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Tsunami Ray Tracing Method for Shortest Travel-Time Path

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We propose a ray-tracing method to solve the two-point boundary value problem for tsunamis based on the long-wave theory. In the long-wave theory, the tsunami wave velocity is proportional to the square root of water depth, which is available from global bathymetric atlases. Our method computes the shortest travel times starting from each of the two given points and calculates the local ray direction to trace the ray path. We utilize an explicit, non-iterative tracing scheme that exhibits robust results and applies to any tsunami-accessible locations, and the global-shortest travel-time path is derived. In simple and real bathymetry cases, our method demonstrates stable results with neglectable low uncertainties. The ray-tracing method is then applied to analyze the path of tsunamis from different directions to four important bays in Japan. The result shows that tsunami ray paths are significantly influenced by local bathymetry, and some crucial structures, such as trench and trough, behave as the primary routes of this region. Deploying stations near these routes will be most beneficial for tsunami early warning. The existing tsunami-observing system off the Honshu area works well for tsunamis from the east side but slightly deficient for tsunamis from the west side. The far-field ray tracing shows that tsunamis traveling from Chile to Japan through two main routes—one via north Hawaii and the other via the south— depending on the location of the source.