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Jahr: 1977
Kollektion: fid.geo
Signatur: 8 Z NAT 2148:
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Werk Id: PPN1015067948_0043
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948_0043

LOG Id: LOG_0076
LOG Titel: On the excitation of the earth's seismic normal modes
LOG Typ: article

Übergeordnetes Werk

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PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948
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On the Computation of Theoretical Seismograms for Multimode Surface Waves

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It is needlessly expensive to use standard computational techniques, when applying inverse Fourier transformation to construct theoretical seismograms from frequency-domain data for multimode surface waves. Such techniques require the evaluation of dispersion and attenuation information for each mode, at each of a dense set of points which are equally spaced in frequency. These evaluations are by far the most expensive part of the computation of theoretical seismograms for surface waves. By further development of a method proposed by Aki, and departing from the standard, equal-frequency-interval computational techniques, it is possible to decrease the required number of dispersion and attenuation evaluations. With our new method we obtain an increase in computational efficiency of 200% for the fundamental mode and 500% for the higher modes. With the proposed techniques: (a) a quadratic fit to the amplitude spectrum is applied in each frequency interval, (b) a linear or quadratic fit to the phase spectrum is used in each interval, (c) automatic control over the accuracy of the theoretical seismograms is maintained, and (d) with this control feature we can apply the method over as extensive a period range as one desires, irrespective of how rapidly the group velocity varies.

Reference

Calcagnile, G., Panza, G.F., Schwab, F., Kausel, E.: On the computation of theoretical seismograms for multimode surface waves. Geophys. J. **47**, 73–81, 1976

On the Excitation of the Earth's Seismic Normal Modes

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The excitation of the earth's normal modes is formulated as an initial value problem. The static state of the earth, stressed from its hydrostatic reference situation, is considered as the initial state. The initial state is relaxed, at the time of the earthquake, by the removal of the forces maintaining the departure from hydrostatic equilibrium. Expressions are derived for the coefficients giving the relative excitation of the individual modes for the cases where these forces are compensating volume forces or compensating tractions on the faces of a dislocation. It is demonstrated that a point slip dislocation has a body force equivalent in the form of a double couple with a deviatoric moment tensor. However, for a source with volume change no moment tensor equivalent can be found. The

volume change, apart from an elastic effect which can be represented by an isotropic moment tensor, has a direct gravitational effect on the excitation. This effect is due to a balanced force field consisting of a point force at the source and a continuous distribution of volume forces throughout the earth. The latter distribution, if not taken into account, may give rise to artificial phases in the frequency spectrum of the normal modes.

Reference

Vlaar, N.J.: On the excitation of the earth's seismic normal modes. Pure and Appl. Geophys. **114**, 863–875, 1976

Seismic Velocities and Density of an Attenuating Earth

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The dispersion that accompanies attenuation has been taken into account in many recent body wave studies. In free oscillation and surface wave investigations, however, the effect has been assumed to be of second order and, hence, has been ignored. Liu, Anderson, and Kanamori (1976) have recently re-examined this effect and have shown it to be first order across the seismic band. In order to compare data from different frequency bands, then, a frequency-dependent correction must be applied to the observed phase velocities. The corrected data will then be representative of the elastic properties of the earth at the selected reference frequency. In the case of the free oscillations and long-period surface waves corrected to body wave frequencies (about one cycle/s), this correction factor is of the order of 1%, many times larger than the uncertainty of the raw data.

As a first step in determining the appropriate attenuation corrections, a satisfactory Q model must be developed. We have used free oscillation, surface wave, and body wave observations to obtain a new average Q structure for the earth, designated model SL1. This model includes a low Q zone at both the top and the bottom of the mantle. In these regions, seismic velocities will be frequency dependent. This Q model has been used to correct the observed eigenperiods of the spheroidal and toroidal modes to a reference period of 1 s. The corrected data set was then inverted to obtain the radial variation of density and seismic velocities within the earth. The largest changes from previous gross earth models, obtained through inversion of uncorrected data, occur in the upper mantle and at the very base of the lower mantle. In the upper 700 km of the earth, the inferred compressional and shear velocities increase by about 2% over previous results. The resulting body wave travel-times no longer show the large discrepancies with times predicted by body wave studies. In particular, the shear wave travel-times show only a 1.0 s baseline shift relative to the Jeffreys-Bullen values as compared to the 6–10 s shift of past models. Deep continental-oceanic mantle differences are no longer required to explain this feature.

The fact that seismic velocities depend significantly on frequency considerably complicates efforts to determine the structure and composition of the mantle. A detailed knowledge of the frequency dependence of Q from ultrasonic frequencies to normal mode frequencies as well as the distribution of attenuation with depth is necessary before seismic data can be interpreted with confidence. The development of a Standard Earth is substantially hindered as well. If the Standard Earth is a valid concept, then a standard Q model and reference frequency must also