Cross-Network Microseismic Relocations of Some Aftershocks From the 1992 Nicaraguan Tsunami Earthquake

Grant T. Farmer, Andrew V. Newman, Abhijit Ghosh, Amanda M. Thomas

Georgia Institute of Technology, School of Earth and Atmospheric Science, Atlanta, GA 30332
http://geophysics.eas.gatech.edu/anewman/research/Nicoya/

Georgia Institute of Technology

Georgia Institute of Technology Geophysics School of Earth and Atmospheric Sciences

Abstract:

Using earthquake phase information from discrete earthquake catalogs in Central America (Nicaragua and Costa Rica) we are determining precise earthquake locations for improving our understanding of the Middle America Trench (MAT) seismogenic interface near the southern terminus of the 1992 Nicaraguan "tsunami earthquake" (TsE). The Nicaraguan event, like other such TsEs, is unique in its slow rupture and increased tsunami potential, possibly due to reduced elastic strength in the shallow subduction environment [e.g., Masayuki and Kanamori, 1995].

- The CRSEIZE network, which consisted of 20 on-land and 14 offshore broadband and short-period stations, ran from December 1999 through July 2001, and recorded ~10,000 events.
- The Nicaraguan network, consisting of numerous short-period, on-land stations and running for over 20 years, is well equipped to record continental seismicity, however it is unable to adequately resolve hypocenters offshore and along the MAT interface. Over a 20 year period the network has recorded ~30,000 regional earthquakes; of which ~1000 events were co-located by the CRSEIZE network immediately south in Nicoya Peninsula, Costa Rica.
- We relocate the Nicaraguan earthquakes in a new 3D regionally constrained VP, VP/VS seismic velocity model determined by the CRSEIZE velocity model [DeShon et al., 2005] and extended to cover on and offshore Nicaragua.
- Additionally, for events identified by both networks, P and S phase picks were merged and events were relocated using the extended velocity model. The ~450 resulting events improve the resolution of the shallow subduction environment near the southern terminus of the 1992 Nicaraguan TsE.

Introduction:

The first step to relocate earthquakes from the Nicaraguan network was to apply an appropriate velocity model. The Vp, Vp/Vs velocity model for the Nicoya subduction zone was obtained from Deshon et al., 2005. That model was adjusted to be applied along dip for north and south of the region it was originally defined for. The new model extended the values corresponding to Profile 5 (northern most profile) of DeShon et al, 2005 to the northwest and the values corresponding to Profile 1 (southern most profile) to the southeast. The region of interest for this study is the region to the northwest. The nodes of the values extended are highlighted by the red line. The velocity model is represented by a contour of the values along the cross section. The changes in the values represent changes due to properties of the subducting slab.

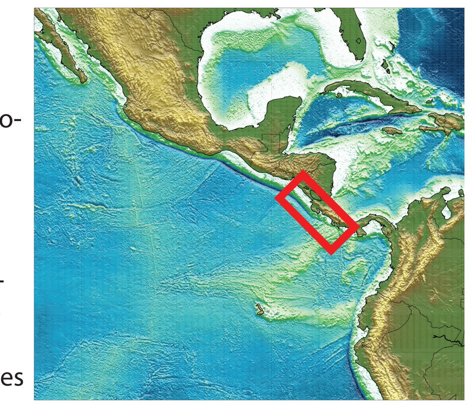


Figure 1: Central American Physiography: Study region including Nicaragua and Northern Costa Rica shown in red box.

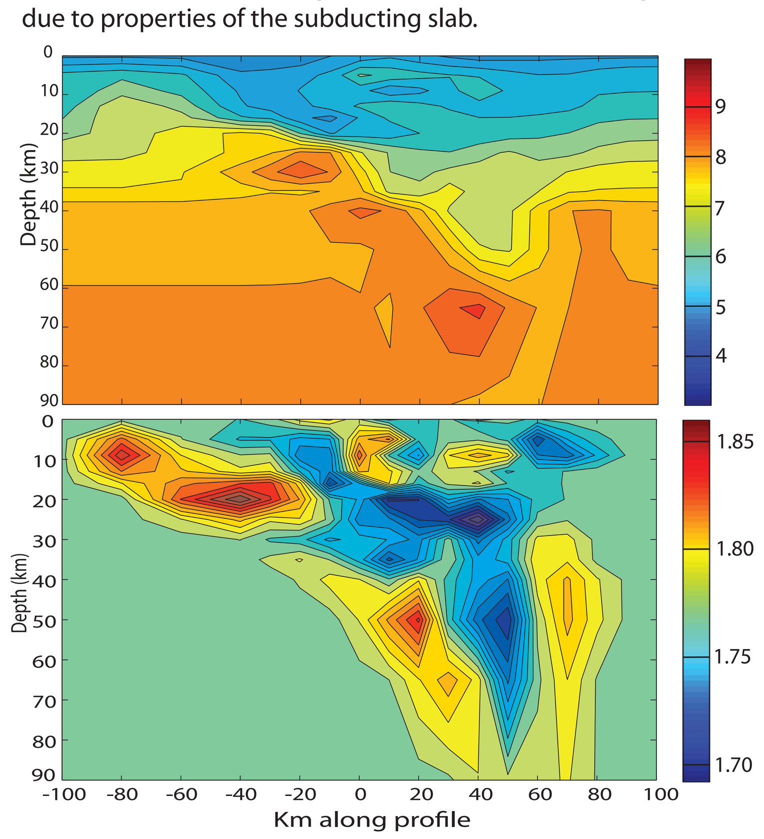


Figure 3:
Cross section representation of Profile 5's velocity model along dip. Above is the representation of P-Wave velocities (km/s). Below shows the ratio of P-Wave to S-Wave velocities. 0 point corresponds to origin with positive in northeast direction.

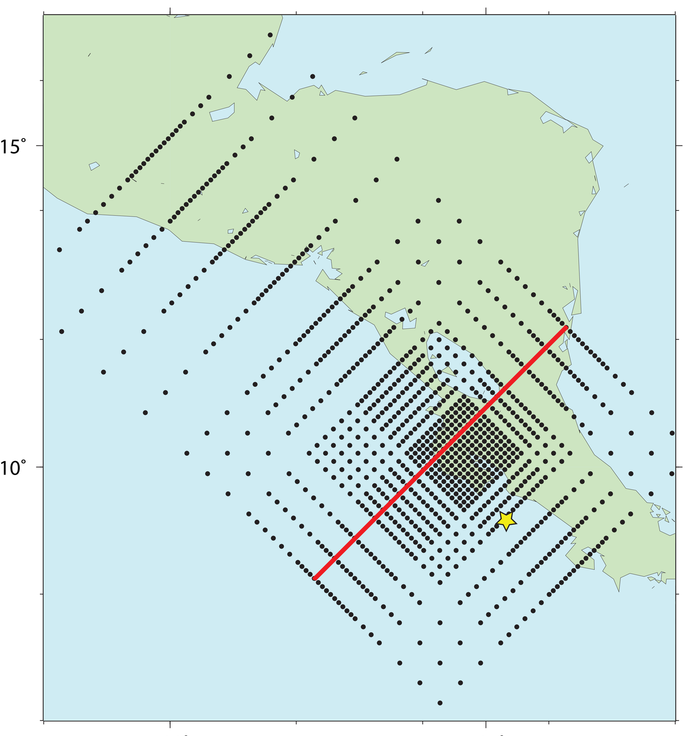


Figure 2:
Map of region with structure nodes of velocity model drawn. Star indicates origin. Red line indicates the plane of nodes that corresponded to Profile 5 of DeShon et al, 2005. The values of the velocity model in this plane was applied to the northwest of the original model.

Seismicity and Network Details:

The two seismic networks ran for different time periods (figures 7 & 8) and show unique rates of activity in their catalogs. Both catalogs were relocated using the extended velocity model. The following figures show the seismicity of the Nicoya network from different orientations: map view (figure 4), cross section along dip (figure 5), and cross section along strike (figure 6). Features included 1) Pronounced slab seismicity with steep dip angle 2) strong onset of seismicity between 10-20 km depth 3) pronounced but poorly located aftershocks of Mw 6.4 outer-rise EQ in July 2000.

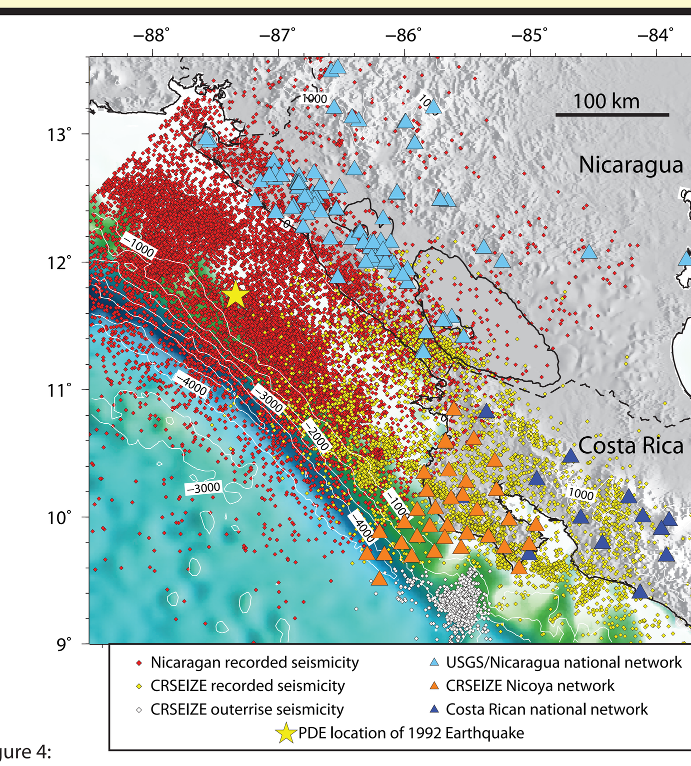


Figure 4:
Overview map view of seismicity and Nicaraguan and Nicoya networks.

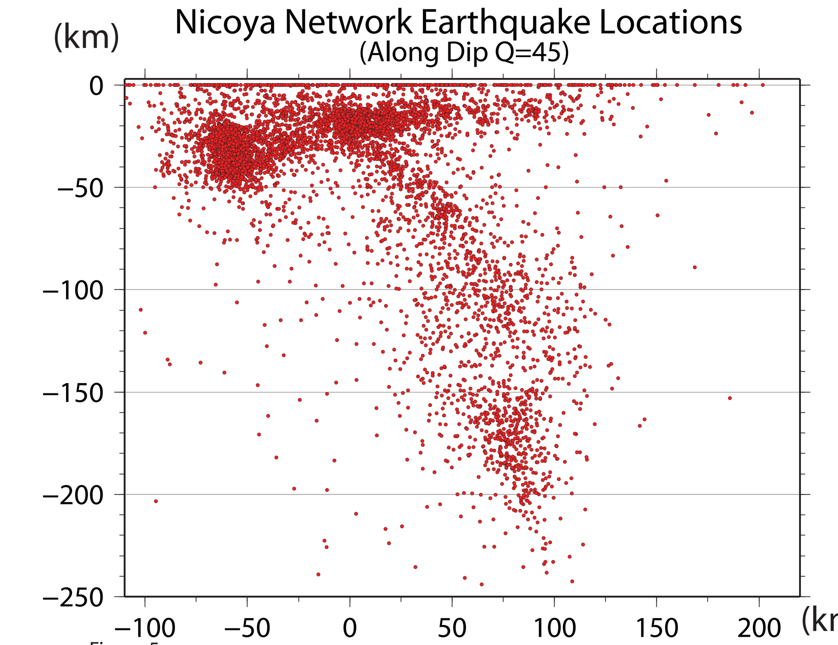


Figure 5:
Cross sectional view of Nicoya seismicity from earthquakes located with new velocity model. View of along dip (0 corresponds to origin, positive is towards northeast direction).

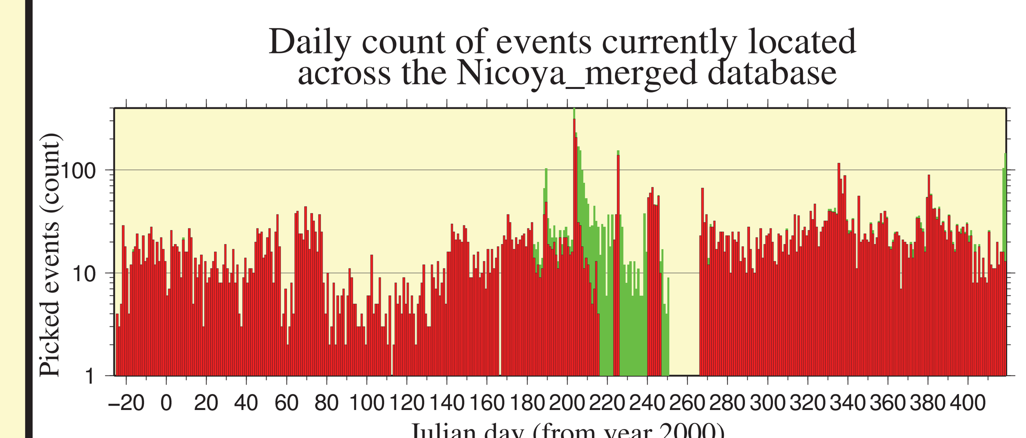


Figure 7:
Timeline and daily count of events in current Nicoya earthquake database from the CRSEIZE network.

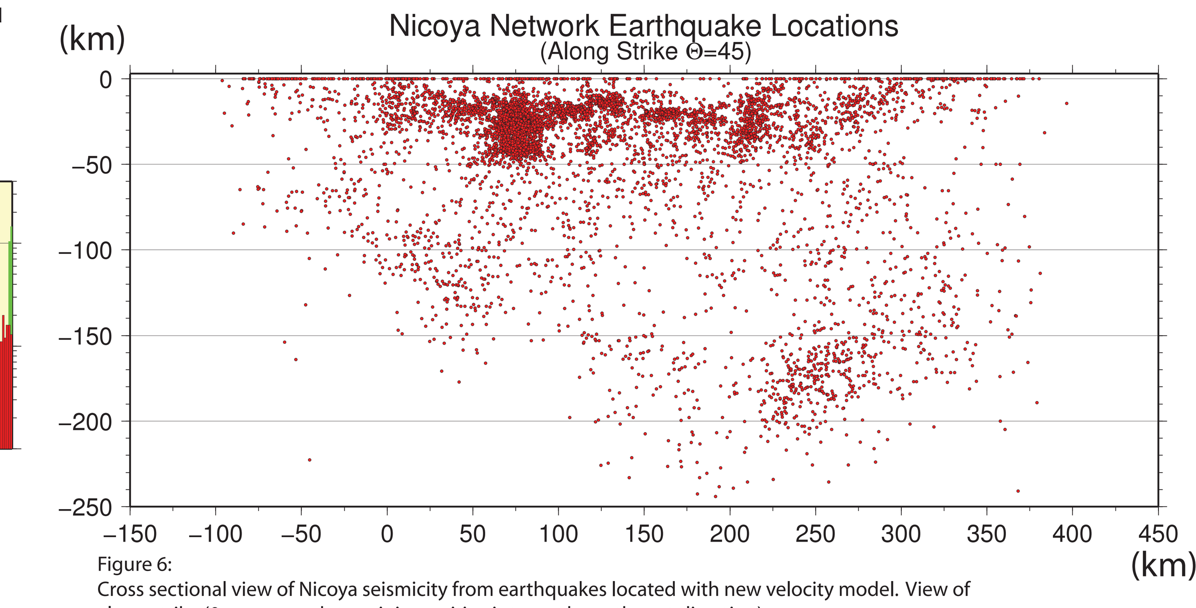


Figure 6:
Cross sectional view of Nicoya seismicity from earthquakes located with new velocity model. View of along strike (0 corresponds to origin, positive is towards northwest direction).

Nicaragua Relocations:

The Nicaraguan network previously located earthquakes in the region using a 1-D velocity model that does not include a slab. When the earthquakes were relocated using the new velocity model, the results were compared with the catalog's previous locations (Figure 9). Locations did not change significantly. Interestingly a gap in seismicity persists between ~ 35-50 km depth.

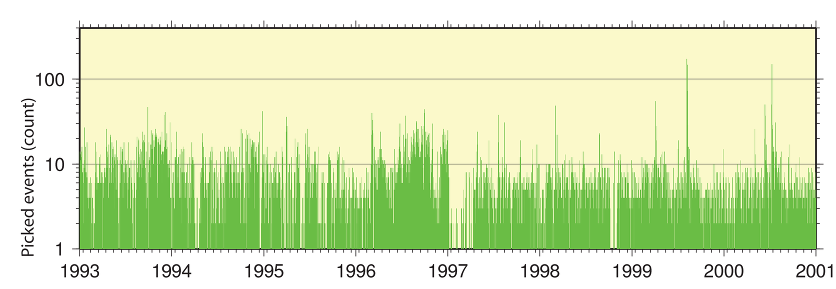


Figure 8:
Timeline and daily count of events in Nicaraguan database from 1993 to 2001.

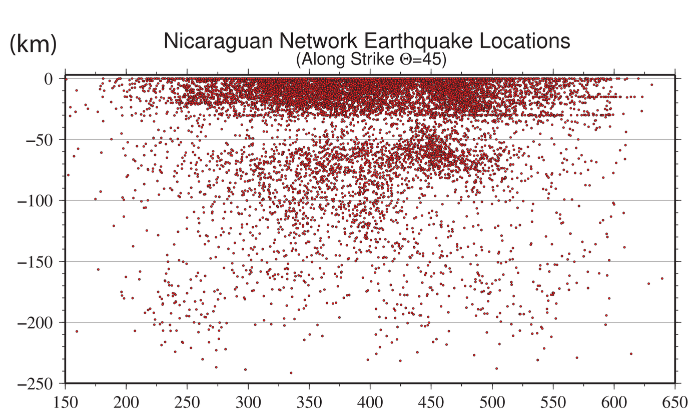


Figure 11:
Cross section along strike of Nicaraguan seismicity from earthquakes located with new velocity model.

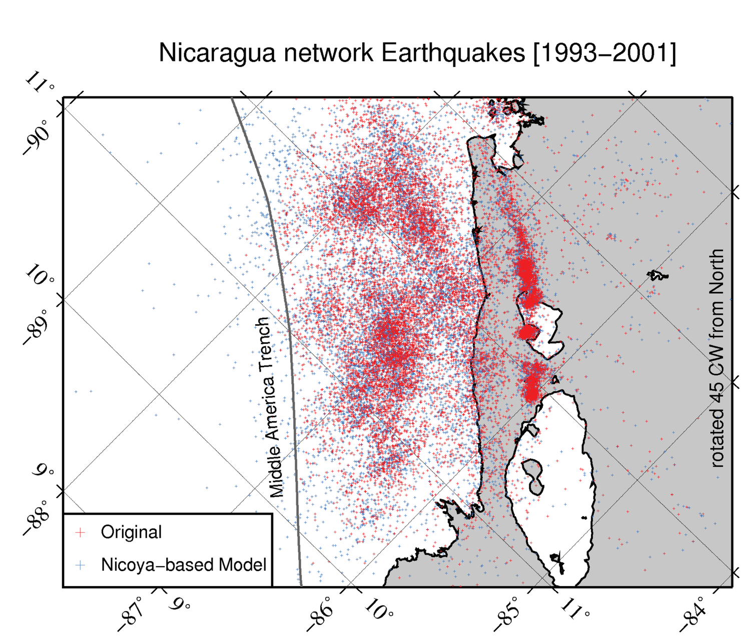
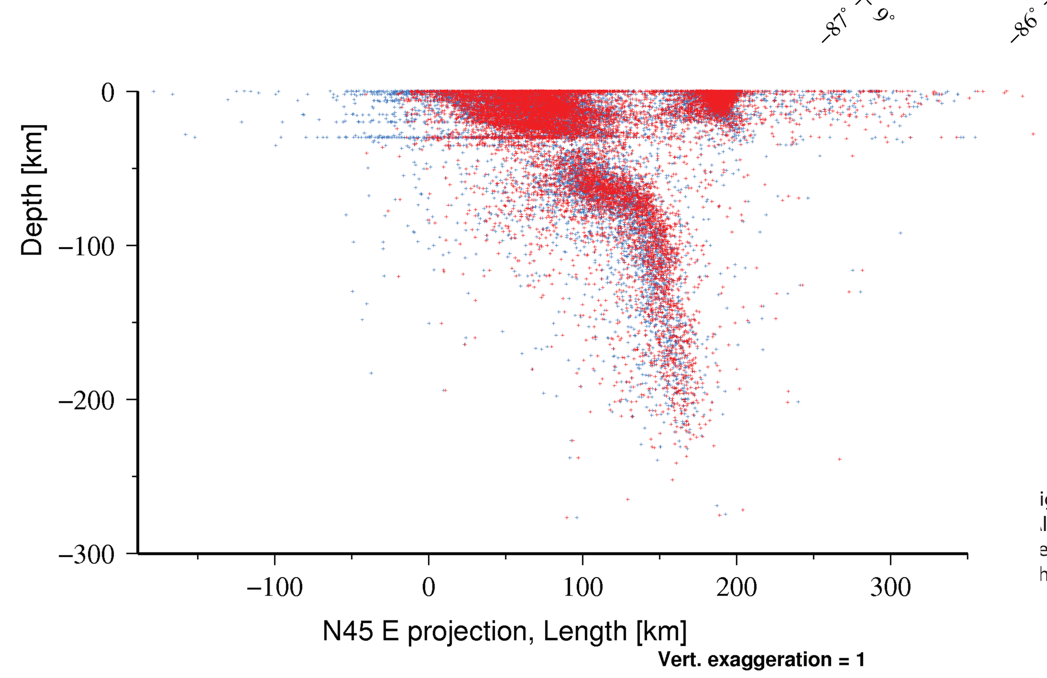


Figure 9:
Map view of Nicaraguan seismicity. Original locations (Blue) are shown beneath relocated events (Red).



igure 10:
long dip cross section of Nicaraguan eismicity. Original locations (Blue) are hown beneath relocated events (Red).

Cross Network Relocations:

The relocated earthquakes from both catalogs were compared temporally and geographically to determine what events overlapped both catalogs. The event data (phase picks) from each catalog were merged for overlapping events (events that occur between the were within 10 seconds and 1 degree). This overlapping phase catalog was then located using the new velocity model. The results are plotted in figures 11, 12, and 13 as well as locations as determined by the individual networks.

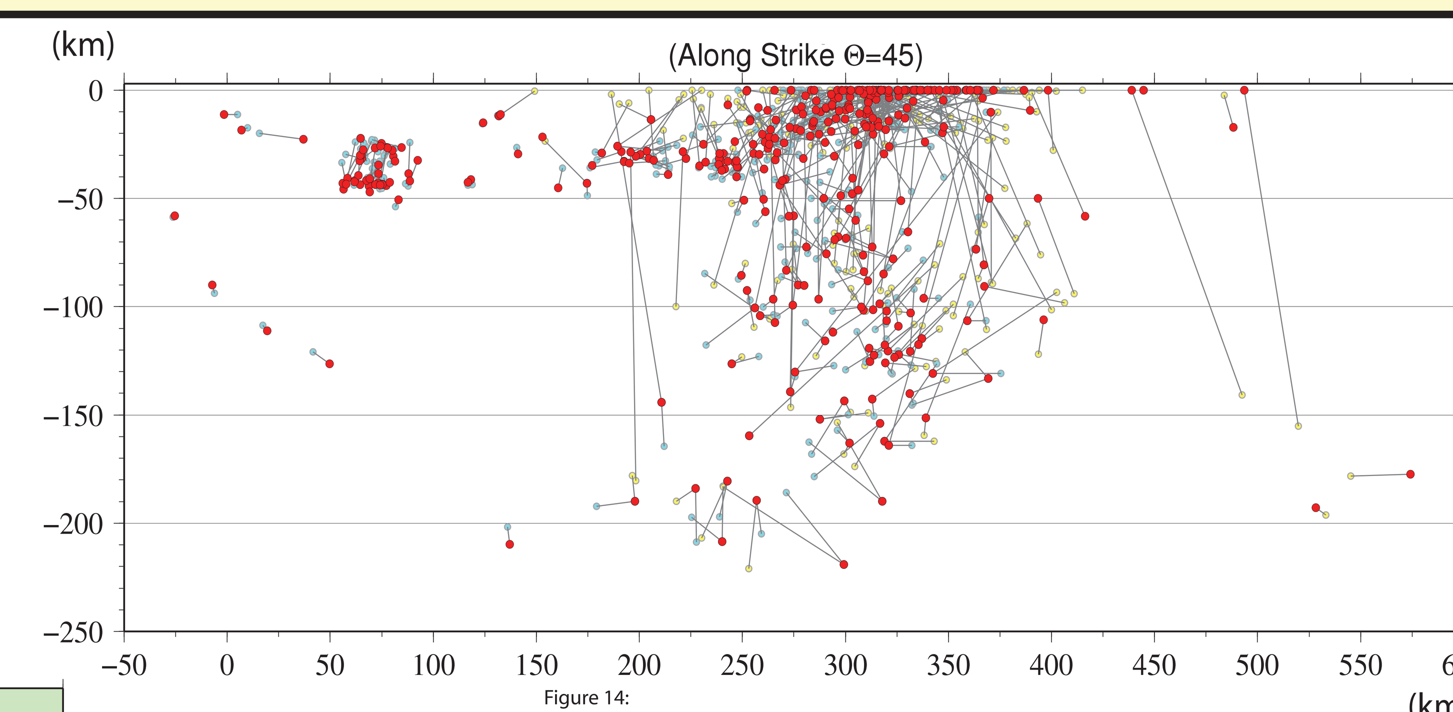


Figure 14:
Cross section view along strike of earthquakes relocated from combination of phase information from both networks. Red dots are new locations and small dots are original location(s).

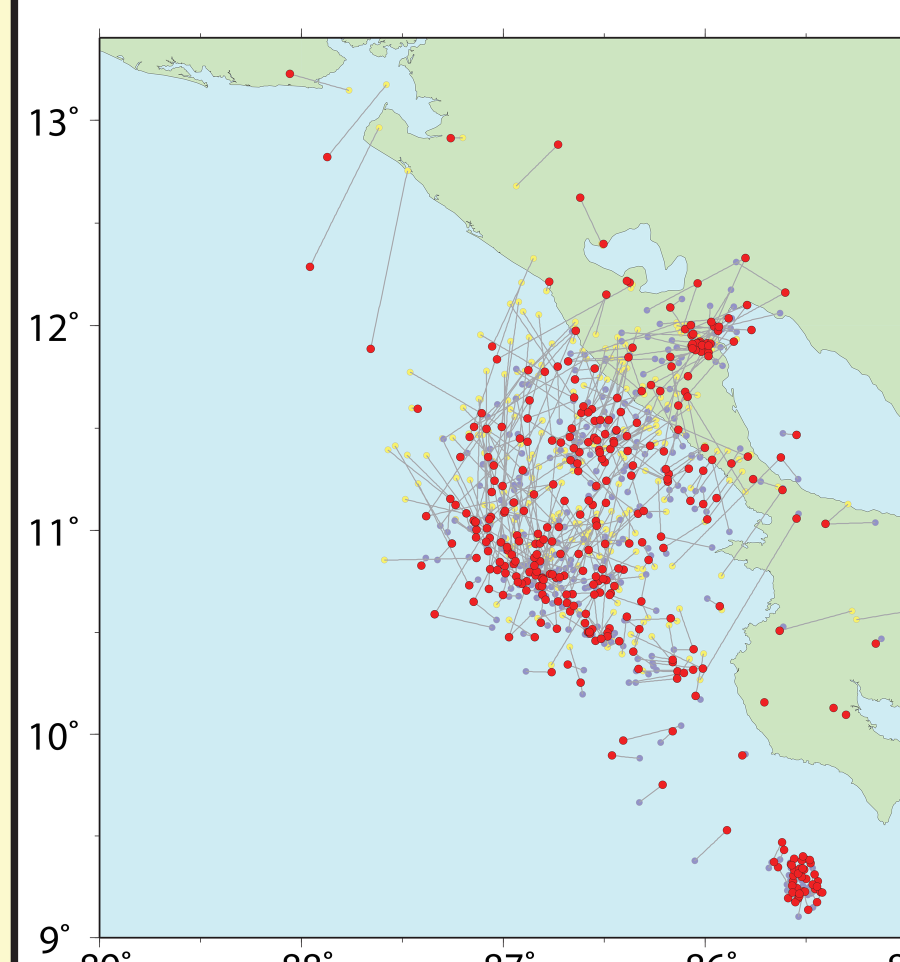


Figure 12:
Map view of earthquakes relocated from combination of phase information from both networks. Red dots are new locations and small dots are original location(s) (blue is from Nicoya network, yellow is Nicaraguan network).

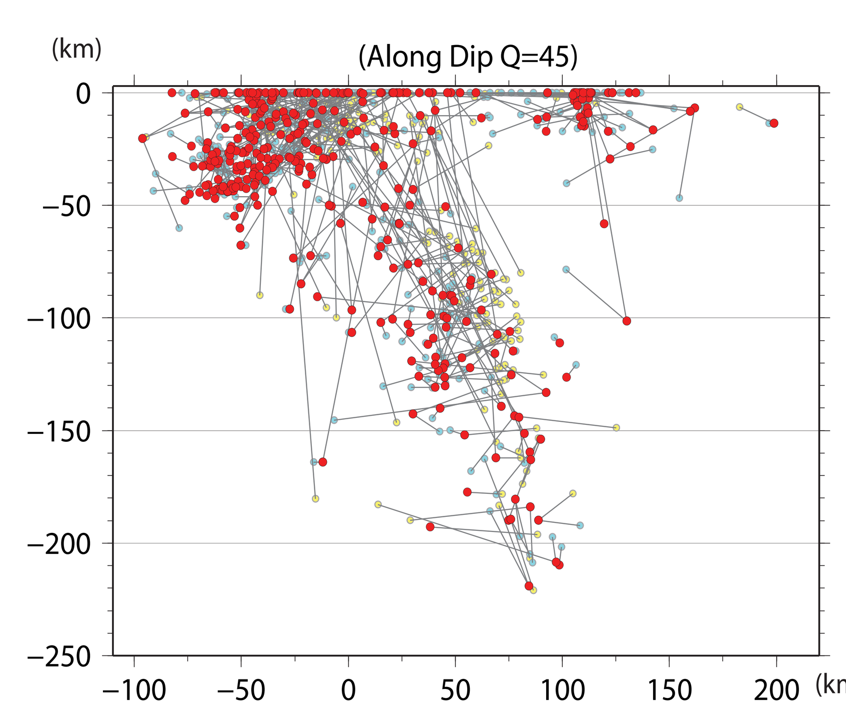


Figure 13:
Cross section view along dip of earthquakes relocated from combination of phase information from both networks. Red dots are new locations and small dots are original location(s).

Summary:

We expanded the Vp and Vp/Vs seismic velocity models of DeShon et al [2005] from Northern Costa Rica to Nicaragua to incorporate the effect of a subducting slab. While it is no longer the simplest model possible, it is more geologically realistic and should more accurately locate earthquakes offshore Nicaragua, assuming the slab geometry/velocities do not differ from Northern-most Costa Rica.

We relocate a catalog of ~20,000 Nicaraguan earthquakes with the new model. While details of the locations do not much change, some scattered earthquakes are better resolved and newer events show modestly increased clustering. There is a discontinuity that can be observed in figure 9 that was believed to have possibly been an error in the velocity model used or an actual artifact. This reanalysis of the phase pick data using a new velocity model provides evidence for the latter.

We use overlapping phase information from both Nicaragua and Costa Rica seismicity catalogs to relocate events. That we determined by both in order to improve coverage offshore southern Nicaragua. While results are preliminary, they show a linear trend of seismicity parallel to the trench (figure 11), possibly marking the updip limit of current interface seismicity there. This lineation, which is near the southern terminus of the 1992 Nicaraguan Tsunami Earthquake, appears much nearer the trench than in Nicoya (figure 4; and Newman et al., [2002]), which is possibly a feature of shallow seismogenisis in tsunami earthquake aftershocks.

References:

DeShon, H. R., Schwartz, S.Y., Newman, A.V., Gonzalez, V., Protti, M., Dorman, L.M., Dixon, T.H., Sampson, D.E., Fluech, E.R. (2006), Seismogenic zone structure beneath the Nicoya Peninsula, Costa Rica, from three-dimensional local earthquake P- and S-wave tomography, Geophysical Journal International, 164, 109-124.

Kikuchi, M., Kanamori, H. (1995), Source characteristics of the 1992 Nicaragua tsunami earthquake inferred from teleseismic body waves, Pure and Applied Geophysics, 144, 441-463.

Newman, A. V., S. Y. Schwartz, V. Gonzalez, H. R. DeShon, J. M. Protti & L. Dorman (2002), Along-Strike Variability in the Updip Limit of the Seismogenic Zone Below Nicoya Peninsula, Costa Rica Geoph. Res. Lett., 29 20, 38:1-4, doi:10.1029/2002GL015409.