JOURNAL OF COMPUTATIONAL PHYSICS 54, 1–2 (1984)

Workshop on Computational Seismology

PREFACE

The following six papers represent a distillation of papers presented at a workshop on computational seismology, held at Salishan Lodge, Gleneden Beach, Oregon, on March 23–26, 1981. The workshop was sponsored equally by the Air Force Office of Scientific Research, the Department of Energy, the National Science Foundation, and the Office of Naval Research.

The computation of synthetic seismograms is a major contributor to our understanding of earth structure and of seismic sources. In the structure problem the source is presumed known, and the material is to be reconstructed from the seismograms. This technique is used, for example, in seismic prospecting.

In the seismic-source problem the earth structure is presumed known, and the seismograms are used to determine the source. This sort of problem arises in the study of earthquake mechanisms. It also arises from our desire to be able to distinguish earthquakes from underground explosions. It usually happens in these problems that neither the structure nor the source is known very well, and we want to determine both.

The workshop had as its theme the computation of synthetic seismograms from a given source and a given earth structure. This theme, the direct problem, is basic to the solution of the above inverse problems, because the solution of an inverse problem is an iterative parameter-estimation procedure involving the solution of many direct problems.

The major current computational methods in seismology are based on ray tracing, integral transforms, and finite differences or finite elements. Each of these methods has advantages and disadvantages. Ray tracing is appropriate for the high-frequency behavior but not for the low-frequency tail. In petroleum prospecting, integral transforms are sometimes used with an acoustic approximation, but the seismogram may contain shear-wave signals in addition to the P-waves the seismologist expects. Since shear waves travel more slowly than P-waves, the interpretation of them as P-waves leads the seismologist to insert phantom deep layers into the model structure. In global and regional seismology integral transforms of the full elastic equations are used, but they give rise to difficult quadrature problems: poles as well as an oscillatory integrand. As a consequence, the method produces absurd answers when the distances are too long or the layers too thin. Finite differences and finite elements introduce numerical dispersion, so they are valid only at short distances. We have reached the stage where the newly available high quality digital data call for interpretations based on better theoretical and numerical procedures than are presently available. More complicated problems, such as, laterally heterogeneous media and diffraction phenomena, cannot be adequately treated with present methods.

0021-9991/84 $3.00

In the first paper of the six presented here, K. Aki shows how short-period seismograms are used to determine the earth's structure. The next paper, by Chin, Hedstrom, and Thigpen, explains to numerical analysts the computational problems faced by seismologists, and it gives perspective to seismologists of current numerical techniques. The next three papers give more detailed information on specific numerical methods: Lyness on quadrature for trigonometric integrals, Shampine on automatic identification of stiffness in codes for ordinary differential equations, and Varah on computational linear algebra. Finally, Buland and Gilbert use generalized algebraic eigenvalue techniques to compute the free oscillations of the earth.

R. C. Y. CHIN
FREEMAN GILBERT
GERALD HEDSTROM