A simple velocity model for hypocenter determinations using data from land and ocean observation networks

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Introduction:
In order to improve detection capabilities of earthquakes in the ocean, dense observation networks as DONET by JAMSTEC and S-net by NIED have been developing in recent years. Hypocenter determinations using data from these networks and land observation data will improve the accuracy of earthquake source locations in the ocean. On the other hand, 1D velocity structure may not be appropriate because of strong lateral heterogeneities in subduction zones. Nakano et al. (2015) used 3D velocity model for hypocenter determinations. But this method is not appropriate for real-time or routine operations because of its high computational cost.
In this study, we propose a simple 2D velocity model for hypocenter determinations using data from ocean and land observation networks.
Proposed velocity model:
We propose a 2D model of which 1D velocity structures of land and ocean are connected along a plate boundary. The ray path is assumed not to bend in the horizontal direction. For hypocenter determinations, a travel time table with respect to the source depth, epicentral distance, and the depth where the ray path crosses the plate boundary. The plate boundary is defined according to the hypocenter distribution determined by JMA. The boundary is separated to several segments to represent horizontal bending of the plate boundary.
The proposed velocity model is 2D, but it resembles 3D plate model because we have incorporated horizontal plate bending. The implementation is easy because the travel times can be computed using 1D ray tracings.
Hypocenter determinations:
Using the 2D model proposed above, and 1D models assuming land and ocean, we determined hypocenters. We estimated site corrections for the P- and S-wave travel times for each station, and re-determined the hypocenters. We used P- and S- readings from DONET1 and land stations used in Nakano et al. (2015).
Epicenter distributions are almost the same for the three models, but the source depths are distinctly different: 1D land model overestimates the source depths in the ocean.
At stations in the ocean, the obtained site corrections reflect the thickness of the sediments in the basin, a common feature obtained for the three models. At stations on land, we obtained corrections larger than 1 s for 1D ocean model. Correction values were rather small for 1D land and 2D models on land.
The RMS traveltime residual was 0.45 s, 0.52 s, and 0.46 s for 1D land, 1D ocean, and 2D models, respectively.
Discussion:
The RMS traveltime residual indicate that the 1D land model explains the observed ones as well as the 2D model proposed, while the source depths are overestimated. To explain this feature, we conducted the same analysis above but using data from only DONET stations and earthquakes that occurred beneath the sea for the 1D land and ocean models.
Hypocenter distributions were almost same including the source depths, giving almost similar RMS residuals of about 0.25 s. The site corrections, on the other hand, were very different: For the 1D land model, the corrections for P and S waves were positive (to delay observed one) and negative,

respectively, at almost all stations. This result indicates that setting uniform corrections for travel times compensated the mismatch of the velocity structure.
From this result, we obtained the conclusion that the overestimation of the source depths for 1D land model using ocean and land data was due to compensations of the late travel times for earthquakes in in the ocean, without much degrading the RMS residuals.
Conclusion:
Use of an accurate velocity structure is necessary for appropriate estimations of earthquake source depth, which is crucial for discussions of seismic activities in the ocean and evaluations for tsunami potential. The 2D model proposed in this study would be appropriate especially for real-time source determinations.

Keywords: DONET, S-net, Subduction zone

