many layers should be used to parametrize the bottom). We will demonstrate this for a range-dependent inversion, in which in one case there is a bottom inclusion (bottom properties are abruptly different over some range interval between the source and receiver), and another case where there is an internal wave. After reviewing these examples, we will discuss some practical issues in applying adjoint models to real data.

2:05

1pSP4. Adjoint approach to the physical characterization of a shallow-water environment. Matthias Meyer, Jean-Pierre Hermand (Dept. of Optics and Acoust., Université libre de Bruxelles, av. F. D. Roosevelt 50, CP194/05, B-1050 Bruxelles, Belgium), Mohamed Berrada (Université de Pierre et Marie Curie, 75252 Paris Cedex 05, France), and Mark Asch (Université de Picardie Jules Verne, 80039 Amiens Cedex 1, France)

In underwater acoustics a variety of different applications of adjoint models has been proposed in recent years. Adjoints have been derived for normal modes and for both the standard parabolic equation and Claerbout's wide-angle approximation. This paper reviews the analytic nonlocal boundary control approach proposed in an earlier paper by the authors [Meyer & Hermand, "Optimal nonlocal boundary control of the wide-angle parabolic equation for inversion of a waveguide acoustic field," J. Acoust. Soc. Am. **117**, 2937–2948 (2005)] and presents a numerical extension that allows direct inversion of the geoacoustic parameters that are embedded in a discrete representation of the nonlocal boundary condition at the water-sediment interface. The effectiveness of this numerical adjoint approach for the physical characterization of a shallow-water environment is illustrated with applications for geoacoustic inversion and ocean acoustic tomography. In particular, it is shown how a joint inversion across multiple frequencies can enhance the performance of the optimization process, especially for the case of a sparse receiver array spanning part of the water column. In an additional example we combine the two applications and discuss the feasibility of geoacoustic inversion in the presence of an uncertain sound-speed profile.

2:25

1pSP5. Bathymetry inversion in shallow water using an adjoint method. Isabelle Charpentier (Project Idopt (CNRS, INRIA, UJF, INPG), BP 53, F-38041, Grenoble Cedex 9, France) and Philippe Roux (Universite Joseph Fourier, Grenoble, France)

Bathymetry inversion is performed at low frequency on a kilometer-scale shallow water waveguide between two vertical arrays of sources and receivers. The inversion is based on the use of the adjoint of a wide-angle Pade PE code. The adjoint is obtained using automatic differentiation software. The bathymetry is decomposed under a limited number of spline functions. Inversion results improve with the number of source/receiver pairs and when a multiple-frequency approach is used. Application to experimental at-sea data is discussed.

Contributed Paper

2:45

1pSP6. Time-reversal-based noniterative exact inverse scattering of multiply scattering point targets. Edwin A. Marengo and Fred K. Gruber (Dept. of Elec. and Comput. Eng., Northeastern Univ., Boston, MA 02115)

This research investigates within exact scattering theory time-reversal-based approaches for the inverse scattering in a known but rather arbitrary embedding background medium of an unknown total scatterer composed of a number of dominant subwavelength (pointlike) scattering centers (targets) that are located at unknown positions and have unknown scattering strengths or reflectivities (characterizing a scattering potential). Of particular interest is the formulation of a new inverse scattering method (com-

prising both inverse support and inverse medium aspects) based on a two-step procedure. The first step (support inversion) consists of the localization of the targets via signal subspace approaches such as time-reversal MUSIC and a new, high-dimensional signal subspace method that is shown to be linked to maximum likelihood estimation. The second step (nonlinear medium inversion) is a new, noniterative scattering strength inversion formula for the reconstruction of the target scattering strengths or reflectivities. Importantly, the derived method is valid even in the presence of multiple scattering between the targets, which is remarkable since the mapping from the reflectivities to the field data is then nonlinear. The theory is illustrated with several computer examples. [Work supported by AFOSR under Grant FA9550-06-01-0013.]

3:00−3:20 Break

Invited Papers

3:20

1pSP7. Application of the acoustic adjoint equation to normal mode propagation in a waveguide. Aaron Thode (Marine Physical Lab., Scripps Inst. of Oceanogr., UCSD, La Jolla, CA 92093-0238)

This presentation reviews work that applied the acoustic adjoint equation to situations where the propagating acoustic field in an oceanic waveguide can be expressed as a sum of normal modes. The acoustic adjoint equation [Norton, "Inertive inverse scattering algorithms: Methods of Computing Fréchet derivatives," J. Acoust. Soc. Am. **106**, 2653–2660 (1999)], Hurksy *et al.*, "Adjoint modeling for acoustic inversion, J. Acoust. Soc. Am. **115**, 607–619 (2004)] which has a form very similar to the Born approximation, provides an expression for multiple-order derivatives of the received acoustic field with respect to an infinitesimal change in an environmental parameter, which in turn can be used to derive the gradient of an error or ambiguity function without resorting to numerical derivatives. For the situation of a range-independent environment, closed-form analytical expressions can be obtained for pressure derivatives with respect to range-independent perturbations in refractive index and density in the water column and sediment, as well as derivatives with respect to frequency. Expressions have also been derived for derivatives with respect to three-dimensional refractive index perturbations, which permits the evaluation of certain horizontal refraction effects of environmental perturbations without resorting to three-dimensional propagation codes. Current work on obtaining derivatives with respect to perturbations in waveguide boundary conditions (bottom bathymetry or sea surface shape) will also be discussed. [Work supported by the ONR Uncertainty Program.]