FOCAL MECHANISM DETERMINATION OF LOCAL EARTHQUAKES IN ECUADOR USING POLARITY DATA

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ABSTRACT

We determined focal mechanisms of earthquakes that occurred in between 2014 and 2017 in the Guayaquil area (costal side of Ecuador) using P wave polarity. We used waveform data recorded at local stations of the National Seismic Network of Geophysical Institute to prepare dataset. We compared the focal mechanism solutions of the three events obtained in this study to the moment tensor solutions from other methods; they are rather similar. To explicitly investigate the effects of depth errors and velocity structures, we determined focal mechanisms for different sets of focal depths and velocity models. The results indicate that the difference between the focal mechanisms and the moment tensor solutions are partly due to these effects. Among the twenty one events that we analyzed we obtained relatively high quality solutions for seven events whose magnitudes are in the range between 4.0 and 5.8. These results suggest that it is possible to increase focal mechanism solutions by analyses of local data.

Keywords: Guayaquil – Ecuador, Focal Mechanisms, Local data.

1. INTRODUCTION

The Geophysical Institute of the National Polytechnic School (IGEPN) is the main center of seismic and volcanic monitoring in Ecuador, and is maintaining an active program of real-time monitoring. One of the main objectives of the IGEPN has been continuous monitoring (24 hours a day, 365 days a year) of seismic activity in the national territory. The National Seismic Network of Geophysical Institute (RENSIG) has 120 seismic stations consisting of short period and broadband seismographs, which are deployed nationwide. The information observed at these stations is transmitted in real time to the IGEPN. The information observed by the seismic network (RENSIG) is very important for the IGEPN, because it allows us to determine hypocenters, magnitudes of earthquakes and focal mechanisms. These seismic stations allow us to monitor volcanic activities. The IGEPN has established communication protocols with other institutions in the case of earthquakes in the coastal areas or in the continental zone.

The information of earthquakes is processed in the center of information processing, seismic and volcanic alert (TERRAS Center). The results are sent to the Oceanographic Institute of the Navy (INOCAR), which is the focal point of Ecuador in the Pacific Tsunami Warning Center (PTWC), and is responsible for the National Tsunami Warning Center (CNAT) for monitoring and diagnosing tsunami affecting the Ecuadorian coast and the island region. The information is also sent to Secretary National of Risk Management (SNGR), as this institution is in charge of providing economic and human resources to respond to the emergency caused by earthquakes or volcanic eruptions at the nationwide. Also the information obtained by the IGEPN about earthquakes and volcanic eruptions is transmitted to the community by web page and social networking services such as Twitter, Facebook. The institutional mission is to reduce impacts on the people and infrastructure caused by seismic and volcanic phenomena

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in Ecuador through permanent monitoring, scientific research and technological application to promote the creation of a culture of prevention.

TERRAS Center uses SEISCOMP3 software for locating and calculating magnitudes of earthquakes. The focal mechanisms are calculated by the SWIFT system (Nakano *et al*., 2008). It provides source parameters using waveform inversion in the frequency domain. The system assumes a double couple mechanism to stabilize a solution using data from a small number of stations. At present, it is not possible to determine focal mechanisms of events whose magnitudes are less than 4.5 Mlv. It is because the program uses bandpass filtering, if the noise is larger than signal, the program does not generate solutions for the small and middle size earthquakes. The purpose of this study is to determine focal mechanisms of local earthquakes (including events whose magnitudes are smaller than 4.5) in Ecuador using P wave polarity data.

2. METHODOLOGY

2.1. SEISAN

We processed waveform data using the SEISAN program (Havskov and Ottomoller, 1999). The SEISAN includes a set of tools for the basic processing of earthquake data. Figure 1 shows examples of vertical component waveform data with P arrival time and polarity. Figure 1(a) shows the waveform recorded at CAB1 station, where the epicentral distance is 202 km, and the polarity is dilatation (D). In Figure 1(b) shows the waveform recorded at station ANTG. The epicentral distance is 246 km and the polarity is compressional (C).

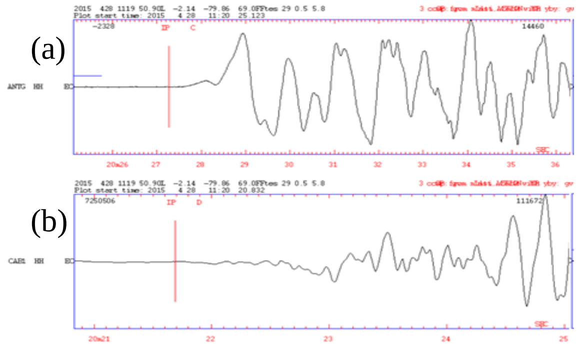

Figure 1. Examples of the waveform data for the April 28, 2015 event. (a) the vertical component seismogram recorded at the CAB1 broadband station. (b) the vertical component waveform data recorded at the ANTG broadband station.

2.2. HASH

HASH is a FORTRAN program to determine focal mechanisms using first motion by a grid search to find all the acceptable solutions (Hardebeck and Shearer, 2002, 2003). Focal mechanism uncertainty is evaluated considering polarity errors, event location errors and effects of seismic velocity structures. We prepared the following information to run HASH program: a station list, velocity models, data information of P wave polarities, and input parameters.

One of the advantages of the HASH program is consideration of uncertainty due to polarity errors, event location error, and effect of velocity models. HASH program conducts iterations by changing the source location and choosing velocity model for this consideration. The solution is evaluated using four parameters, misfit, RMS difference, station distribution ratio and probability solution. In addition, the preferred solution is evaluated by the average of the acceptable solutions.

2.3. FOCMEC

FOCMEC is a program to determine focal mechanisms by a grid search and find acceptable solutions based on selection criteria for the number of polarity errors and errors in amplitude ratios (Snoke et al., 1984). The SEISAN provide the interface between the database and FOCMEC. We used the FOCMEC for comparison of focal mechanism solutions.

3. DATA

3.1. Event locations and waveform data

We used hypocenters from the catalog of the IGEPN in Ecuador. The IGEPN stored waveform data from short period and broadband stations. We selected the Guayaquil area considering that both shallow and intermediate depth events occurred and that the coverage of the seismic network is relatively good. We selected 21 earthquakes that occurred in between 2014 and 2017 in the Guayaquil area for determinating focal mechanisms. Figure 2 shows the distribution of the earthquakes in the study area. The magnitudes are in the range between 3.5 and 5.8. Focal mechanisms from other method (SWIFT and GCMT) are available for three events.

3.2. Velocity Models for HASH

To investigate effects of velocity structures on focal mechanism determinations, the HASH uses several different velocity models. We used seven velocity models; one of which is the IASP91 (Kennett and Engdahl, 1991) used by IGEPN. The other six models are those from the global crustal model CRUST1.0 by Laske et al. (2013) near the study area. Figure 3 shows these seven models.

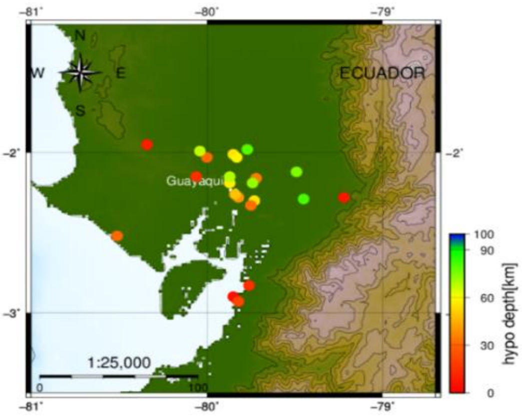

Figure 2. The epicenters of the earthquakes analyzed in this study.

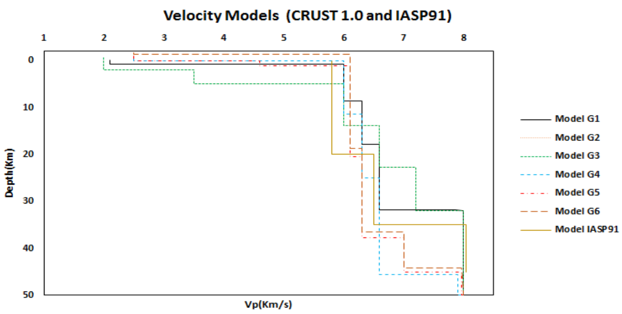

Figure 3. The seven velocity models for Guayaquil zone according to CRUST 1.0 (Laske et al., 2013), and IASP91 (Kennett and Engdahl, 1991).

4. RESULTS AND DISCUSSION

4.1. Focal mechanisms and comparison to other solutions

We show results of the focal mechanism determination of three events for which moment tensor solutions obtained by the SWIFT in 4.1 (for one event, a global centroid moment tensor solution is available). We show results of the other events in 4.2.

4.1.1. October 15, 2014 Guayas Earthquake (M_{lv} 4.5)

Twenty-three waveform data are available for the October 15, 2014 event (M_{lv}4.5) and we obtained twenty three polarity data. Figure 4 shows the epicenter and the location of the seismic stations.

We used HASH program, setting the grid angle for search to 5°, and obtained 116 acceptable solutions with quality B. Figure 5 shows all the acceptable solutions and the preferred solution obtained by the HASH.

We also used the FOCMEC to obtain focal mechanism solutions with model IASP91, setting increment to 5° to search focal mechanism. The number of acceptable solutions is 76 (Figure 5). The number of the inconsistent data is 1. Then we compared the preferred solution to the focal mechanisms by SWIFT system to find that they are rather consistent. The angular difference between preferred solution and the SWIFT focal mechanism is 34°.

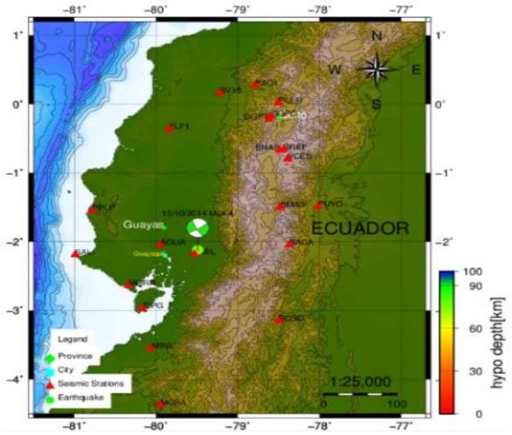

Figure 4. Distribution of the stations used for the analysis of the October 15, 2014 earthquake.

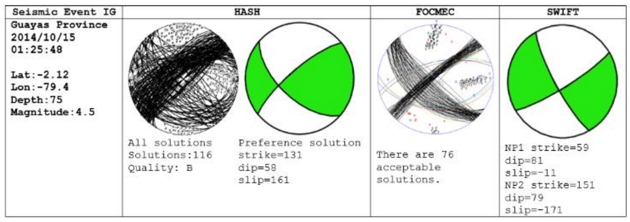

Figure 5. Comparison of focal mechanism of the October 15, 2014 Guayaquil-Ecuador earthquake.

4.1.2. November 26, 2014 Guayas Earthquake (M_{lv} 4.6)

Twenty two waveform data are available for the November 27, 2014 event (M_{lv} 4.6) and we obtained twenty two polarity data. Figure 6 shows the epicenter and the location of the seismic stations.

We used HASH program, setting 5° of grid angle to search focal mechanism, and obtained 191 acceptable solutions with quality B. Figure 7 shows all the acceptable solutions and the preferred solution obtain by the HASH.

We also used the FOCMEC to obtain focal mechanism solutions with model IASP91, setting increment to 5° to search focal mechanism. The number of the inconsistent data is 0. The number of the acceptable solutions is 114 (Figure 7). The strike-slip angles of the preferred solution were different from those of the SWIFT solution. The angular difference between preferred solution and the SWIFT focal mechanism is 28°.

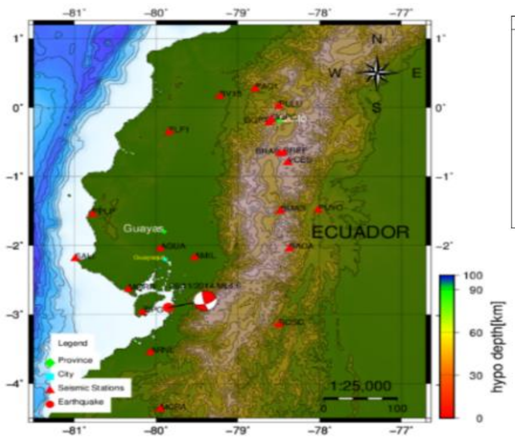

Figure 6. Distribution of the stations used for the analysis of the November 26, 2014 earthquake.

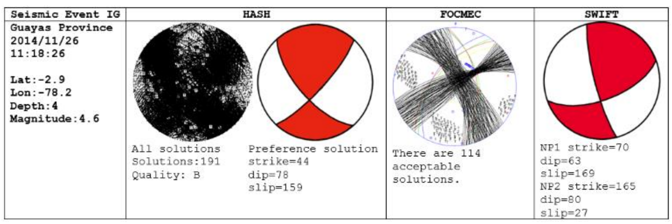

Figure 7. Comparison of focal mechanisms for the earthquake on November 26, 2014 Balao – Ecuador earthquake.

To explicitly investigate the effects of depth errors and velocity structures, focal depths, that are the focal depth of the IGEPN catalog and those deviated its standard deviation. Figure 8 shows the focal mechanisms obtained by the FOCMEC program for model three. This solution are similar to that of the SWIFT. The focal mechanisms depend on focal depths and velocity structures.

The difference between the HASH preferred solution and the SWIFT solution is likely to be due to these dependencies.

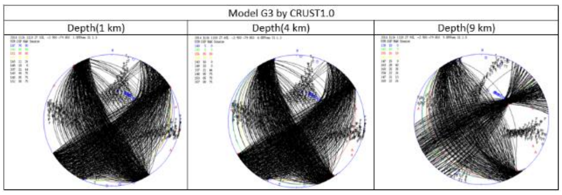

Figure 8. Focal mechanism solutions of the event on November 26, 2014. Balao – Ecuador earthquake.

4.1.3. April 28, 2015 Guayas Earthquake (M_{lv} 5.8)

Twenty six waveform data are available for the April 28, 2015 event and we obtained twenty six polarity data. Figure 9 shows the epicenter and the location of the seismic stations.

We used HASH program, setting 5° of grid angle to search focal mechanism, and obtained 55 acceptable solutions with quality A. Figure 10 shows all the acceptable solutions and the preferred solution obtained by the HASH.

We also used the FOCMEC to obtain focal mechanism solutions for model IASP91, setting increment to 5° to search focal mechanisms. The number of the inconsistent data is 0. The number of the acceptable solutions is 45 (Figure 10). Then we compared the preferred solution to the focal mechanisms by SWIFT and GCMT to find that they are consistent. The angular difference between preferred solution by SWIFT and GCMT is 25° and 13 ° respectively.

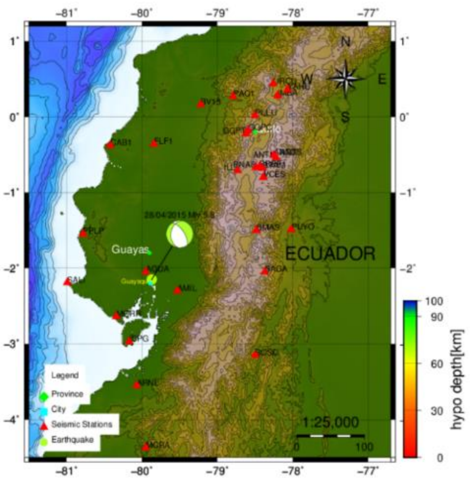

Figure 9. Distribution of the stations used for the analysis of the April 28, 2015 earthquake.

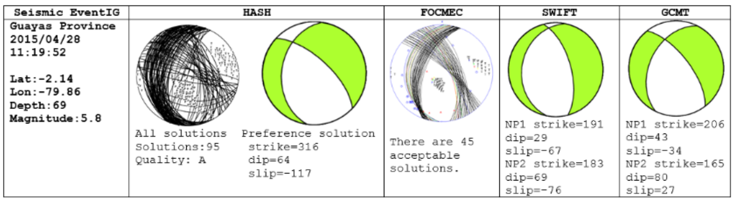

Figure 10. Comparison of focal mechanisms of the April 28, 2015 Guayas – Ecuador earthquake.

4.2. Focal mechanism solutions in the study area

We obtained twenty one focal mechanism solutions in the study area. The numbers of solutions with Qualities A (the highest quality), B, C, and D (the lowest quality) were 1, 6, 5, and 9, respectively.

Figure 11 shows the seven events with quality A and B. The two events are shallow, while the focal depths of the other five events are deeper than 50 km. The focal mechanisms of the latter are thrust, normal, and strike slip mechanisms. Event 3 with a magnitude M_{lv} 5.8 whose focal depth is 69 km is the biggest earthquake among those analyzed and the focal mechanism corresponds to the normal fault.

The focal depth is close to the slab geometry from the Slab 1.0 by Hayes et al. (2012). Considering the focal mechanism and the uncertainty of the focal depth, this event is likely to have occurred in the subducting slab. Event 2 is a shallow event and the focal mechanism is strike slip, which is consistent with the relative motion along the Puna-Pallatanga fault.

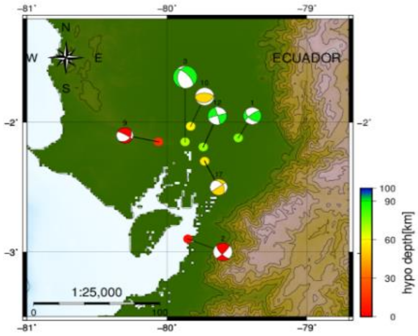

Figure 11. The focal mechanisms of the seven events with quality A and B.

5. CONCLUSIONS

In this study, we analyzed twenty one earthquakes that occurred in the Guayaquil area in between 2014 to 2017. We used broadband waveform data recorded at the local stations in Ecuador, which we retrieved from the database of the National Seismic Network of Geophysical Institute.

We conducted focal mechanism determinations using the HASH program. We used SEISAN to prepare P wave polarity dataset. We used seven velocity models, which are IASP 91 and six models chosen from CRUST 1.0 for HASH. We compared the solutions of three events to the moment tensor solutions of SWIFT and GCMT to find that they are relatively consistent.

To investigate the effects of depth errors and velocity structures, we determined focal mechanisms for different sets of focal depths and velocity models using FOCMEC. The differences between the focal mechanisms obtained in this study and the moment tensor solutions are likely to be partly due to the effects of depth errors and velocity structures.

Among the twenty-one events that we analyzed we obtained relatively high quality solutions for seven events whose magnitude range is between 4.0 to 5.8. This result suggests that it is possible to increase focal mechanism solutions by analyses of local data.

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