinity

Arkona Basin Mecklenburg Bay



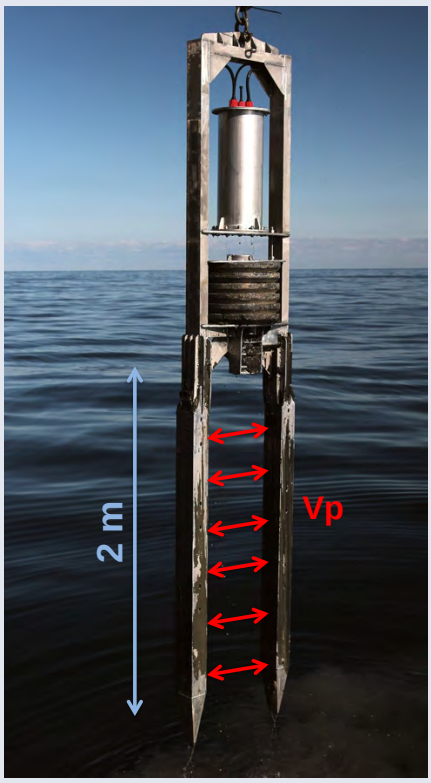


Vp-shift of **20m/s** per **15psu**!

Regional Variance!

10

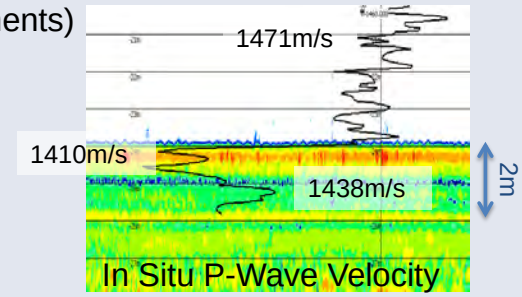
In Situ Probe Prototype



measures:

- P-Wave Velocity
- P-Wave Attenuation
- Wet Bulk Density = f(Rx,Vp)
- Inclination
- Depth

uses **multiple** frequencies in the range of sediment acoustic profilers (important for **gassy** sediments)

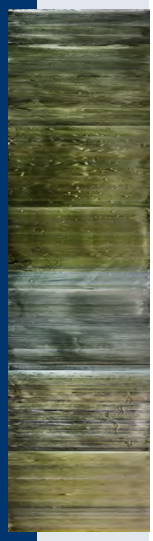


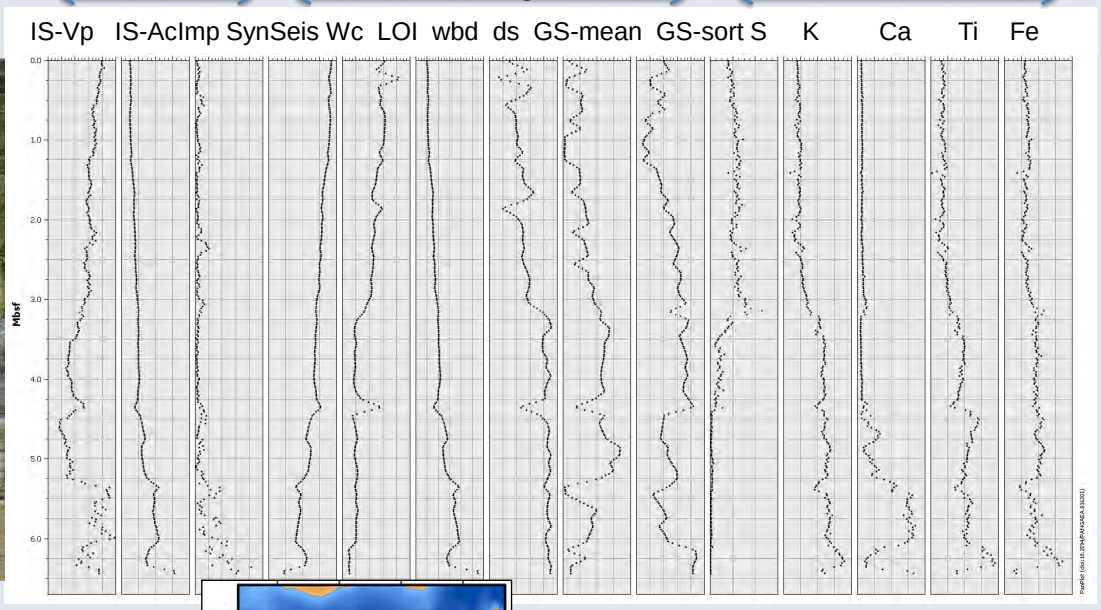
11

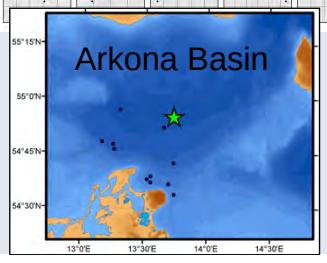
Results: Model Performance

EMB058-15-8gc

acoustical ↔ sedimentological ↔ chemical



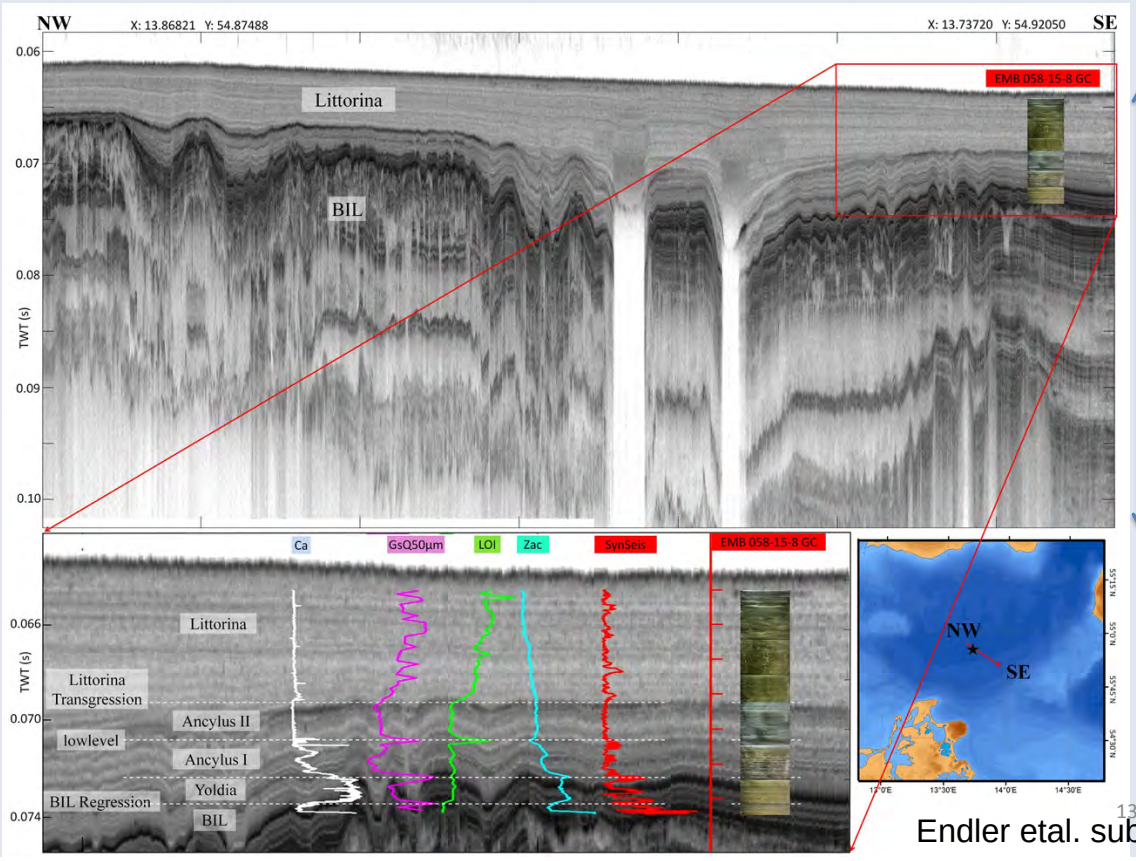




12

Results: Model Performance

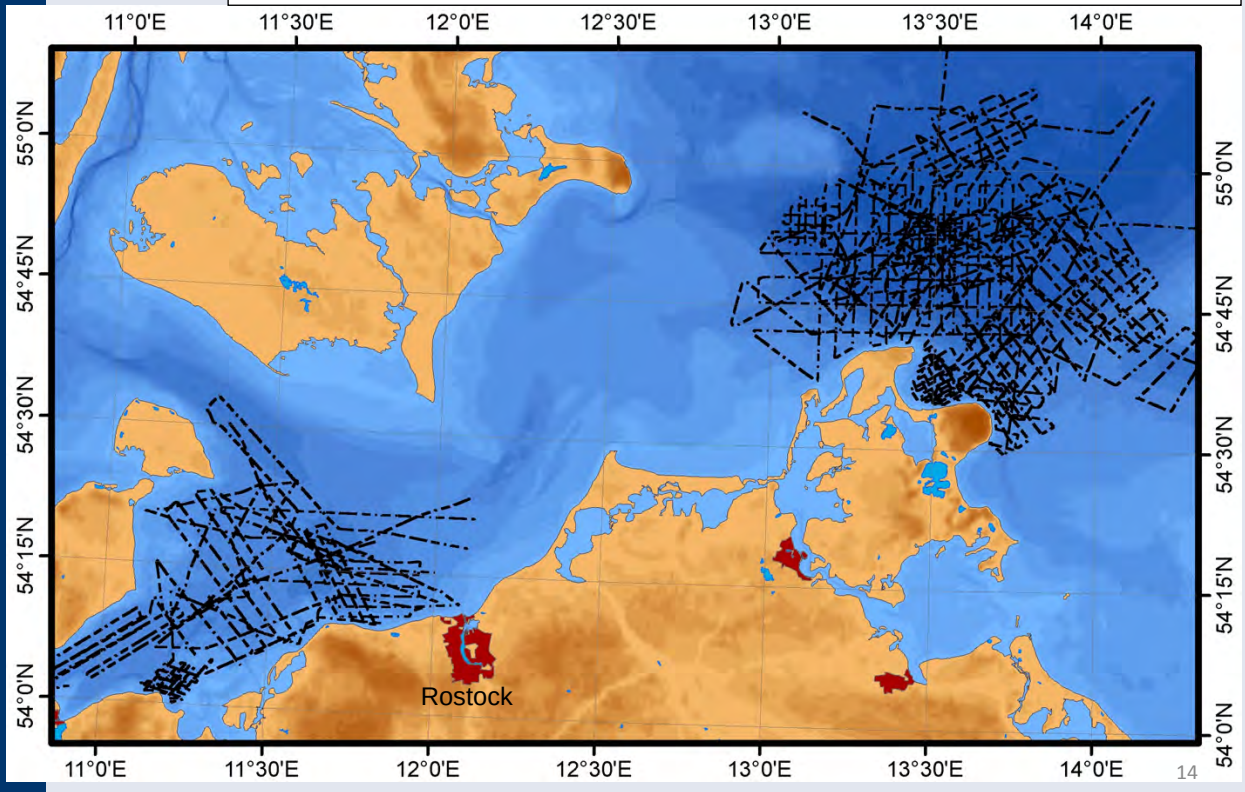
Plotting data precisely into acoustic profiles



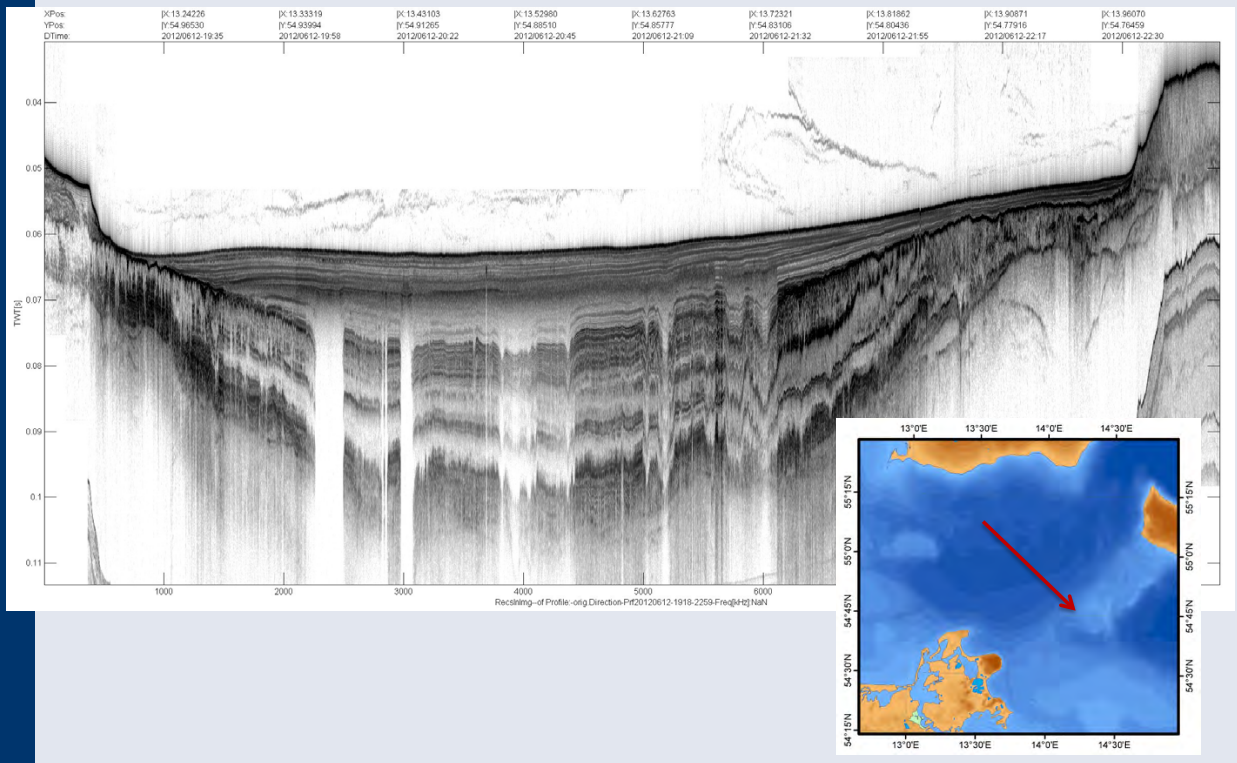
Endler etal. subm.

Working Areas and Data Base

a dens net of acoustic profile lines for mapping sedimentary units

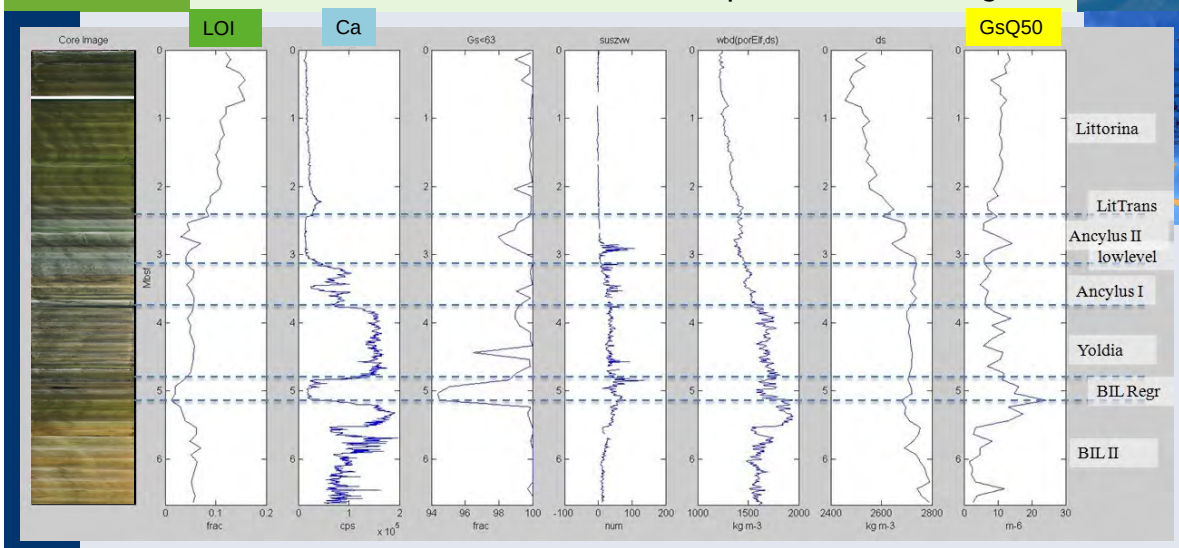


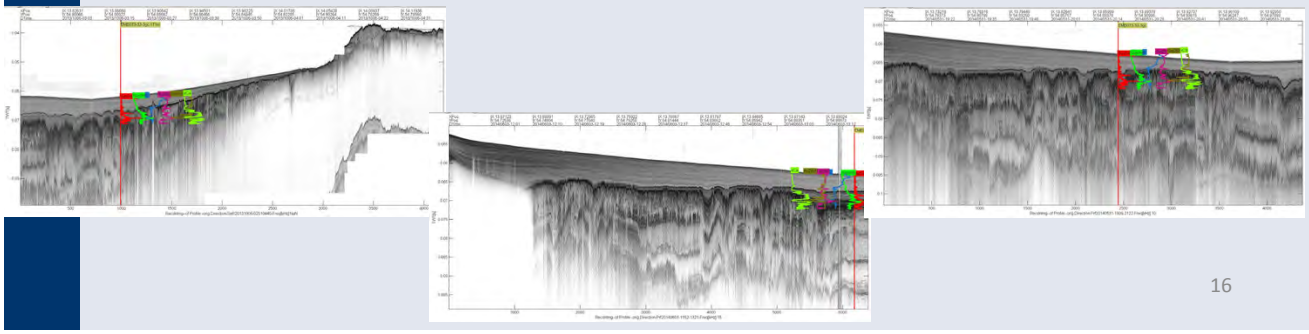
Mapping the Arkona Basin

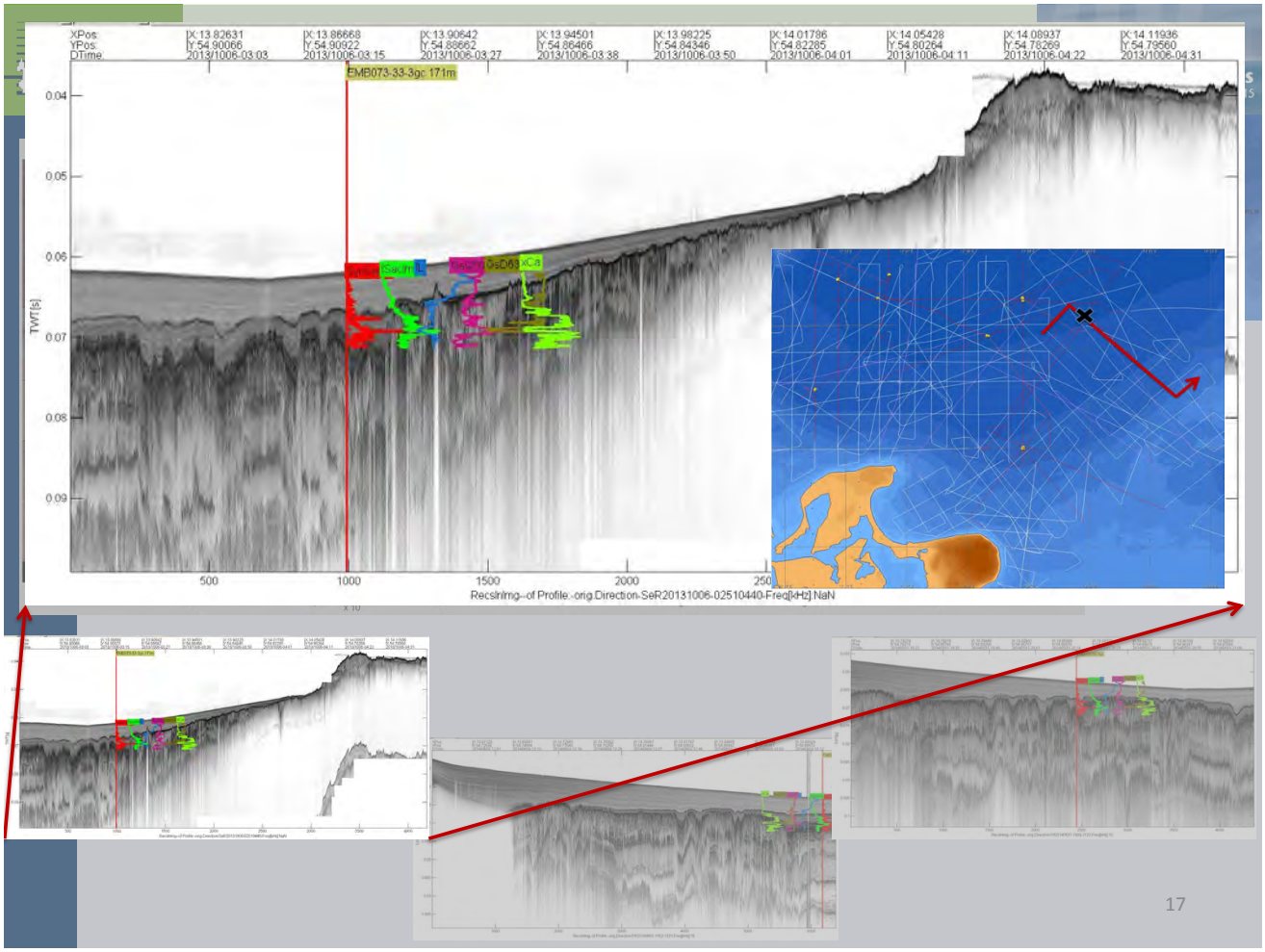


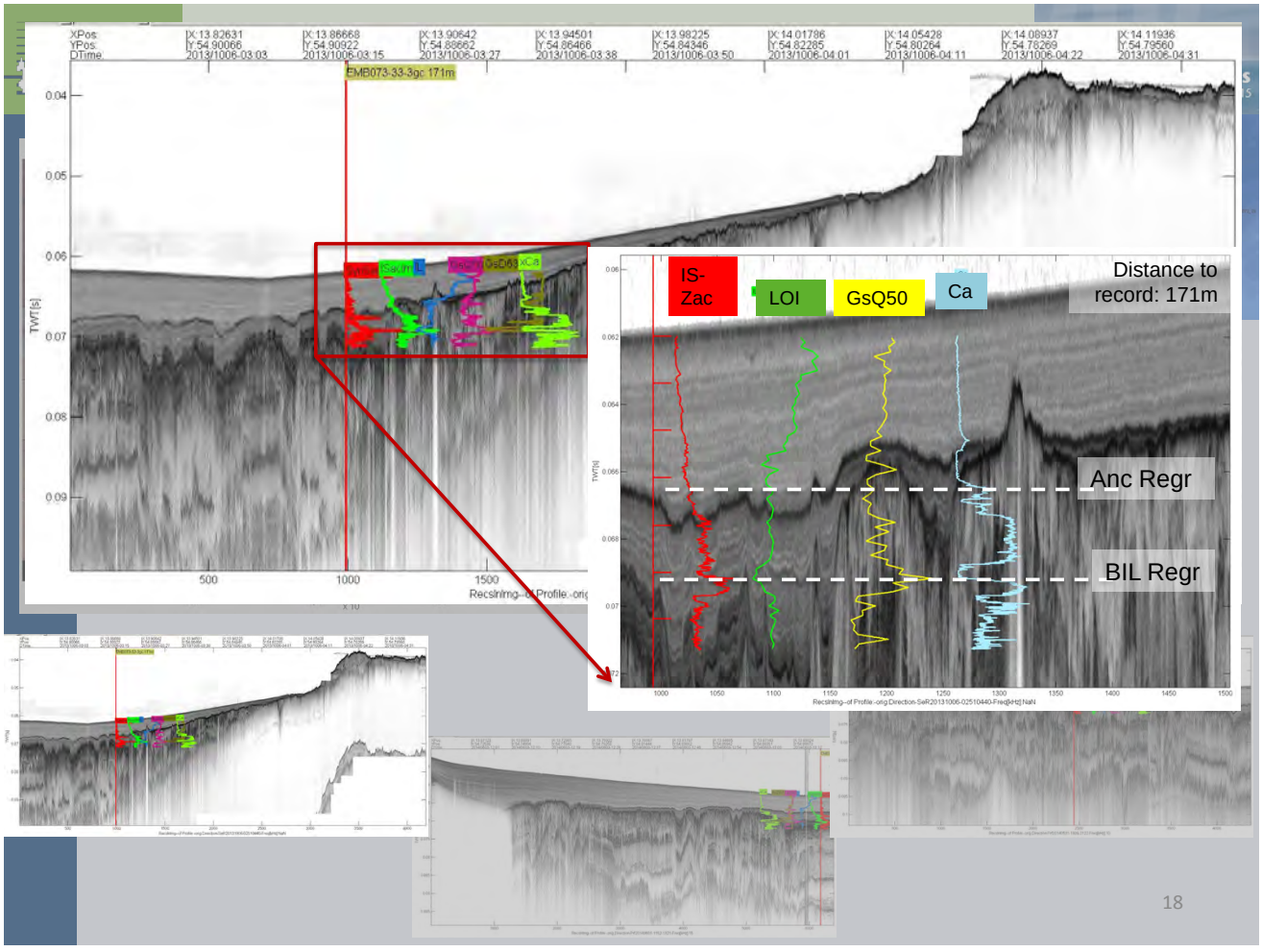
Mapping Workflow

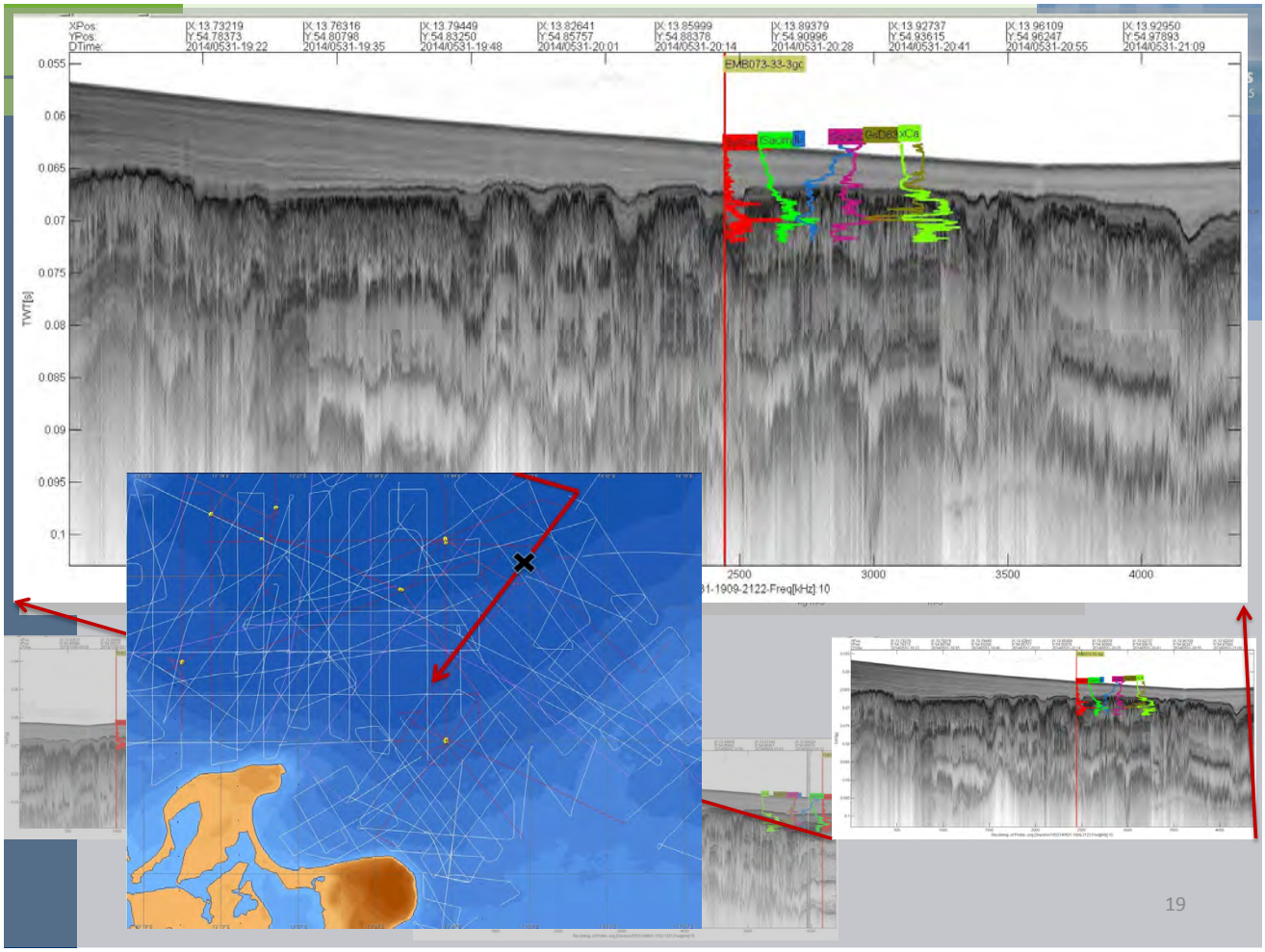
example EMB073-33-3gc

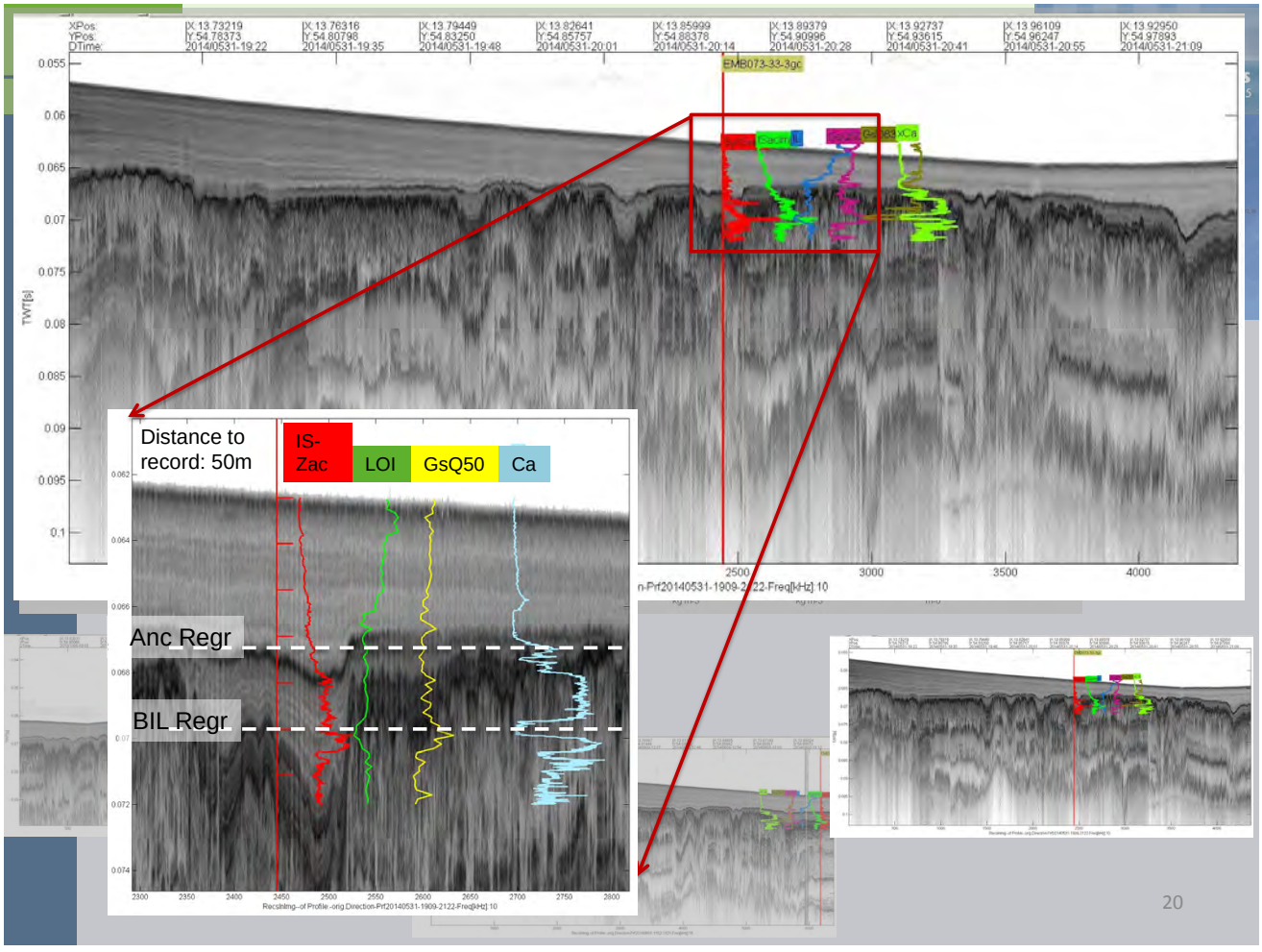





17


IS-Zac
LOI
GsQ50
Ca
Distance to record: 171m
Anc Regr
BIL Regr
18


19

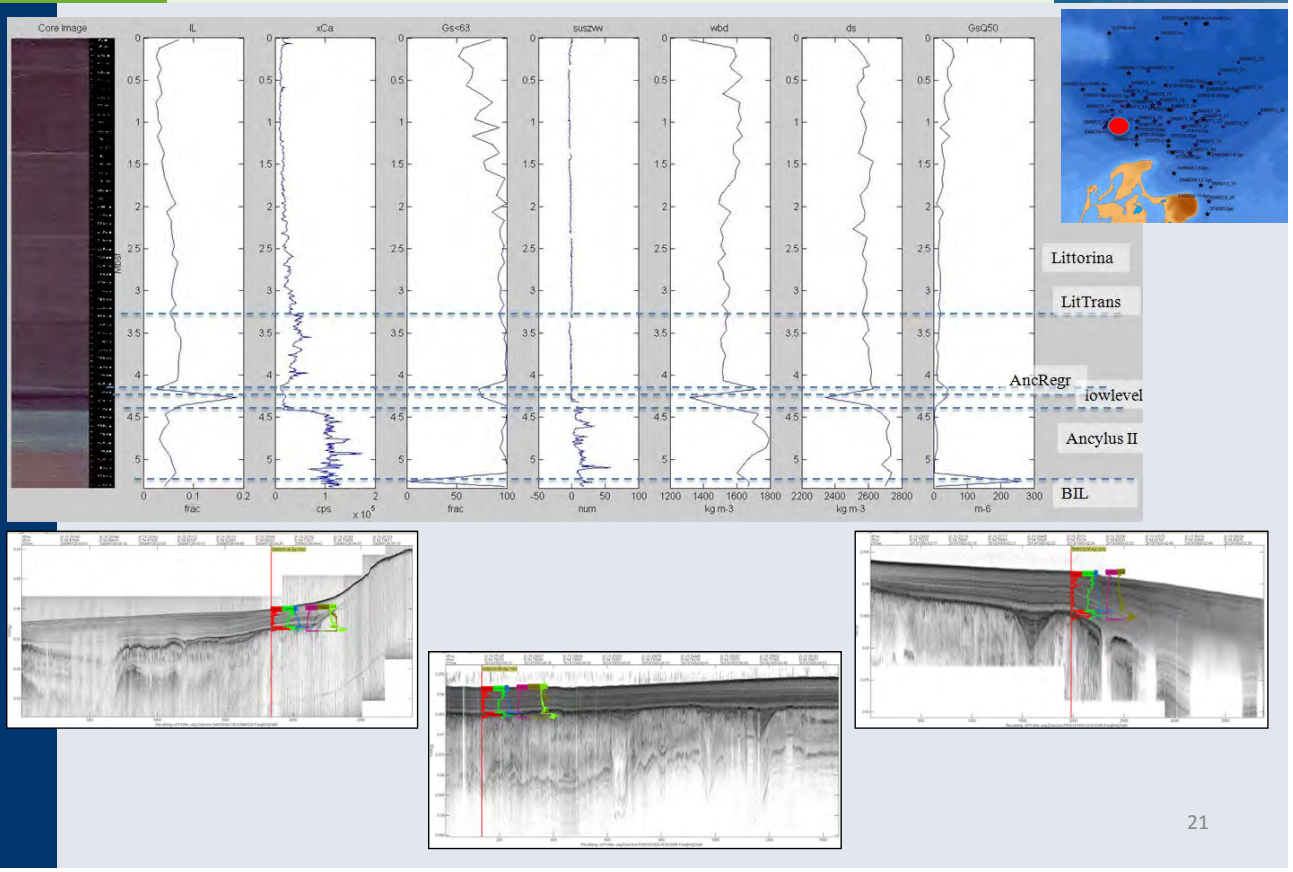

Distance to record: 50m
IS-Zac
LOI
GsQ50
Ca
Anc Regr
BIL Regr
20

Leibniz Institute for Baltic Sea Research Warnemünde

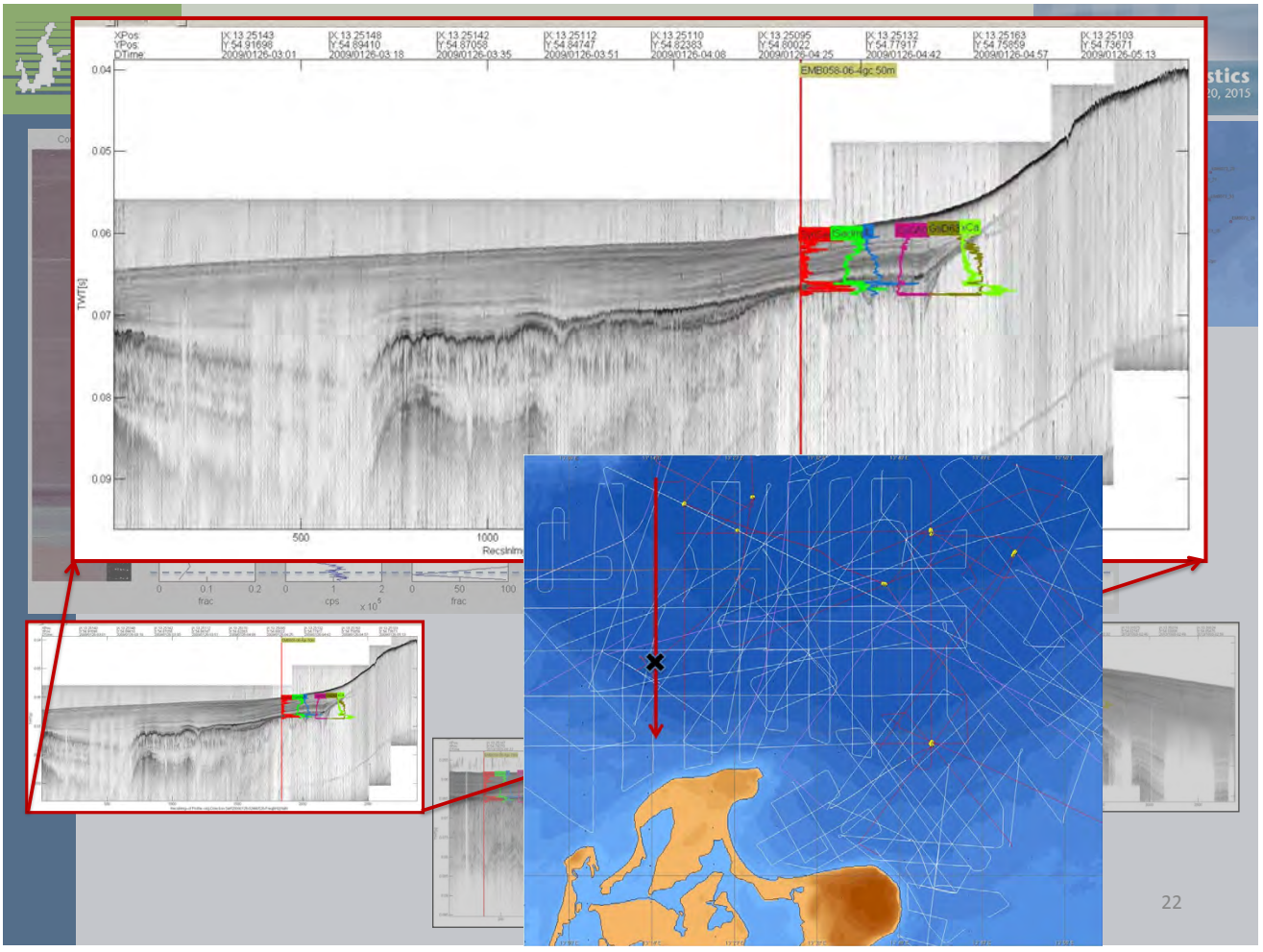
Results: Application of the Model

EMB058-06-4gc

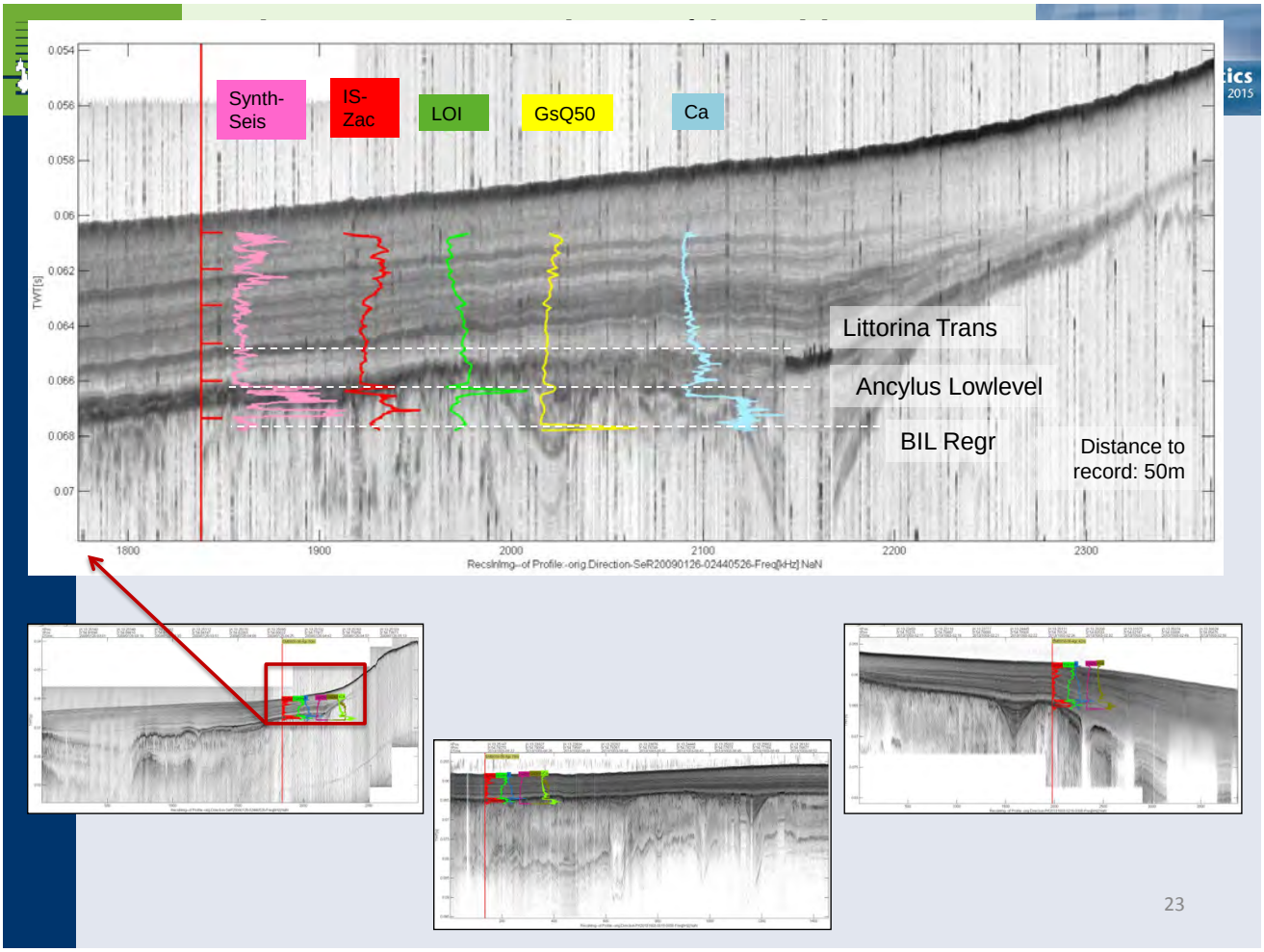
7th Workshop Seabed Acoustics Rostock, November 19 - 20, 2015

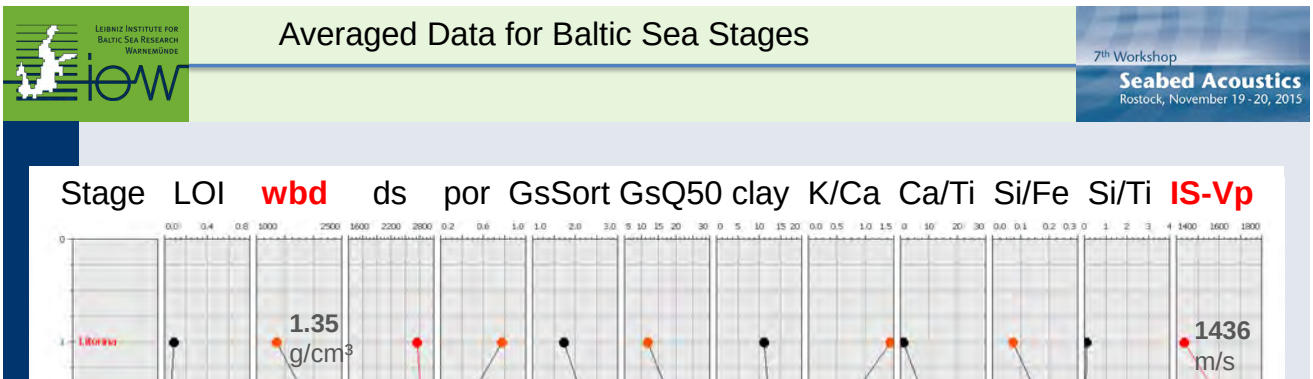


21



22


Synth-Seis
IS-Zac
LOI
GsQ50
Ca
Littorina Trans
Ancylus Lowlevel
BIL Regr
Distance to record: 50m
TWT[s]
0.054
0.056
0.058
0.06
0.062
0.064
0.066
0.068
0.07
1800
1900
2000
2100
2200
2300
RecsInImg--of Profile--orig.Direction-SeR20090126-02440526-Freq[kHz].NaN
23


Leibniz Institute for Baltic Sea Research Warnemünde
IOW
Averaged Data for Baltic Sea Stages
7th Workshop
Seabed Acoustics
Rostock, November 19-20, 2015
Stage LOI wbd ds por GsSort GsQ50 clay K/Ca Ca/Ti Si/Fe Si/Ti IS-Vp
Littorina
Sandy Layer
Peat
Ancylus-Yoldia
BIL
1.35 g/cm³
2.32 g/cm³
1.07 g/cm³
1.41 g/cm³
1.70 g/cm³
1436 m/s
1740 m/s
1471 m/s
1417 m/s
1437 m/s
24

Summary and Outlook

The **geo – acoustic models** (empiric, Biot-Stoll) show good performance with **low prediction errors (ca. ±20m/s).**

Temperature is the controlling factor of the in situ correction (**up to 40m/s**).

The **predicted acoustic parameters** enable **precise assignment** of sedimentological data into acoustic profiles.

Our results provide **all requirements** for effective and reliable acoustic interpretation and 3D mapping.

Ongoing work: mapping of post glacial sediment sequences (thicknesses, volumes, masses) in Mecklenburg Bay and Arkona Basin

25

Summary and Outlook

The **geo – acoustic models** (empiric, Biot-Stoll) show good performance with **low prediction errors (ca. ±20m/s).**

Temperature is the controlling factor of the in situ correction (**up to 40m/s**).

The **predicted acoustic parameters** enable **precise assignment** of sedimentological data into acoustic profiles.

Our results provide **all requirements** for effective and reliable acoustic interpretation and 3D mapping.

Ongoing work: mapping of post glacial sediment sequences (thicknesses, volumes, masses) in Mecklenburg Bay and Arkona Basin

Thanks for your attention!

26