Hypocenter determination method, using pre-calculated travel time by paraxial ray approximation method

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Calculating travel-times in three-dimensional velocity structure is time consuming process. In this study, we calculate the travel-times of all grid points of the target area and store them in files. Reading the travel time, we get the travel-time at any point in the target area, very quickly. It is also possible to relocate hypocenters in three-dimensional structure, very quickly.

We use the paraxial ray approximation method to execute ray tracings, as ray shooting method. In this method, wave front as well as travel time is also calculated along the ray. It means that it is possible to extrapolate the travel time around the ray using the wave front. We can also accelerate the ray shooting efficiently by correcting the emergence angle at the starting point of ray tracing utilizing the wave front.

We calculate travel times and the related parameters at all grid points and all seismic stations with this method. The result is saved in files as follows.

/grid_latitude/grid_longitude/grid_depth/ray_parameter_file_of_all_stations

We read the file of the nearest grid of a given event location.

We apply our method to one-dimensional velocity structure, at first. The target area is 34.-37N x 136-141E x 40-140km. The grid interval is 0.125 x 0.125 x 12.5km. The evaluated mean travel time error is approximately 0.005 sec. 4392 events are relocated in 64.7 sec (0.0147sec/event).

We next apply to three-dimensional case. The target area is 35.5-36.0N x 139.5-140.0E x 40-65km. The grid interval is 0.050 x 0.050 x 5.0km. The evaluated mean travel time error is approximately 0.03 sec. 141 events are relocated in 2.61 sec (0.0185sec/event).

When keeping the ray parameter data in the computer memory instead of the file system, the processing time is reduced to approximately 2 millisecond /event in both 1-D and 3-D cases.