geophysical data collected in the area. Details of the upper part of the sediment column that can be resolved from the short- and long-range data are presented. Sediment sound speed was better defined than density and attenuation.

9:20

5aUW6. A numerical adjoint parabolic equation (PE) method for tomography and geoacoustic inversion in shallow water. Jean-Pierre Hermand (Dept. of Optics and Acoust., Université Libre de Bruxelles, Belgium), Mohamed Berrada (Université Pierre et Marie Curie, Paris, France), Matthias Meyer (Royal Netherlands Naval College, Den Helder, The Netherlands), and Mark Asch (Université de Picardie Jules Verne, Amiens, France)

Recently, an analytic adjoint-based method of optimal nonlocal boundary control has been proposed for inversion of a waveguide acoustic field using the wide-angle parabolic equation [Meyer and Hermand, J. Acoust. Soc. Am. **117**, 2937–2948 (2005)]. In this paper a numerical extension of this approach is presented that allows the direct inversion for the geoacoustic parameters which are embedded in a spectral integral representation of the nonlocal boundary condition. The adjoint model is generated numerically and the inversion is carried out jointly across multiple frequencies. The paper further discusses the application of the numerical adjoint PE method for ocean acoustic tomography. To show the effectiveness of the implemented numerical adjoint, preliminary inversion results of water sound-speed profile and bottom acoustic properties will be shown for the YELLOW SHARK '94 experimental conditions.

9:35

5aUW7. Geoacoustic inversion by mode amplitude perturbation. Travis L. Poole (MIT/WHOI Joint Program in Oceanogr. and Oceanogr. Eng.,Woods Hole Oceanogr. Inst., Woods Hole, MA 02543, tpoole@whoi.edu), James F. Lynch, Allan D. Pierce (Woods Hole Oceanogr. Inst., Woods Hole, MA 02543), and George V. Frisk (Florida Atlantic Univ., Dania Beach, FL 33004)

In a shallow-water waveguide the geoacoustic properties of the seafloor have a significant effect on the way sound propagates through the water. Because of this, measurements of the pressure field in the water can be used to estimate bottom properties. In this talk a perturbative method is presented which allows one to use measurements of the modal amplitudes to estimate a set of bottom parameters. A key component of the method is an expression for the derivative of the mode functions with respect to some bottom parameter. Following from the work of Thode and Kim [J. Acoust. Soc. Am. **116**, 3370–2283 (2004)], the derivative is expressed as a weighted sum over all modes (both propagating and leaky). It is thought that this method can be used alongside eigenvalue perturbation [Rajan *et al.*, J. Acoust. Soc. Am. **82**, 998–1017 (1987)] to provide an inversion scheme more robust to measurement noise. To demonstrate its feasibility, the method is applied to synthetic and real data. [Work supported by the WHOI education office.]

9:50–10:05 Break

10:05

5aUW8. Physics-based clutter via semi-deterministic simulation with bathymetric fractal realizations. Charles Monjo and Juan Arvelo, Jr. (Johns Hopkins Univ./Appl. Phys. Lab., 11100 Johns Hopkins Rd., Laurel, MD 20723-6099)

A semi-deterministic normal-mode reverberation model has been developed that accounts for bistatic bottom micro-slopes generated via bathymetric fractal realizations to simulate clutter scattering from seafloor interface features. This clutter simulator also accounts for uncertainties of the subbottom geoacoustics and on range-dependent interface scattering that varies with the seafloor sediment type. This physics-based approach is compared against measured clutter-rich bottom reverberation from the TMAST02 experiment. [This work is sponsored by ONR.]

10:20

5aUW9. Relating the distribution of bathymetry to clutter distributions. Bruce Newhall and Juan Arvelo, Jr. (Johns Hopkins Univ./Appl. Phys. Lab., 11100 Johns Hopkins Rd., Laurel, MD 20723-6099)

One source of clutter for active sonar in shallow water is backscatter from the rough ocean bottom. Backscatter may often be dominated by Bragg scale roughness. Bathymetry measurements are not generally made at sufficient resolution to determine the Bragg scale roughness distribution directly. We examine the distribution of ocean bottom slopes and determine power law relationships. These relationships can be used to define fractals which allow extrapolations of bathymetry to finer scale. The fine-scale bathymetry is then related to the distributions of sonar clutter. The generalized gamma distribution is particularly useful to describe clutter. The upper tail of this distribution approaches a power law related to the power laws in the bathymetry. [This work is sponsored by the Office of Naval Research (ONR).]

10:35

5aUW10. Broadband shallow-water reverberation statistics. Jon C. Reeves, Robert J. Ferlez, Gregory A. Babich, Gary L. Morella (Appl. Res. Lab, The Penn State Univ., P.O. Box 30, State College, PA 16804), and Anthony J. Cuetzo (The Penn State Univ., State College, PA 16804)

Utilizing a wideband transmitting/receiving system, at-sea experimental results for broadband reverberation have been acquired for both harsh as well as moderate ocean acoustic environments. The principal contributor to the backscattered reverberation is bottom features at the shallow-water ocean sites. Replica correlation (so-called match filter) processing of linear FM (LFM) pulse codes is employed to study the degree of reverberation coherence, as measured by the replica correlation coefficient. The database covers several octaves of bandwidth. The corresponding reverberation coherence is computed in terms of the variance of the cross correlation coefficient (cc) as a function of time–bandwidth product. Of particular interest is the possible departure from Rayleigh statistics as signal bandwidth increases. Several bandwidths are compared, using the Kolmogoroff–Smirnof test as a measure of departure from Rayleigh. [This work was sponsored by A. Nucci, ONR 333.]

10:50

5aUW11. Non-Rayleigh reverberation prediction for shallow-water waveguides. Kevin D. LePage (NRL, Code 7144, 4555 Overlook Ave. SW, Washington, DC 20375)

In a previous paper the second moment of monostatic reverberation intensity was derived for rough surfaces in range-independent waveguides with χ_1^2 scatterer amplitude statistics and Gaussian spatial correlation functions [J. Acoust. Soc. Am. **117**, 2611 (2005)]. Here, these results are expanded to bistatic geometries and the implications for the degree of non-Rayleighness of the resulting reverberation pressure envelope statistics are discussed. [Work supported by ONR.]

11:05

5aUW12. Nonlinear compressional waves in marine sediments. B. Edward McDonald (Naval Res. Lab, Code 7145, Washington, DC 20375, mcdonald@sonar.nrl.navy.mil)

A theory for nonlinear waves in marine sediments must account for the presence of a granular frame filled with water and possibly gas bubbles. When grains are in full contact, the stress–strain relation for the sediment contains a contribution varying as strain to the power 3/2, referred to as the Hertz force. The quadratic nonlinearity parameter derived from the second pressure derivative with respect to density thus diverges in the limit of small strain. We present a simple nonlinear wave equation model (a variant of the NPE) for compressional waves in marine sediments that avoids Taylor expansion and the problem of diverging nonlinearity parameter. An equation of state for partially consolidated sediments is derived from consolidation test results. Pressure is found to increase with overdensity to the power 5/2, indicating an increase in the number of contacts per