Earthquake Location

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Introduction: Earthquake location is an interesting and significant aspect of seismology. Locating earthquakes is necessary for compiling useful seismicity information, calculating magnitudes, and study of fault zones, Earth structure and the earthquake process. Methods of earthquake location involve understanding of seismic waves, wave propagation, interpretation of seismograms, Earth velocity structure, triangulation, and the concepts (and mathematics) of inverse problems. Because earthquake location can be approached with relatively simple to very complex methods, it can be included in various levels of educational curricula and for "in-depth" study. Progressively developing a deep understanding of concepts, computational techniques and applications (and the capabilities, limitations and uncertainties of these applications) is a characteristic of science and an opportunity to "learn science by doing science". A number of methods that vary from simple to complex are available for learning about earthquake location. The methods also allow connections to other important concepts in seismology and provide a variety of approaches that address different learning styles and can be used for reinforcement and assessment.

Earthquake Location Methods: The following earthquake location exercises vary from simple to complex and involve different levels of mathematics and technology. Reasonably complete descriptions, education resources or teaching modules are included in the websites listed below.

Virtual Earthquake: An online S minus P time earthquake location simulation. See:
http://www.sciencecourseware.org/VirtualEarthquake/ (old version),
http://www.sciencecourseware.org/eec/Earthquake/ (new version).

Five-Slinky Activity: A hands-on activity using slinkys that illustrates the travel time differences from an earthquake caused by differences in distance related to station location (as well as wave propagation in all directions). The slinky activities are also useful for teaching about seismic waves and wave propagation. http://web.ics.purdue.edu/~braile/edumod/slinky/slinky4.pdf
http://web.ics.purdue.edu/~braile/edumod/slinky/slinky.pdf

Walk-Run Activity: A hands-on simulation of the S minus P earthquake location method using walking and running to represent S and P wave propagation. Activity includes triangulation to locate an unknown event. http://web.ics.purdue.edu/~braile/edumod/walkrun/walkrun.htm

EQlocation: An S minus P earthquake location exercise that uses real seismograms to locate the September 30, 1999 Oaxaca, Mexico earthquake. The S-P times can be measured from printed copies of the seismograms or determined from digital seismograms displayed and analyzed using the AmaSeis software. The earthquake location can then be determined by triangulation using the calculated distances determined from the S-P times and plotting on a globe. The earthquake location can also be plotted accurately along with historical seismicity using the enhanced IRIS Event Search tool. A PowerPoint presentation for this activity is also available.
http://web.ics.purdue.edu/~braile/edumod/as1lessons/EQlocation/EQlocation.htm
http://web.ics.purdue.edu/~braile/edumod/eqdata/eqdata.htm
http://web.ics.purdue.edu/~braile/edumod/as1lessons/EQlocation/SminusP0304.ppt

EqLocate: EqLocate is an interactive earthquake location program that uses actual seismograms and user-selected P-wave arrival times to locate the earthquake. The program uses a method that is similar to the approach that is used by seismologists to routinely determine the location of earthquakes from around the world. In the standard method, tens to hundreds of arrival times (each from an individual seismogram corresponding to a seismograph station) are used by a computer program to automatically find an optimum solution (location and origin time of the earthquake determined such that the observed arrival times match the theoretical arrival times calculated using a well-known seismic velocity model for the Earth). In EqLocate, a limited number of seismograms (3 to 10, or more) and corresponding arrival times are used, and the solution is found by the user selecting trial locations on a map until an optimum location is found. The user is guided in the selection of trial epicenters by graphical information generated by EqLocate from the previous trial location. Once a close epicenter is found, the depth of focus of the earthquake can be estimated by changing the trial depth and selecting additional trial epicenters. A measure of the quality of the final solution is provided by calculation of the differences between observed and theoretical arrival times and by a color coded display of solutions that are close to the optimum location. The software can be downloaded from Alan Jones' website (see below). A tutorial including a description of how the program works, examples of earthquake locations and sample data is available at: http://web.ics.purdue.edu/~braile/edumod/eqlocate/tutorial.htm.

HYPO71, etc.: For advanced undergraduates and graduate students, the programs that are routinely used to locate earthquakes for standard catalogs and for research purposes can be utilized to explore the least squares and inverse methods for determining hypocenter data and estimating location uncertainties. Since about 1970, program HYPO71 and related programs (HYPOCENTER, HYPOINVERSE, HYPOINVERSE-2000, HYPOELLIPSE, and HYPOLAYR) have been used for these purposes. Information about these programs and software can be found at the following websites: http://www.jclahr.com/science/software/hypo71/index.html,
http://www.bssaonline.org/cgi/content/abstract/76/3/771
http://earthquake.usgs.gov/research/software/index.php
http://wrgis.wr.usgs.gov/open-file/of02-171/

Related Links:

Alan Jones' software (Seismic/Eruption, Seismic Waves, AmaSeis, EqLocate):
http://www.geol.binghamton.edu/faculty/jones/

Seismic wave animations: http://web.ics.purdue.edu/~braile/edumod/waves/WaveDemo.htm

Seismic Waves PowerPoint files: http://web.ics.purdue.edu/~braile/new/SeismicWaves.ppt,
http://web.ics.purdue.edu/~braile/new/SeismicWaves4Types.ppt

Prof. Dan Russell wave animations: http://www.kettering.edu/~drussell/demos.html