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Improving automatic earthquake locations in subduction zones: a case study for GEOFON catalog of Tonga-Fiji region

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Automatic earthquake locations are sometimes associated with very large residuals up to 10 s even for clear arrivals, especially for regional stations in subduction zones because of their strongly heterogeneous velocity structure associated. Although these residuals are most likely not related to measurement errors but unmodelled velocity heterogeneity, these stations are usually removed from or down-weighted in the location procedure. While this is possible for large events, it may not be useful if the earthquake is weak. In this case, implementation of travel-time station corrections may significantly improve the automatic locations. Here, the shrinking box source-specific station term method (SSST) [Lin and Shearer, 2005] has been applied to improve relative location accuracy of 1678 events that occurred in the Tonga subduction zone between 2010 and mid-2014. Picks were obtained from the GEOFON earthquake bulletin for all available station networks.
We calculated a set of timing corrections for each station which vary as a function of source position. A separate time correction was computed for each source-receiver path at the given station by smoothing the residual field over nearby events. We begin with a very large smoothing radius essentially encompassing the whole event set and iterate by progressively shrinking the smoothing radius.
In this way, we attempted to correct for the systematic errors, that are introduced into the locations by the inaccuracies in the assumed velocity structure, without solving for a new velocity model itself.
One of the advantages of the SSST technique is that the event location part of the calculation is separate from the station term calculation and can be performed using any single event location method. In this study, we applied a non-linear, probabilistic, global-search earthquake location method using the software package NonLinLoc [Lomax et al., 2000]. The non-linear location algorithm implemented in NonLinLoc is less sensitive to the problem of local misfit minima in the model space. Moreover, the spatial errors estimated by NonLinLoc are much more reliable than those derived by linearized algorithms.
According to the obtained results, the root-mean-square (RMS) residual decreased from 1.37 s for the original GEOFON catalog (using a global 1-D velocity model without station specific corrections) to 0.90 s for our SSST catalog. Our results show 45-70% reduction of the median absolute deviation (MAD) of the travel-time residuals at regional stations. Additionally, our locations exhibit less scatter in depth and a sharper image of the seismicity associated with the subducting slab compared to the initial locations.