Seabed Variability and its Influence on Acoustic Prediction Uncertainty

The G, G & G Team

Charles Holland: team leader; Acoustic measurements/geoacoustic inversion

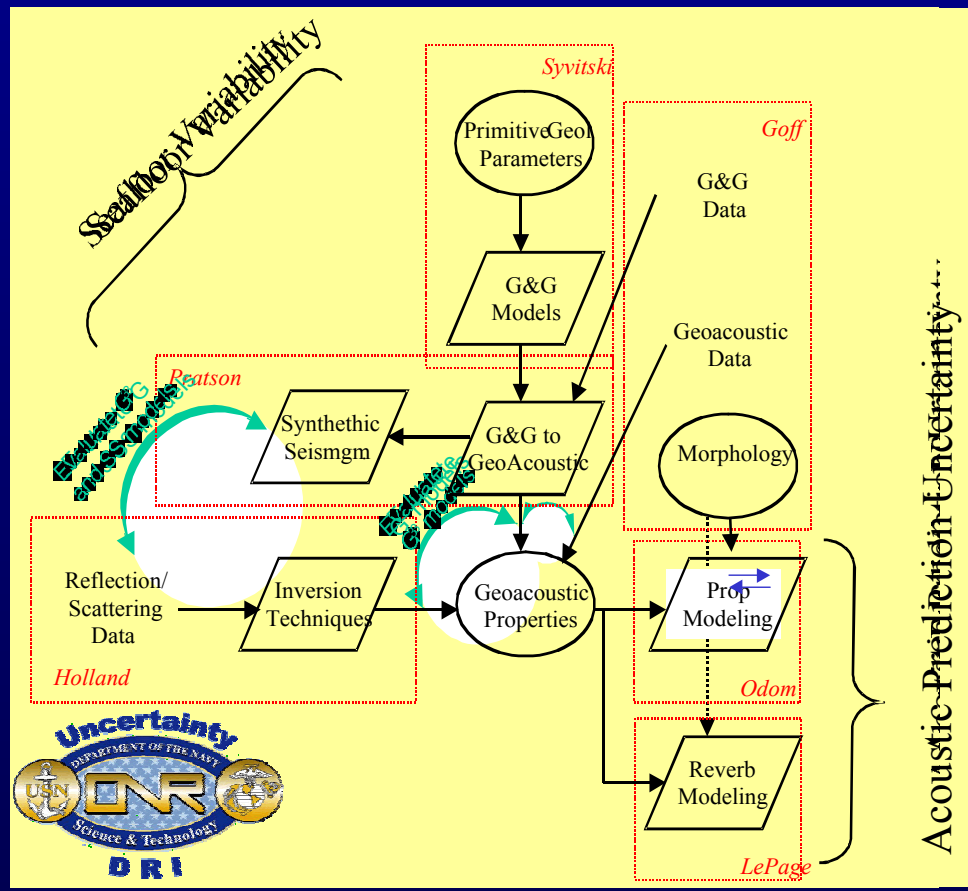
John Goff: Statistical characterization of surface/subsurface properties

Kevin LePage: Reverberation modeling

Bob Odom: Acoustic propagation modeling (forward/inverse)

Lincoln Pratson: Predictive geoacoustic modeling; lab-generated 3D strata

James Syvitski: Predictive geophysical modeling



Long Term Goals

- Assess and characterize the seafloor variability
- Determine the impact of the seafloor variability on acoustic prediction uncertainty

1. Determine Geoacoustic Errors and Uncertainties

- G&G modeling-to-geoacoustics (Syvitski, Pratson, Holland)
- G&G data analysis (Goff, Holland, Syvitski)
- Acoustic inversion (Holland, Pratson, Odom,Goff)
- Recommendations for new measurement-modeling approaches that minimize geoacoustic error/uncertainty (ALL)

2. Provide measures of acoustic prediction uncertainty due to seabed variability and geoacoustic uncertainty

- Develop theory/techniques for modeling uncertainty (Odom, LePage)
- Forward and inverse propagation uncertainty based on deterministic/stochastic geoacoustic data (Odom)
- Scattering and reverberation uncertainty based on deterministic/stochastic geoacoustic data (LePage)

Seabed Variability from Geophysical Modeling -James Syvitski

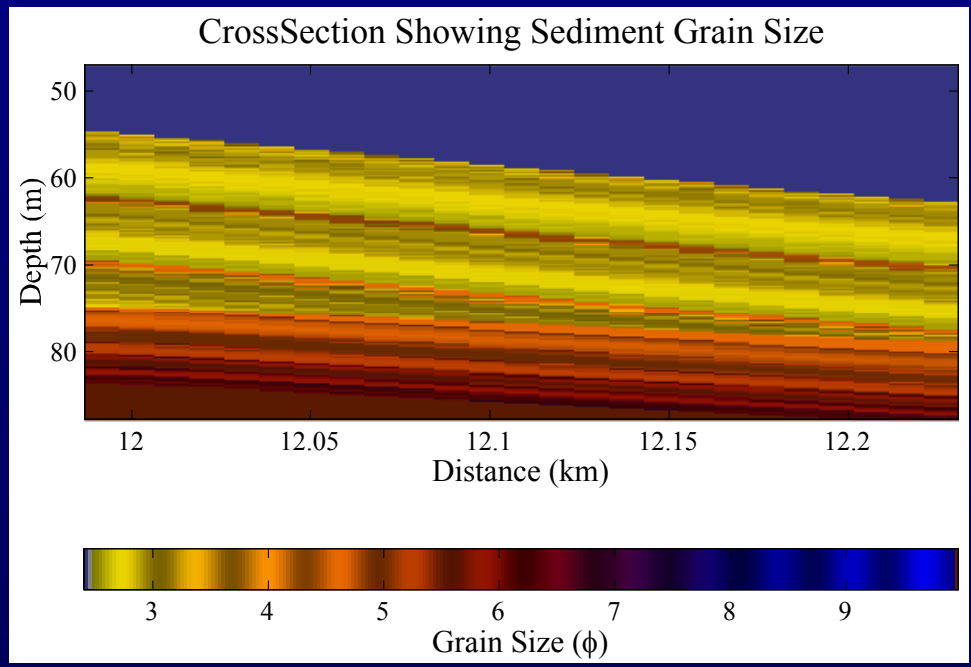
Objectives

Determine the uncertainty related to the natural variability in the environmental parameters that drive ***SedFlux.***

Provide ***SedFlux*** realizations in areas of interest to seafloor geoacoustic team, i.e. seafloor properties, bed coherency.

Coordinate with ONR-GeoClutter Modeling group to explore seafloor uncertainty related to the location of buried channels, their morphology and orientation.

Determine which continental margins would experience seasonal or inter-annual changes in the nature of its seafloor acoustic properties.



STRATAFORM Modeling Effort

Precip. & Temp. Data: GCM predictions, air or ground info
Drainage Basin Relief and Area, Glacier Distribution: satellite info

↓

Hydrological Model

=

daily Q, Qs, Cs, grain size, river velocity, channel size

+

Seafloor Bathymetry: GEOSAT
Ocean Climate (wind & waves): Sat & Buoy Data

↓

River Plume Models

Nepheloid Layer Model (mid water column) ↔ **Shelf Transport Model** (bottom boundary dynamics)

=

Sediment Flux, Accumulation Rate, Seafloor Properties (ρ_{bulk}, grain size) on continental margin (shelf and slope)

↓

Slope Stability Models

=

Compaction, excess pore pressure, sediment strength
potential failure planes, volume of failure

↓

Sediment Gravity Flow Models

=

Seafloor Stratigraphy, Bedding Geometry & Coherency, Erosion Surfaces,
Seafloor Properties (ρ_{bulk}, grain size, porosity)

+

Acoustic Source Signatures (calibrated)

↓

Acoustic Models

=

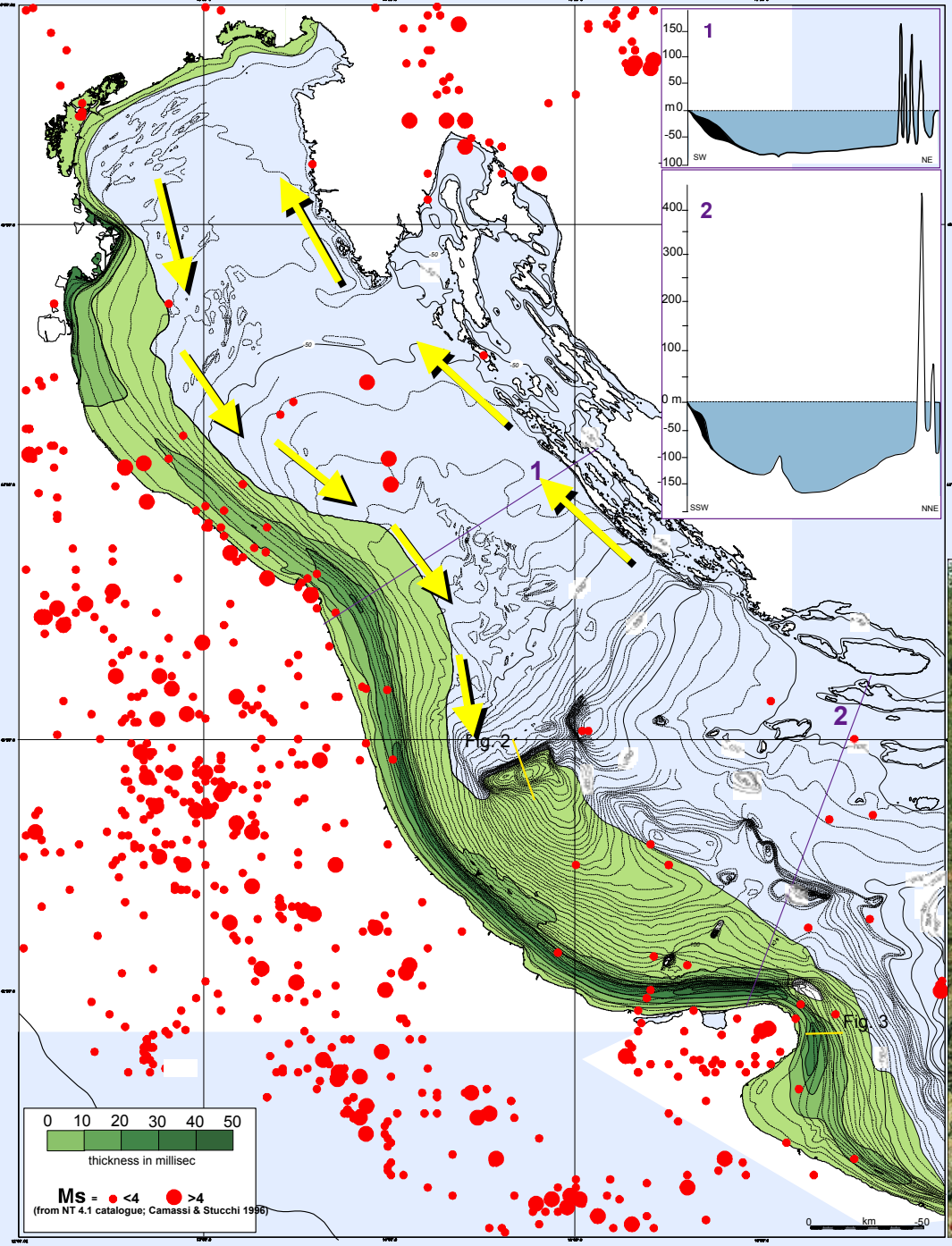
Reflecting Surfaces, Acoustic Absorbtion & Attenuation
Acoustic Geoclutter

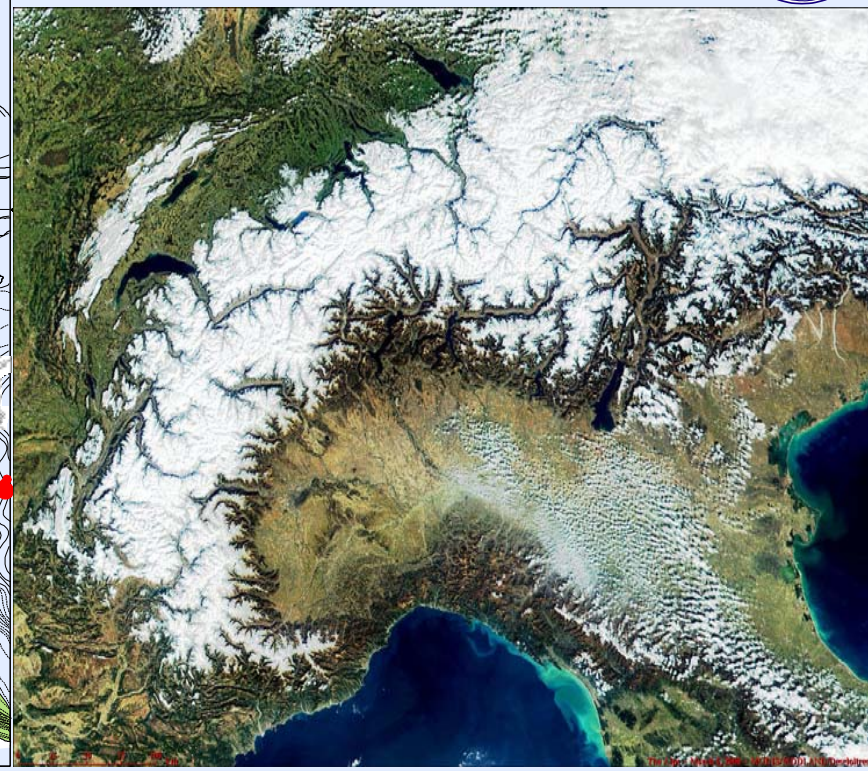
Movie is currently unavailable

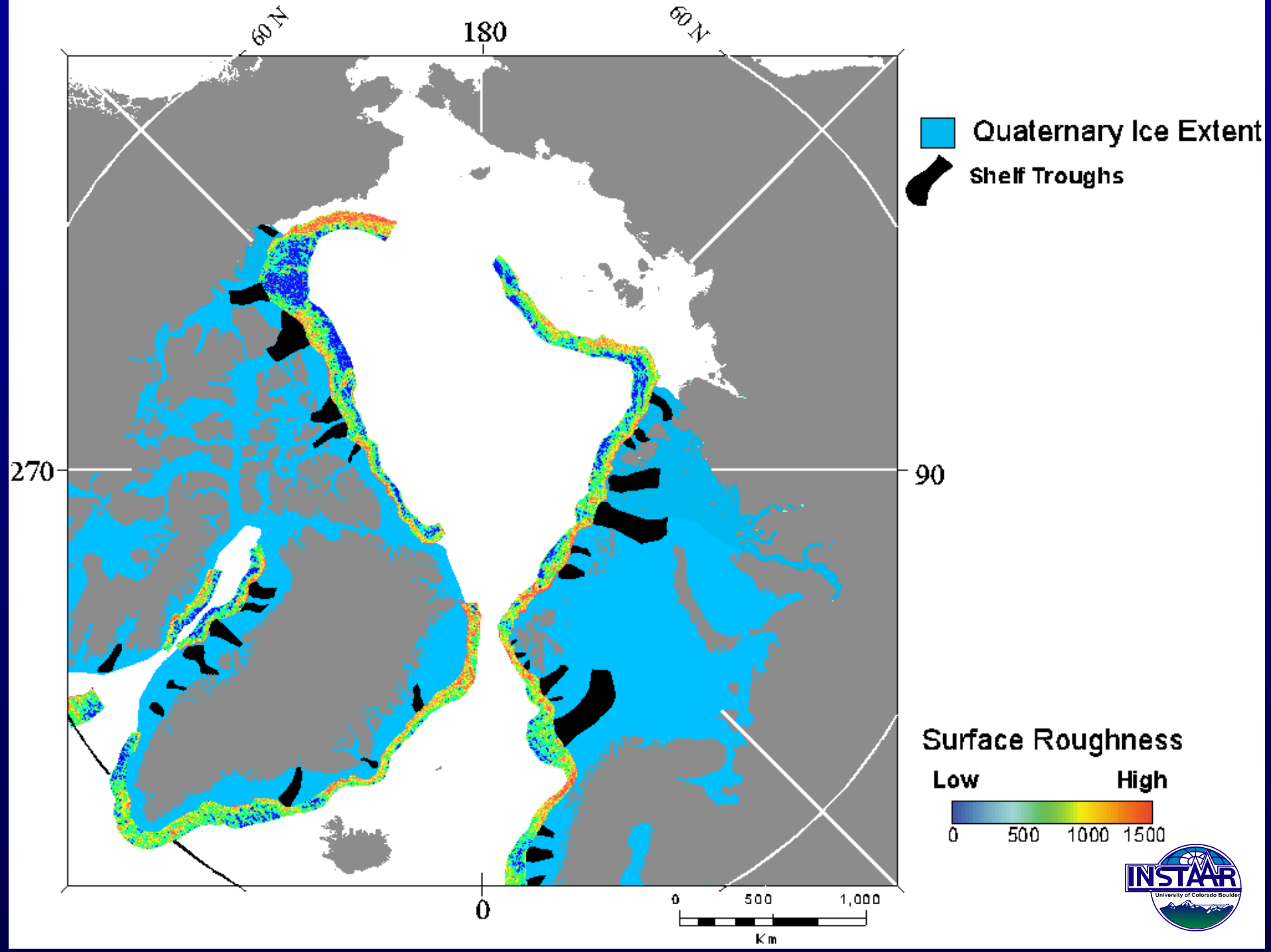
QuickTime™ and a
Photo decompressor
are needed to see this picture.

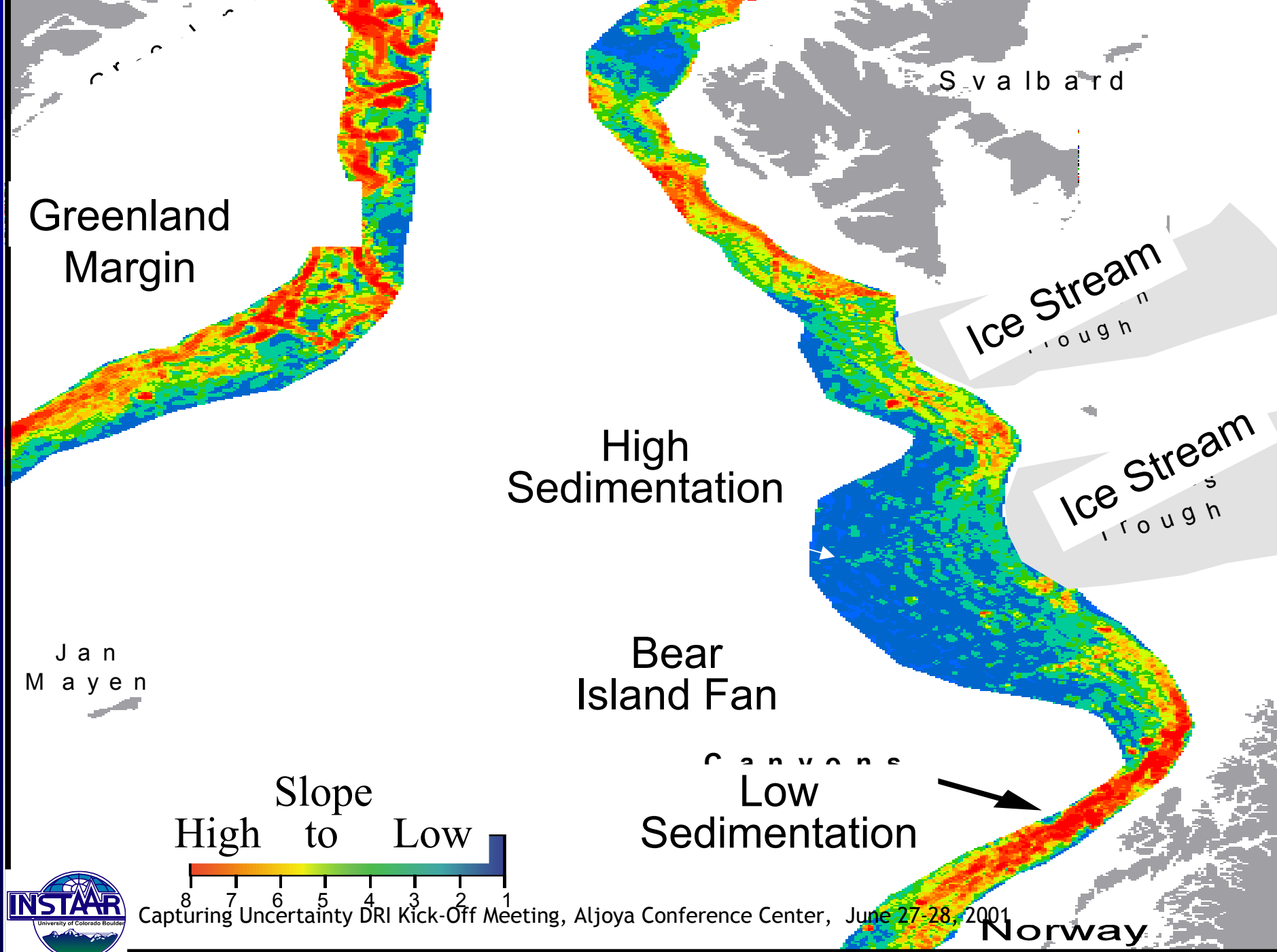
Movie is currently unavailable

Strong coastal circulation can greatly influence the dispersal of sediment, as found within the Adriatic, where sediment is deposited along a tight coastal band.





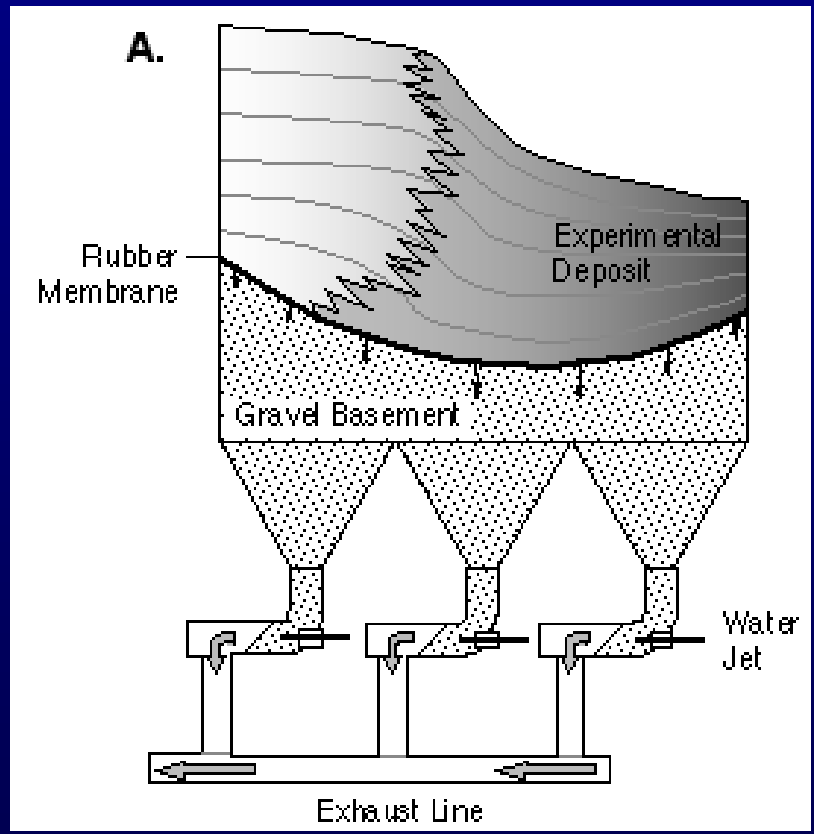

60 N
180
60 N
270
90
0
Quaternary Ice Extent
Shelf Troughs
Surface Roughness
Low
High
0
500
1000
1500
0
500
1,000
Km
INSTAAR
University of Colorado Boulder

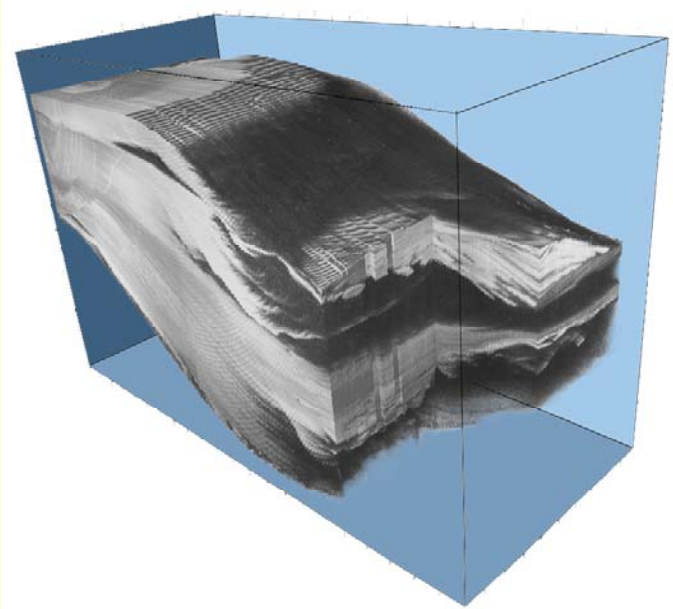

Greenland
Margin
Svalbard
Ice Stream
Trough
Ice Stream
Trough
High
Sedimentation
Jan
Mayen
Bear
Island Fan
Canyons
Low
Sedimentation
Slope
High to Low
8 7 6 5 4 3 2 1
Norway

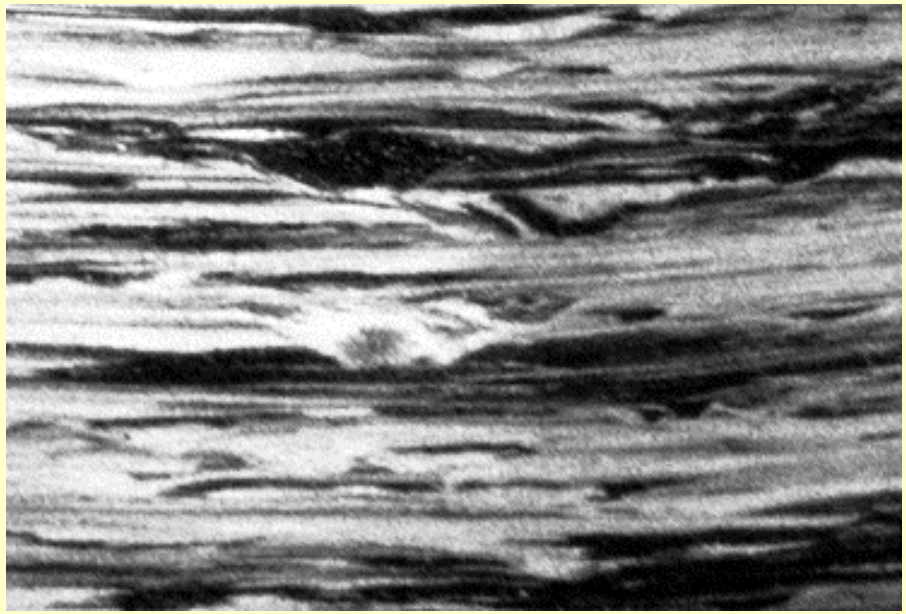
Geoacoustic Properties from Lab and G&G Modeled Strata - Lincoln Pratson

Use computer- and laboratory-generated strata to forward model sea-bed acoustic properties in a variety of littoral settings, and provide statistical measures for use in simulating acoustic propagation and reverberation.

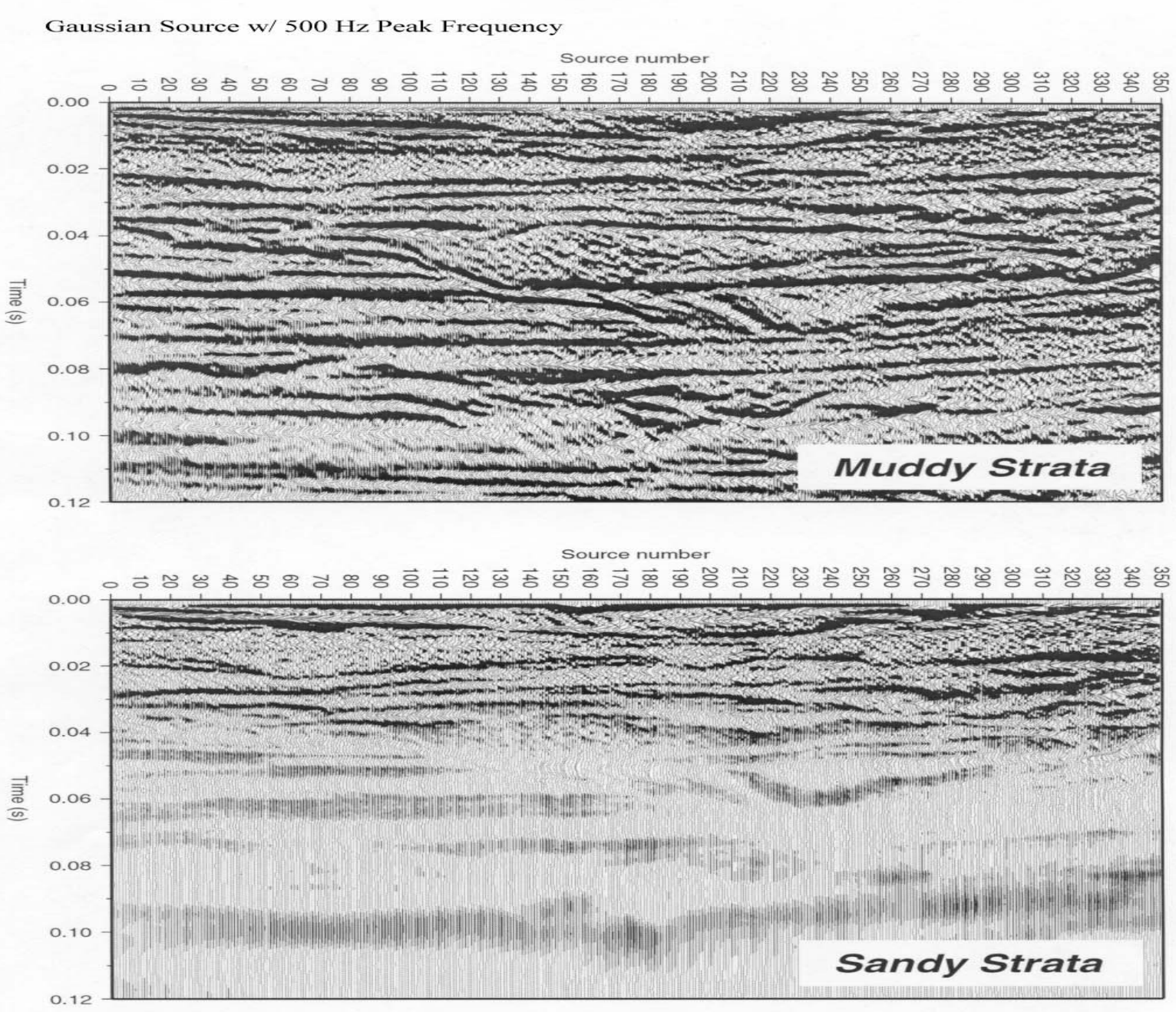
Generate synthetic seismic data of the computer- and laboratory-generated strata for use in testing high-resolution geoacoustic inversion methods.

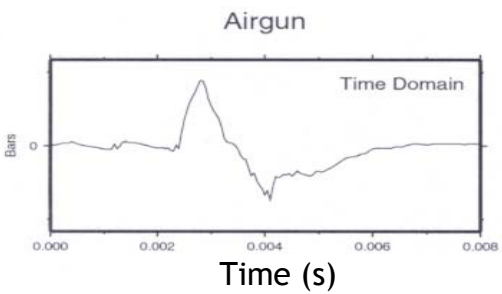


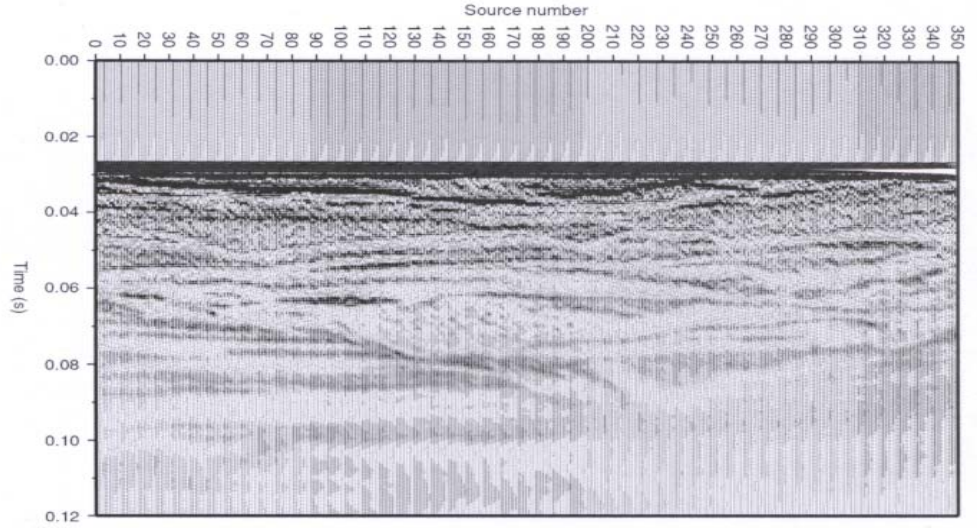


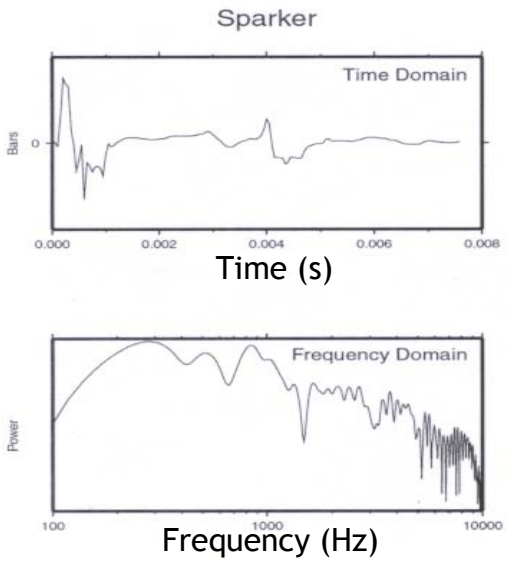


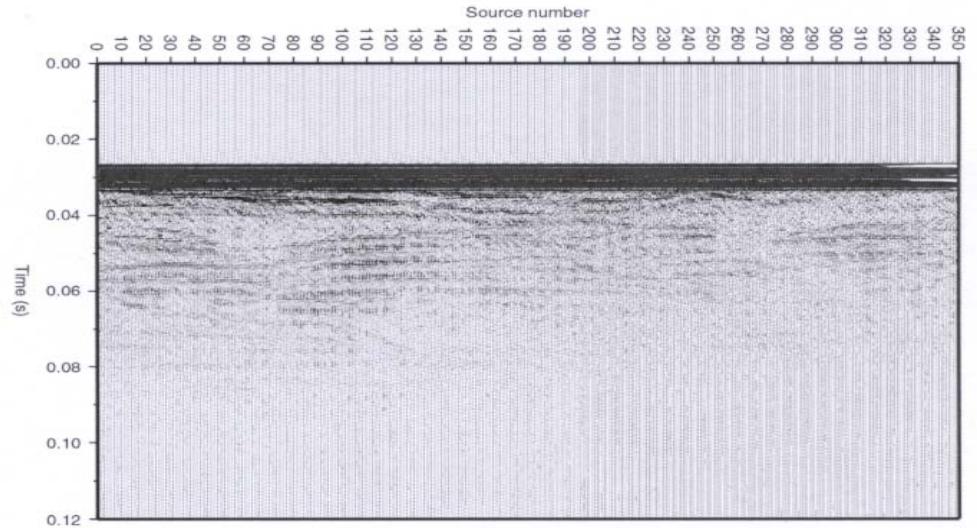
3-D image of experimental delta/slope strata generated in XES Basin. (2) Cross section of buried experimental channels created in XES Basin. In both images, white regions are sand and black regions are coal, which is used as a proxy for mud


Gaussian Source w/ 500 Hz Peak Frequency
Source number
Time (s)
Muddy Strata
Source number
Time (s)
Sandy Strata


Airgun
Time Domain
Bars
0
0.000
0.002
0.004
0.006
0.008
Time (s)
Frequency Domain
Power
100
1000
10000
Frequency (Hz)


Source number
Time (s)
0.00
0.02
0.04
0.06
0.08
0.10
0.12


Sparker
Time Domain
Bars
0
0.000
0.002
0.004
0.006
0.008
Time (s)
Frequency Domain
Power
100
1000
10000
Frequency (Hz)


Source number
Time (s)
0.00
0.02
0.04
0.06
0.08
0.10
0.12

G&G Statistical Characterization - John Goff

Objectives

Investigating the statistical properties of seafloor and sub-seafloor variability into seafloor acoustic models and compared against the geophysical data:

- (1) multibeam bathymetry;
- (2) direct measurements of surface and near-surface properties;
- (3) indirect measurements (sidescan);
- (4) limited direct measurements from long-coring effort;
- (5) indirect measurement of chirp seismic reflection data.

Morphological Complexity in the NJ Geoclutter Area: Surface and Subsurface

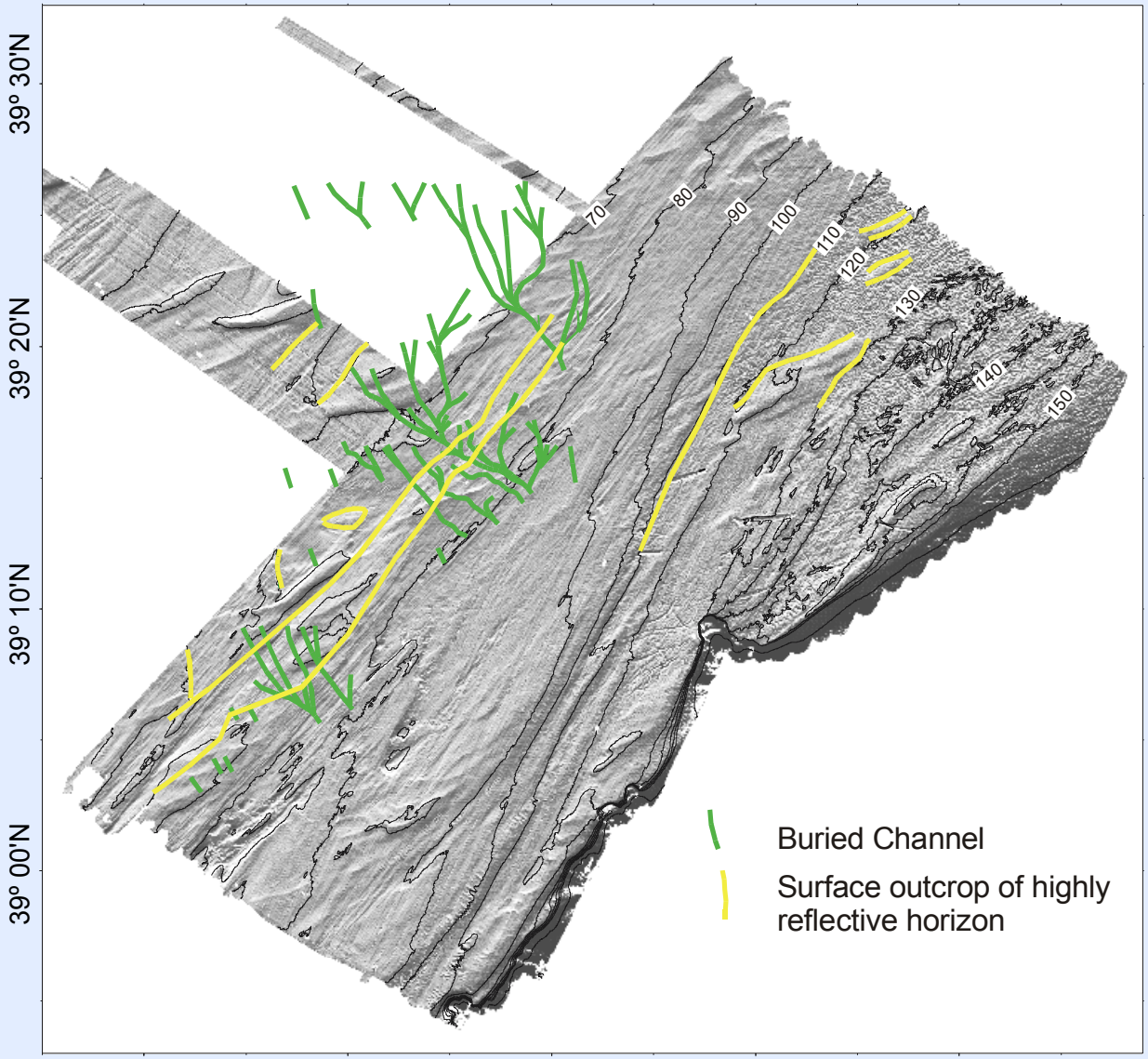
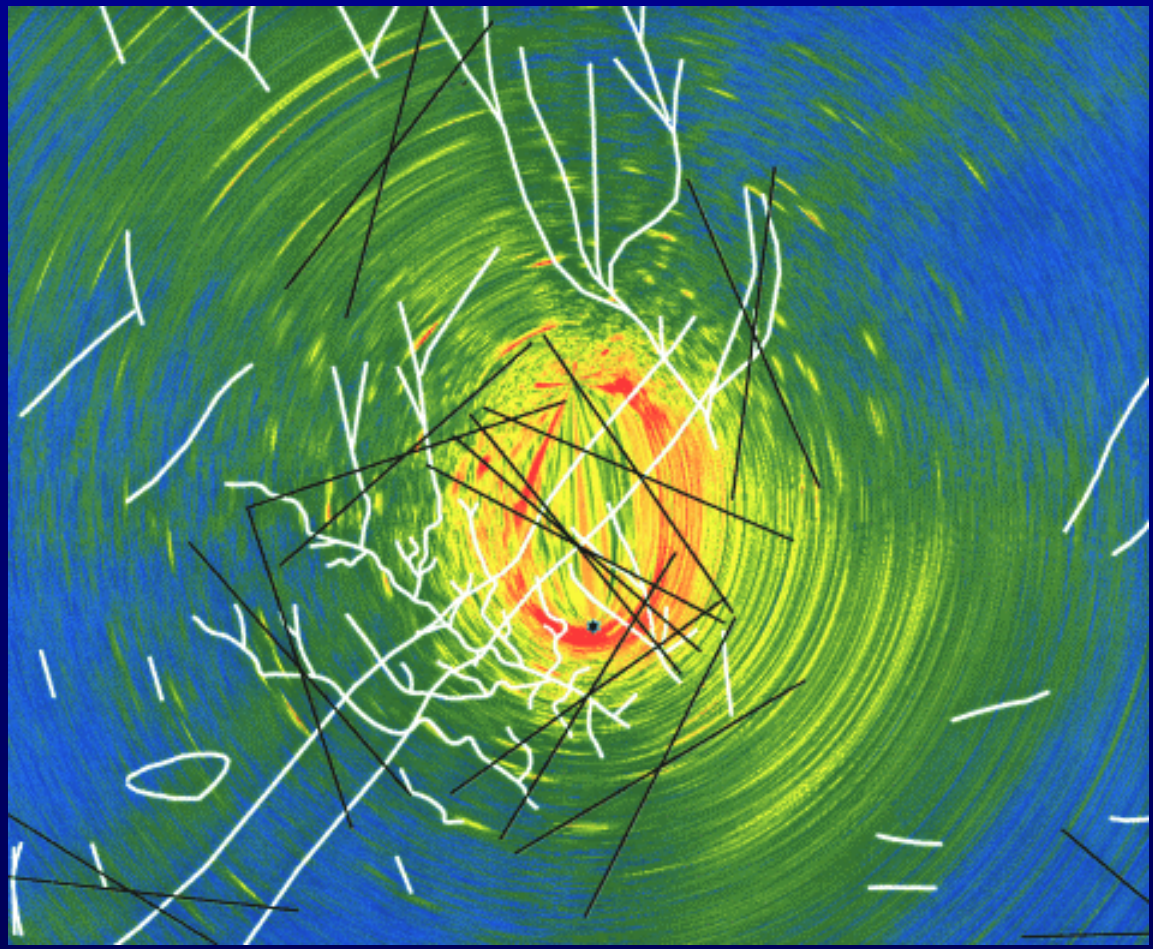


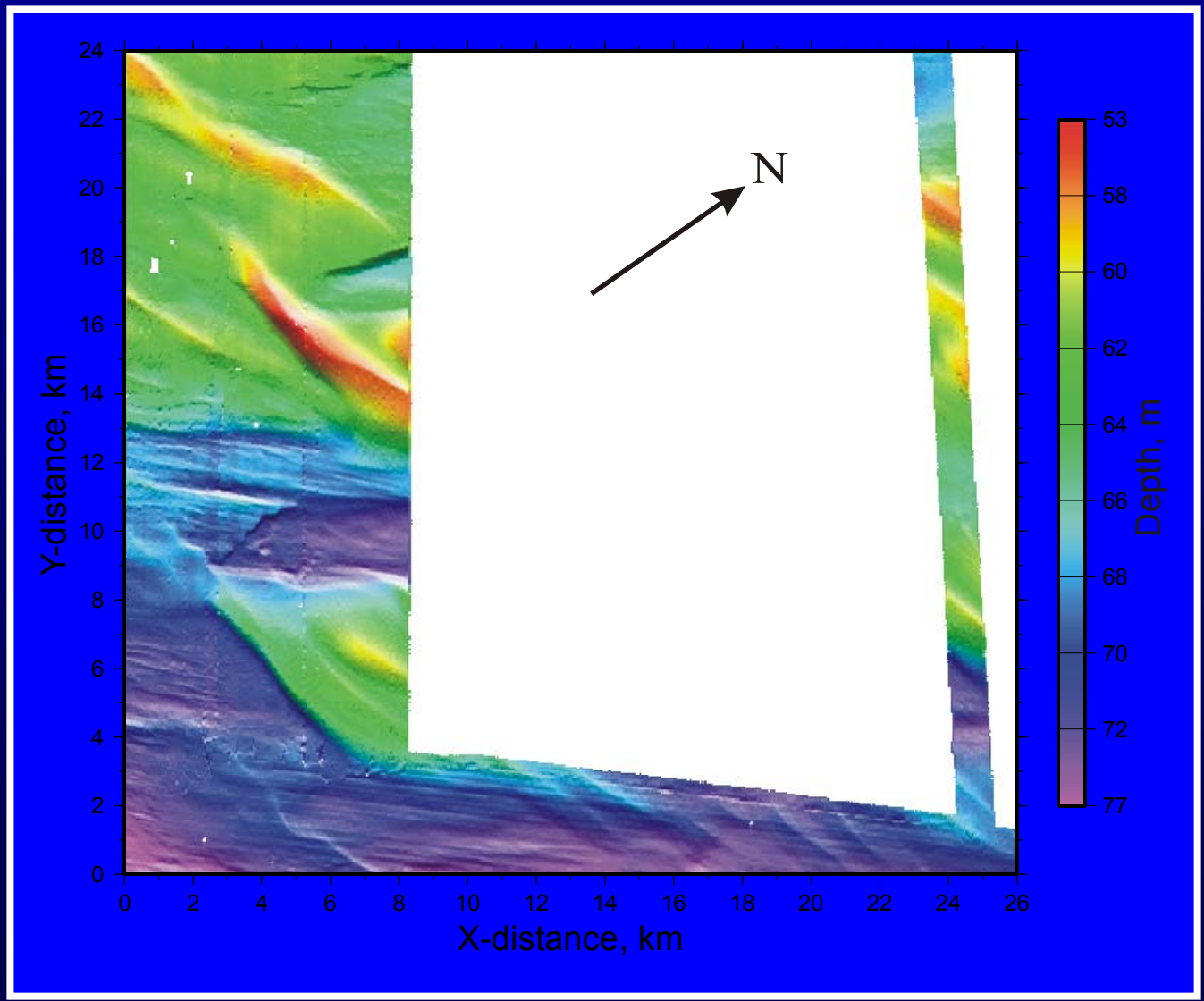
Image courtesy of Nick Makris, MIT

Geoclutter on the New Jersey shelf

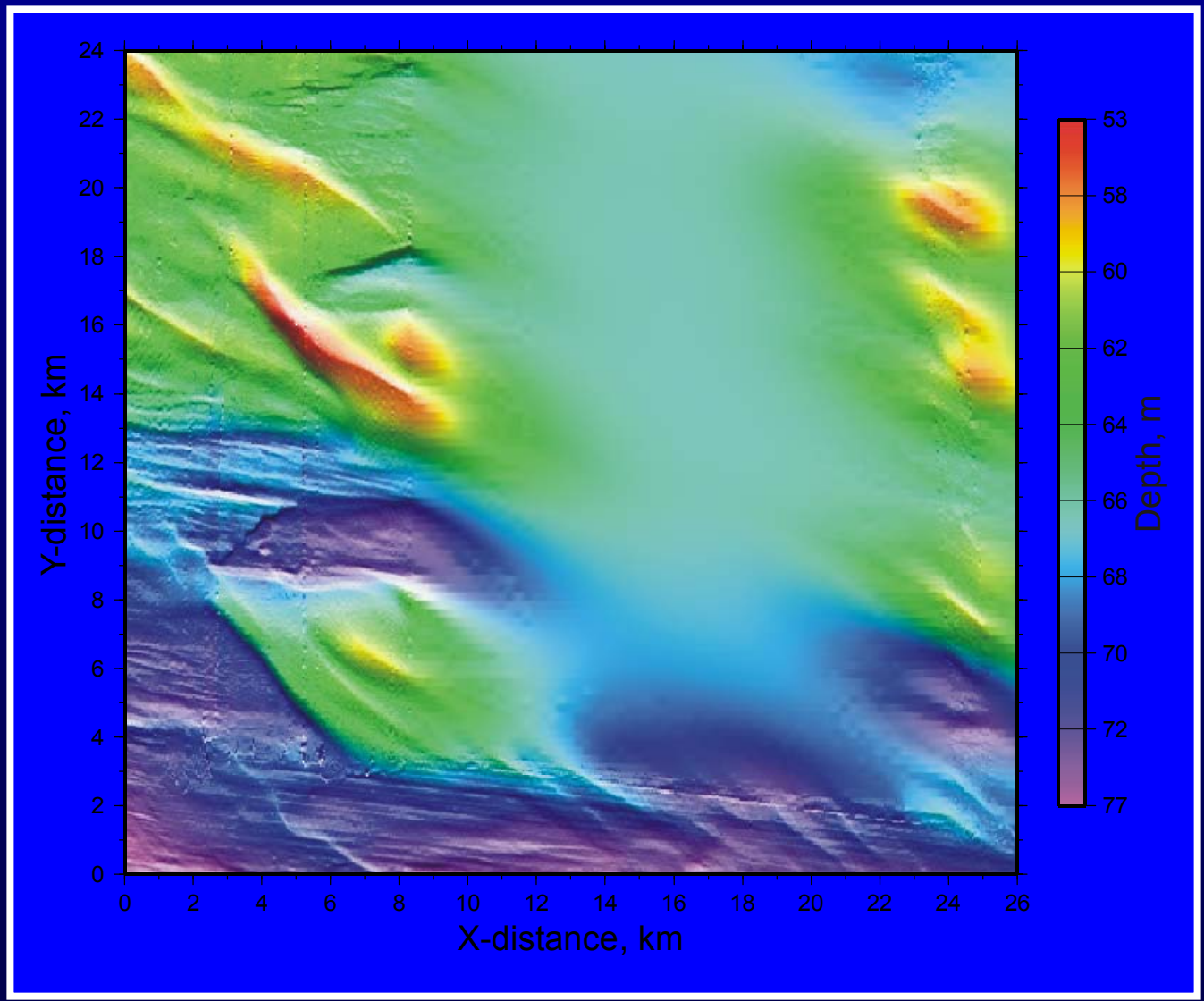


Task: Provide a geologic and geophysical model of surface and subsurface at sufficient resolution to model acoustic reverberation.

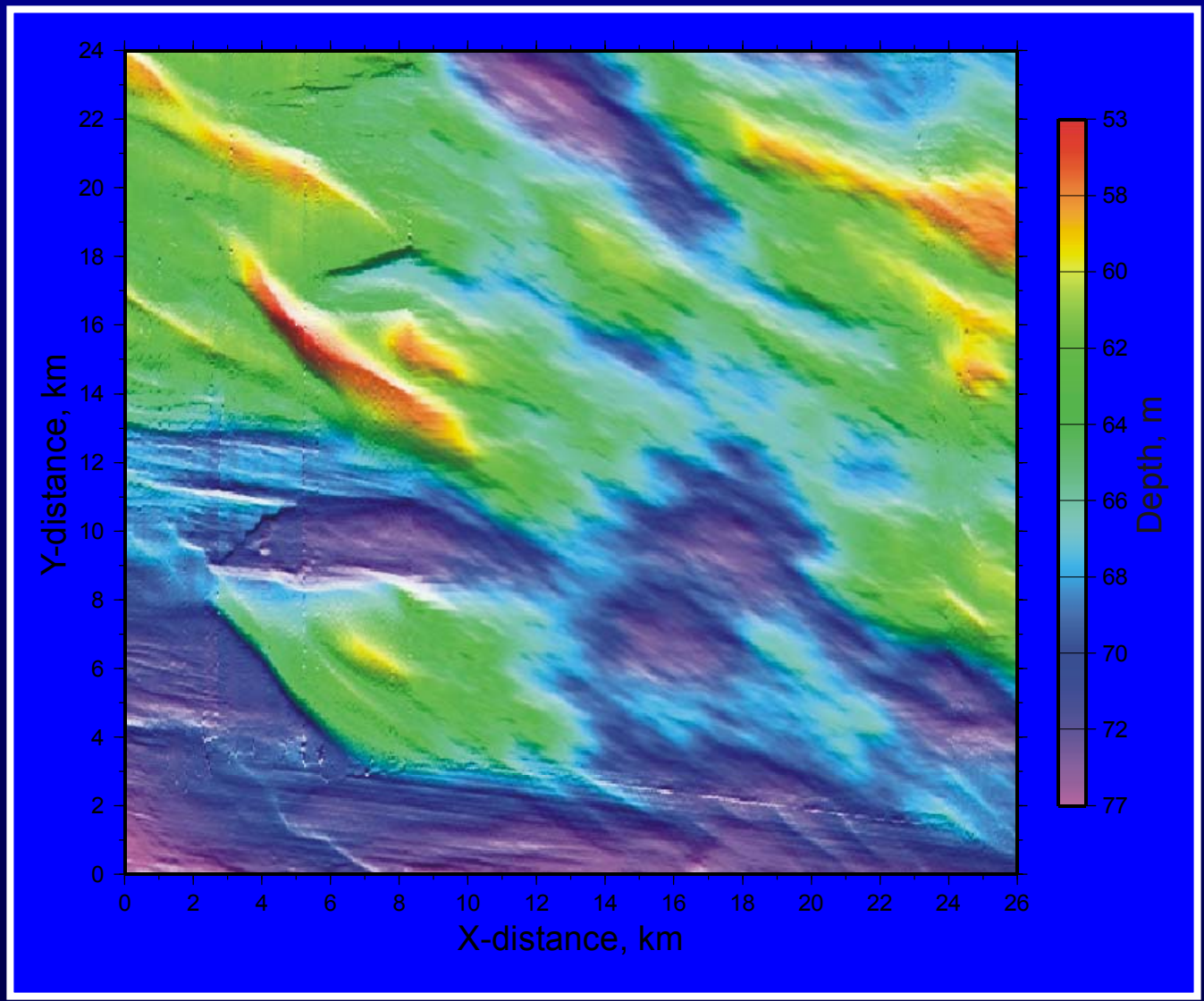
New Jersey Bathymetry



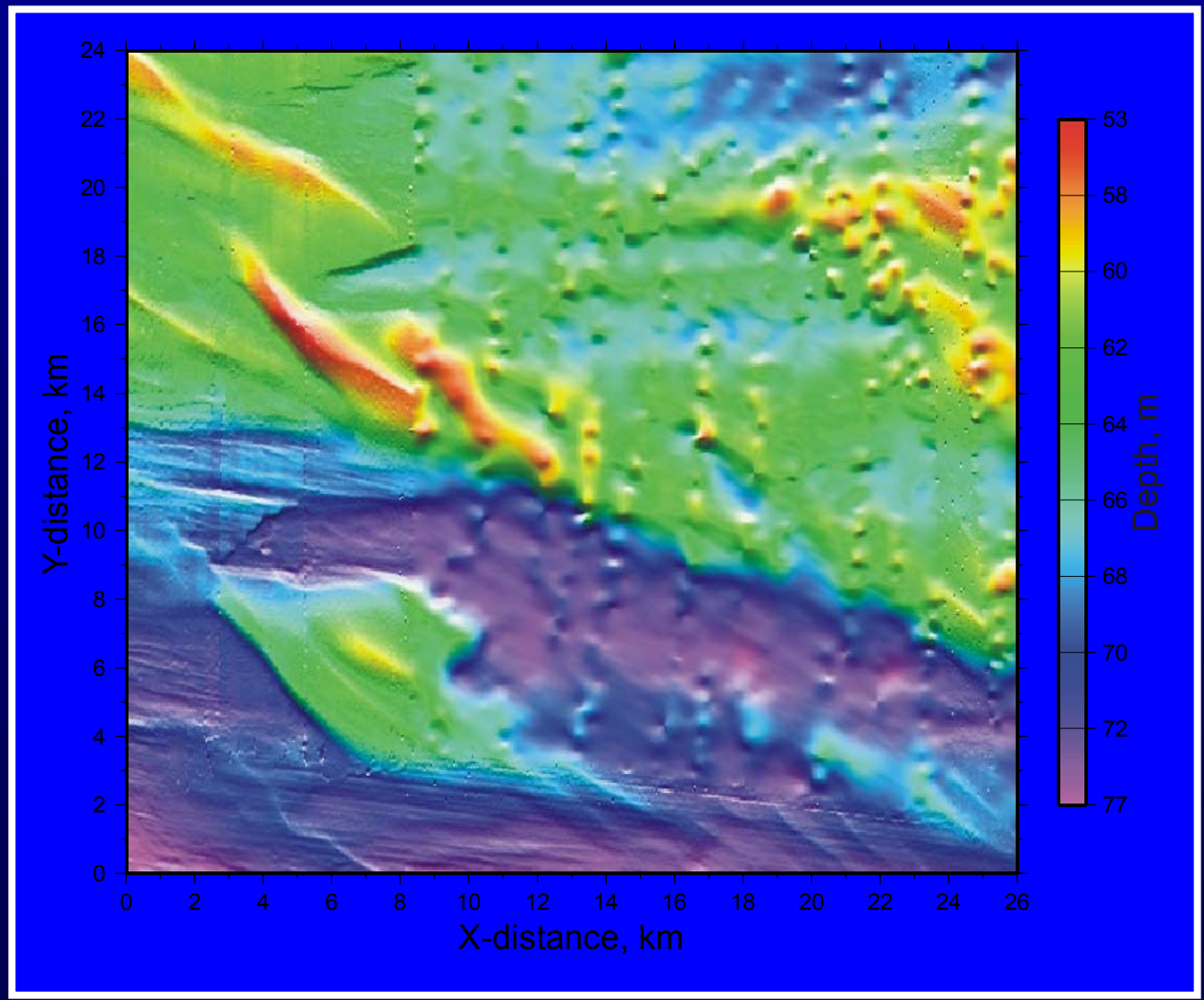
Kriging Interpolation



Conditional Simulation



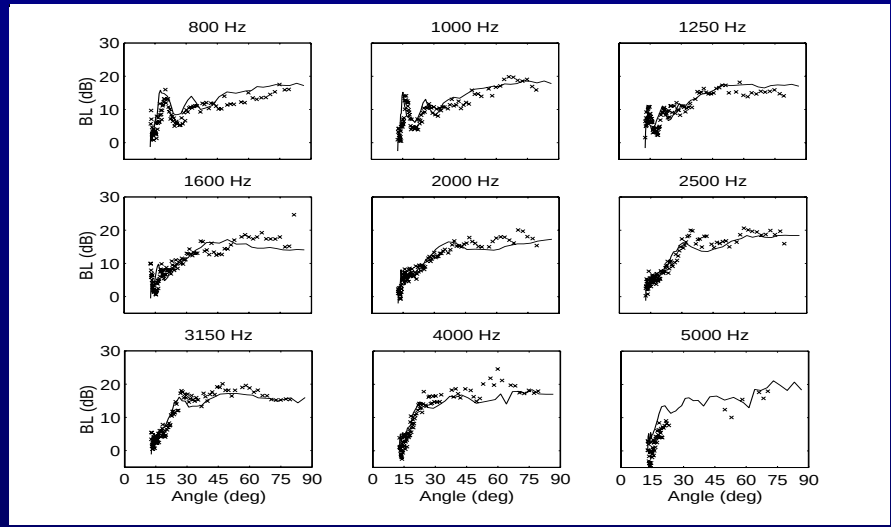
Conditional Simulation w/NGDC Data

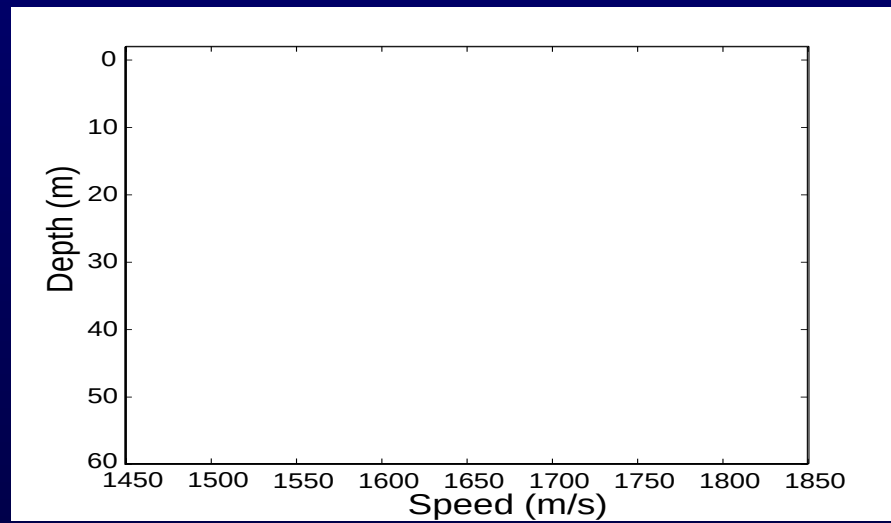


Acoustic reflection and scattering
- Charles Holland

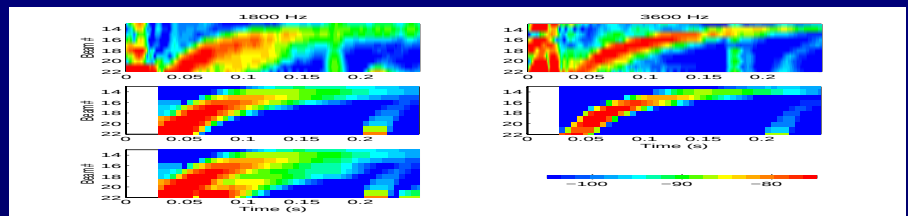
Objectives

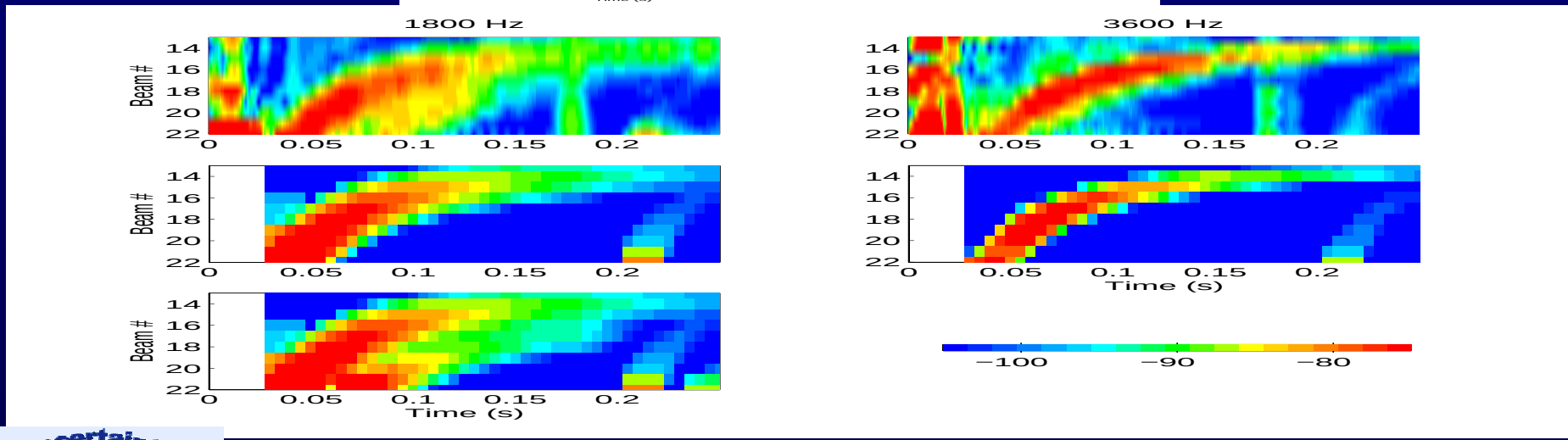
- .characterize the seabed geoacoustic variability using acoustic reflection / scattering data
- .determine uncertainties and errors in measurements and inversion/extraction processing
- serve as liaison to Boundary Characterization Joint Research Project Experiment series





Measured beam time-series from seabed scattering. The main scattering data are contained along the branch starting at 0.04 s. At 1800 Hz there is an additional scattering branch starting at 0.08 s, corresponding to a scatterig horizon 25m below the sub-bottom. The importance of the sub-bottom scattering increases with decreasing frequency. The units in are dB re 1 μPa/s²/Hz and have been normalized by source level.





Seabed Variability Effects on Propagation Prediction Uncertainty - Bob Odom

Objectives

- Compute model and data sensitivities, and resolution and variance trade-offs
- Investigate model parameter correlations, and optimal model parameterizations.
- What model parameters are most important? Can we resolve them? What will be the model variance? What additional data would be useful, if it were available? Which model parameters are essentially unresolvable (unconstrained)?

Analytical Expressions for Partial Derivatives

$$\mathbf{d} = \mathbf{Gm} = \frac{\partial \mathbf{g}}{\partial \mathbf{m}}\mathbf{m}$$

$$\frac{\partial \mathbf{g}}{\partial \mathbf{m}} = \left(\frac{\partial P}{\partial \kappa}, \frac{\partial P}{\partial \rho}\right)$$

$$\frac{\partial P(z_r, t; z_s, 0)}{\partial \kappa(z)} = \frac{1}{\kappa^2(z)} \; P(z, t; z_r, 0) * P(z, t; z_s, 0) * \frac{\partial^2}{\partial t^2} s(t)$$

$$\frac{\partial P(z_r, t; z_s, 0)}{\partial \rho(z)} = \frac{1}{\rho^2(z)} \left\{ \left[\frac{\partial}{\partial z} P(z, t; z_r, 0) * \frac{\partial}{\partial z} P(z, t; z_s, 0) * s(t) \right] - \right.$$

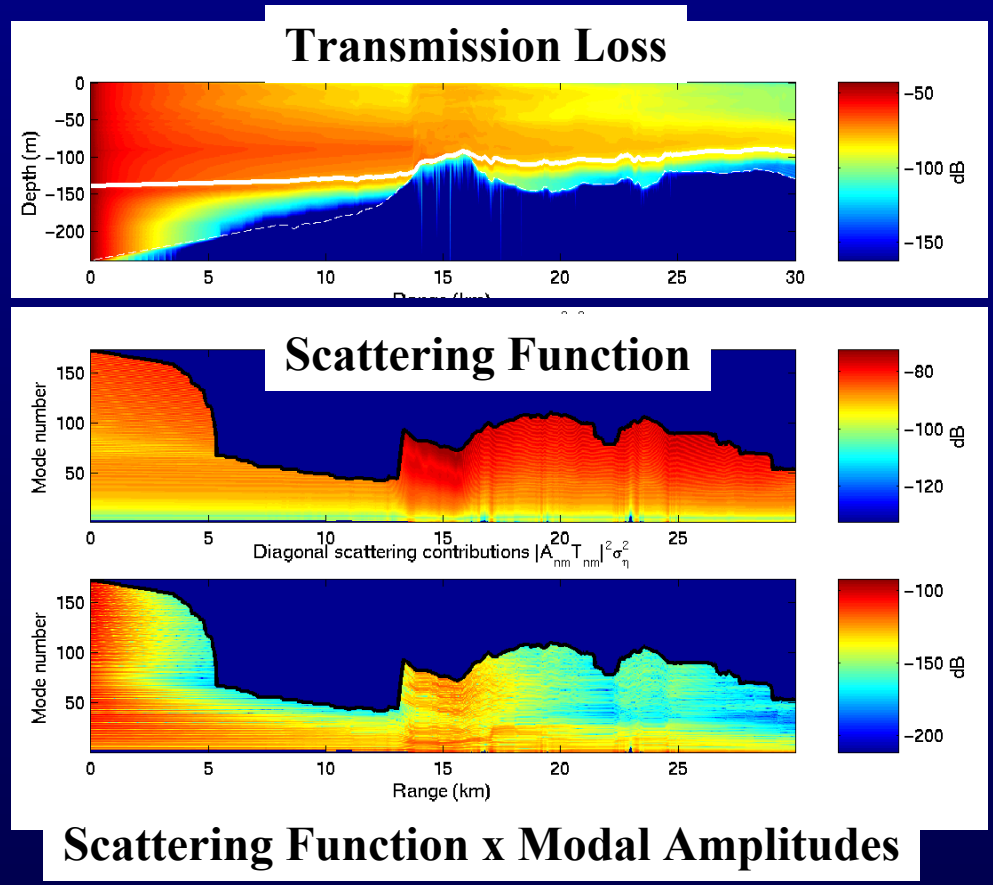
$$\left. \left[p^2 P(z, t; z_r, 0) * P(z, t; z_s, 0) * \frac{\partial^2}{\partial t^2} s(t) \right] \right\}$$

- $\left(\frac{\partial P}{\partial \kappa}, \frac{\partial P}{\partial \rho}\right)$ can be computed from **one pass** of FFP or SAFARI/OASES

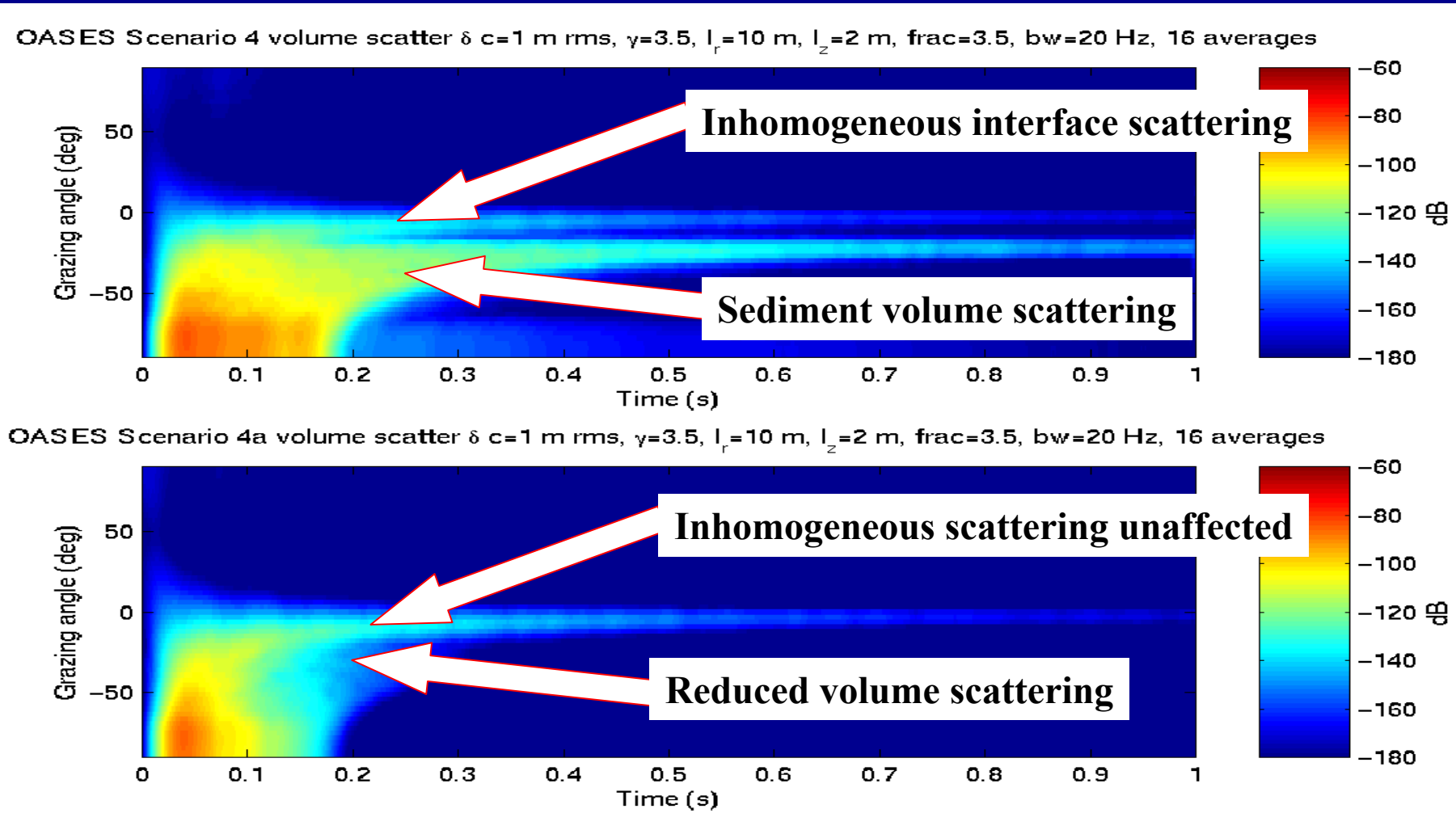
Seabed Variability Effects on Reverberation Prediction Uncertainty - Kevin LePage

Objectives

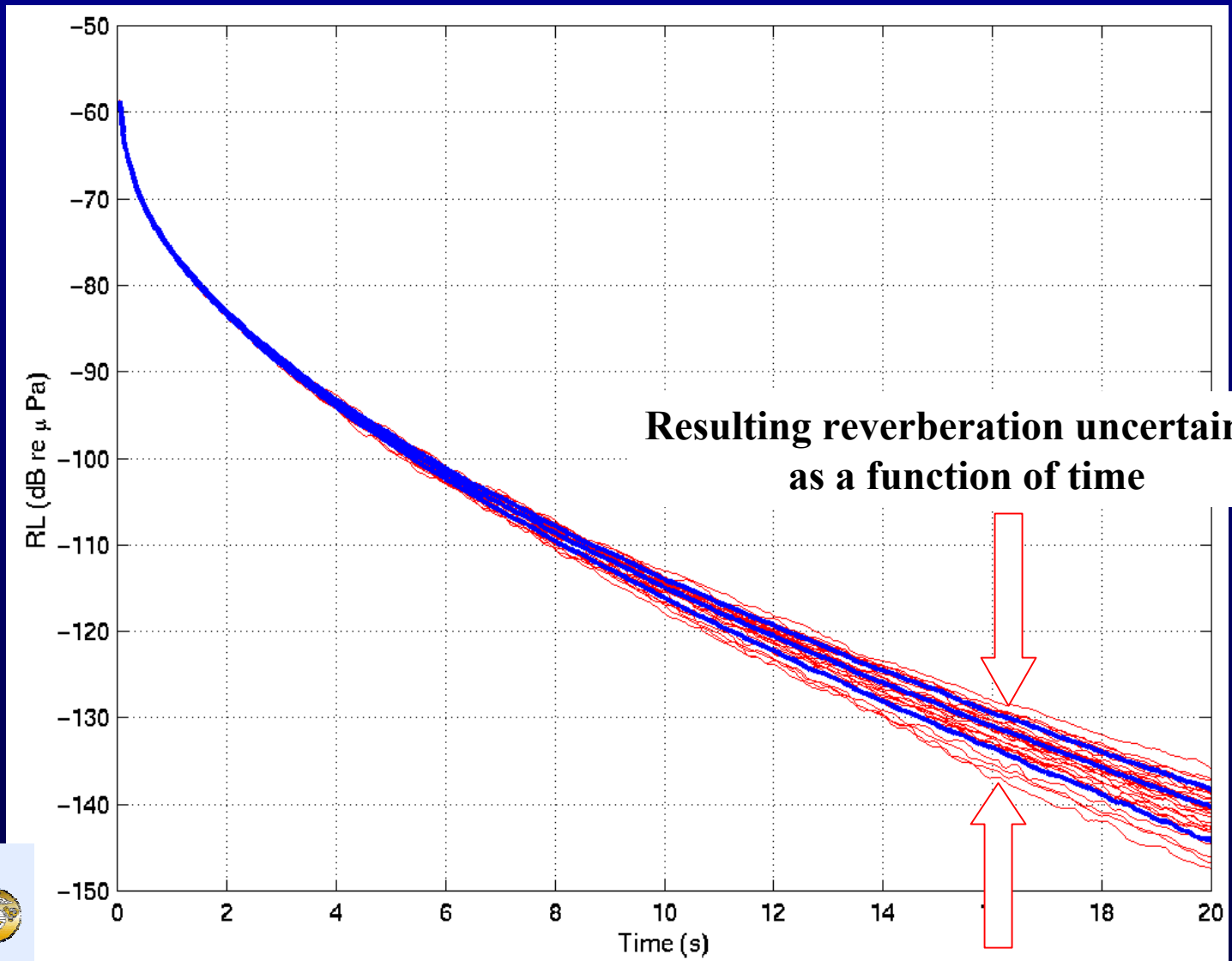
- Determine the fundamental uncertainty of acoustic time series to and from scatterers on and in the seafloor caused by large-scale variability of the seafloor properties.
- Determine the variance of the local scattering process due to the uncertainty of the fine scale variability that is superimposed on the large-scale seafloor structure.
- Determine the variance of the reverberation intensity due to the fundamental uncertainty of the large-scale seafloor variability.
- Determine the variance of the reverberation intensity due to uncertainty in the local scattering process alone



Scattering and re-radiation from small scale features in uncertain seafloors



Reverberation from bottom with large-scale sediment sound speed uncertainty



Products

SedFlux simulation of the seafloor characterization of selected sites: grain size, bulk density, porosity, bedding surfaces, age

Determination of *SedFlux* model uncertainty

Determination of natural variability in primitive environmental parameters

Determination of the impact of rare ocean events on the acoustic properties of continental margins

Seabed acoustic properties developed from (1) lab generated strata, and (2) *SedFlux* simulations.

Synthetic multi-offset seismic data of experimental strata assuming strata are elastic, and poroelastic.

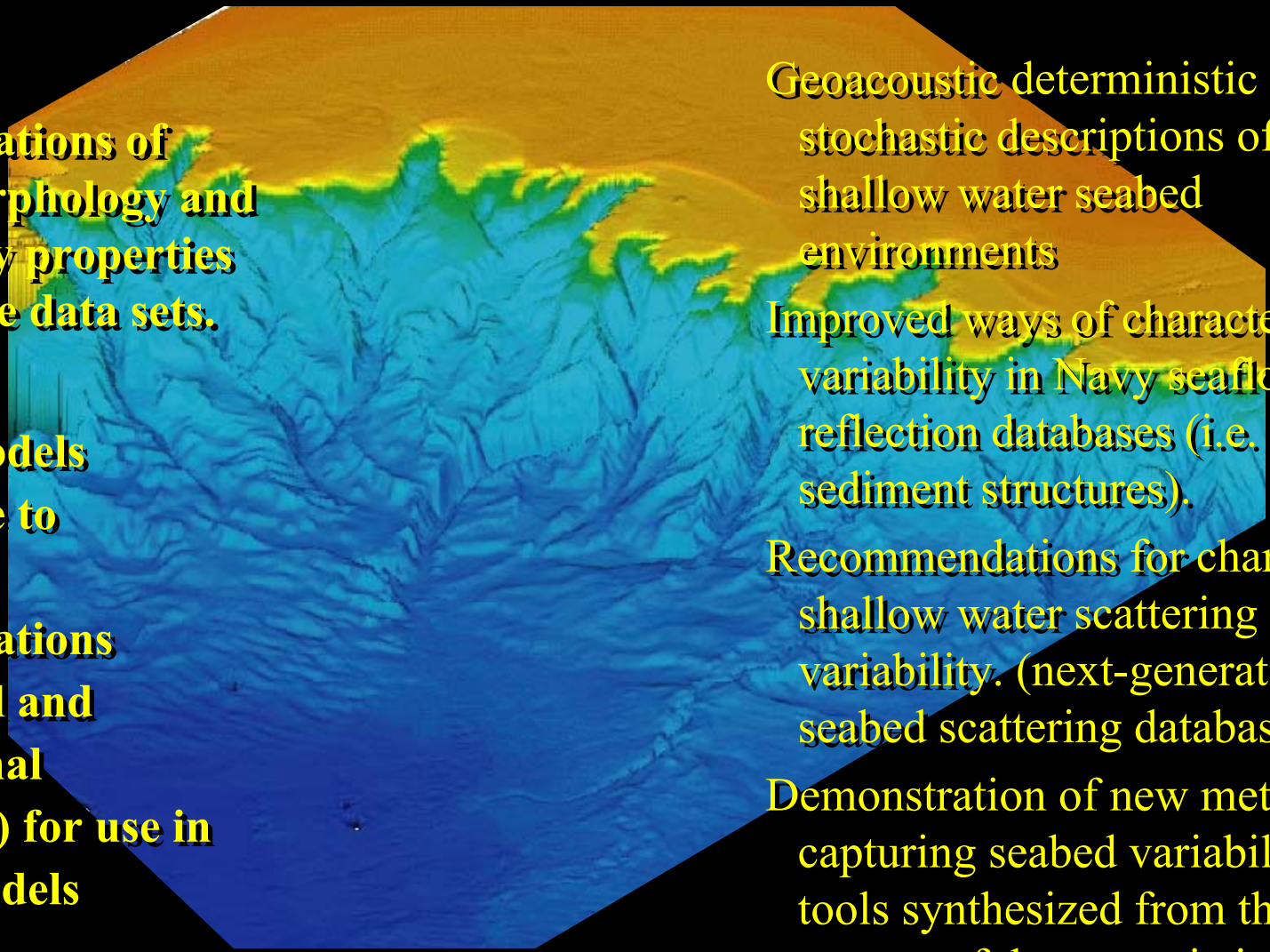
Software for carrying out the physical property modeling.

1D and 2D seismic simulation algorithms for elastic media and for poroelastic media

Products

Statistical characterizations of surface morphology and sedimentary properties for available data sets.

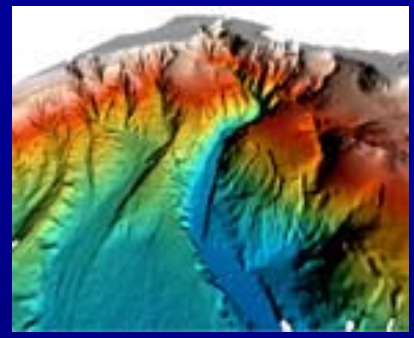
Seafloor models appropriate to statistical characterizations (conditional and unconditional simulations) for use in acoustic models



- Geoacoustic deterministic and stochastic descriptions of 3-D shallow water seabed environments
- Improved ways of characterizing variability in Navy seafloor reflection databases (i.e. new sediment structures).
- Recommendations for characterizing shallow water scattering strength variability. (next-generation seabed scattering database).
- Demonstration of new methods for capturing seabed variability using tools synthesized from the best aspects of the acoustic inversion, G&G modeling and G&G measurements.

QuickTime™ and a
GIF decompressor
are needed to see this picture.

Products



Coding of Frechet derivatives and model and data variance and resolution matrices

Characterization of variance/resolution trade-offs, model parameter correlations, and optimal model parameterization guidelines

Monte-Carlo measures of forward propagation variability for two seafloor sites of interest as a function of seafloor parameter uncertainty and frequency

Monte-Carlo estimates of reverberation intensity variance for sites of interest due to fundamental uncertainty on large scale seafloor variability

Monte-Carlo measures of scattering function variance due to uncertainty of large-scale seafloor composition and uncertainty of statistical characterization of fine scale seafloor roughness and inhomogeneities

Monte-Carlo estimates of the variance of reverberation intensity caused by uncertainty in the local scattering function

Comments?

QuickTime™ and a
Photo - JPEG decompressor
[illegible]

Movie is currently unavailable