

The IMS seismic network used to support and mitigate volcanic risk with one single station method.

A. Gutierrez, IDC

aaron.gutierrez.jimenez@CTBTO.ORG

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ABSTRACT

It is a well known fact that one of the more accurate methods to predict a possible volcanic eruption is through seismic monitoring. The ideal way to approach the monitoring of volcanoes is by complementing and supporting the seismic data with other types of data, such as infrasound, soil deformation (measured by GPS), geochemistry and mineral variation studies in the hydro-thermal system around the volcano, heat measurements of the ash plumes and the volcanic body, etc. However, what if the resources are not enough and there is just a single seismic station in the vicinity of the volcano? Is it possible to record the seismic activity with just one sensor and obtain acceptable locations and confident parameters of the events recorded? This study will discuss how some of the IMS seismic stations that are close to active volcanoes (or potentially active), can be used for early warning in case of poor or no monitoring in the region. Real cases, from around the globe, will be used to support the work in this study.

OBJECTIVES

- Discriminate volcanic events from pure tectonic events and classifying them in base of Lahr-Chouet criteria.
- Make statistics about the number and type of volcanic events
- Calculate the distance to the source, back azimuth and magnitude of the VT events.
- Implement the single station location method to PMCC to make it automatically for a further analyst review.
- In case of increase of seismicity or some other anomalies recorded in volcanoes near the IMS network a special bulletin can be submitted with the categorized events to inform member states and like complement of others volcanic bulletins.

BACKGROUND

Most of every recorded volcanic eruptions has been preceded by a gradually or some cases short time-dramatic increase of seismic activity beneath or near the cone.
About a third off monitored volcanoes has at least one station within (5-30) Km of the active vent but in the other hand a lot of volcanoes are monitored indirectly because a nearby (30-100 Km) seismic station is a part of a larger seismic network. Fig. 1 show an example on 1982 of a dam seismic network that by coincidence was indirectly recording the previous volcanic activity before the eruption of Chichon volcano in Mexico, station CH3 was at 62 km from the cone and despite of that was recording all the types of seismic volcanic events. IMS network has around 20 stations close enough to one or more active volcanos and active volcanic areas that can record volcanic activity to contribute and complement crucial information to predict possible volcanic eruptions.

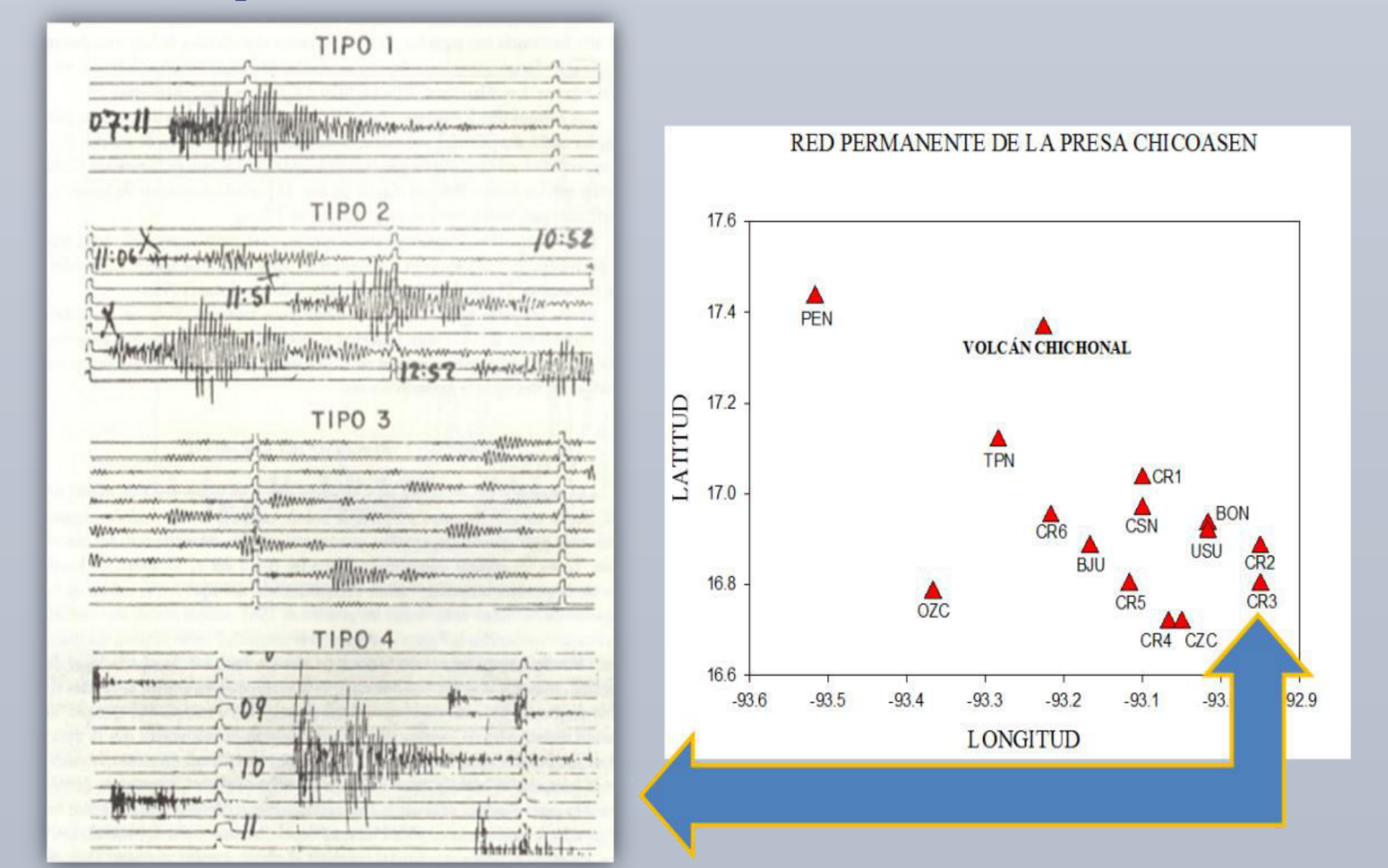


Figure 1. Chicoasen's dam network and the CH3 station seismogram.

CLASSIFICATION OF SESIMIC EVENTS

The classification of the seismic events will be made with the criteria of Lahr-Chouet (1981-1996) like the fig. 2 explains:

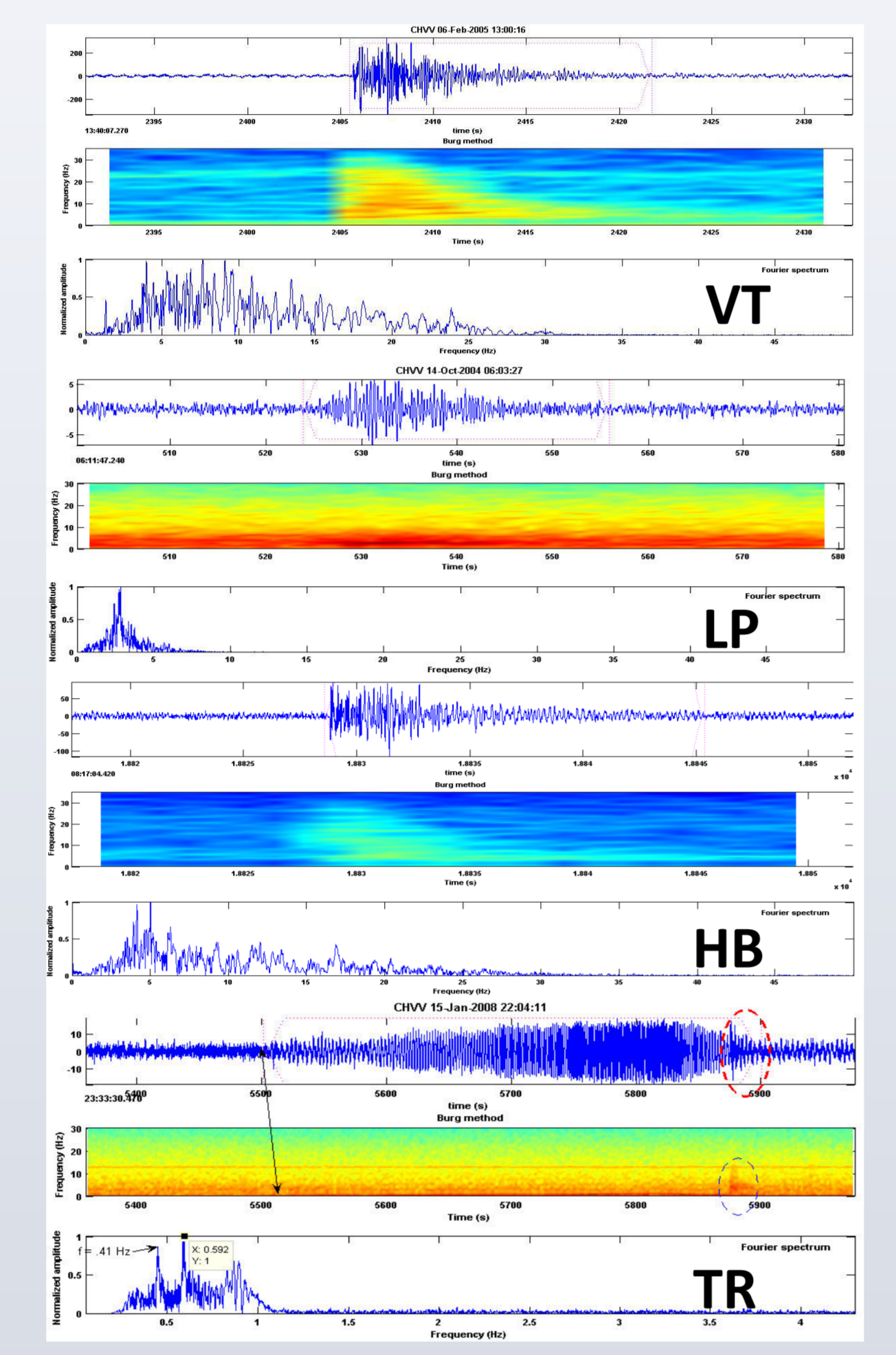


Figure 2. Most common volcanic events types.

Volcano Tectonic (VT): Normally P and S with clear onset and easy to locate, Short S-P, High frequency content (≥ 5 Hz) and low scattering due to the short travel path, well known source mechanism, namely a common shear failure caused by stress buildup and resulting in slip on a fault plane similar to a tectonic earthquake source, depth normally below about 2 km, but also they can have depths around 1 or 2 km but the content of low frequency increase (1-5 Hz) and the onsets are not so clear specially the S phase making the location ambiguous.

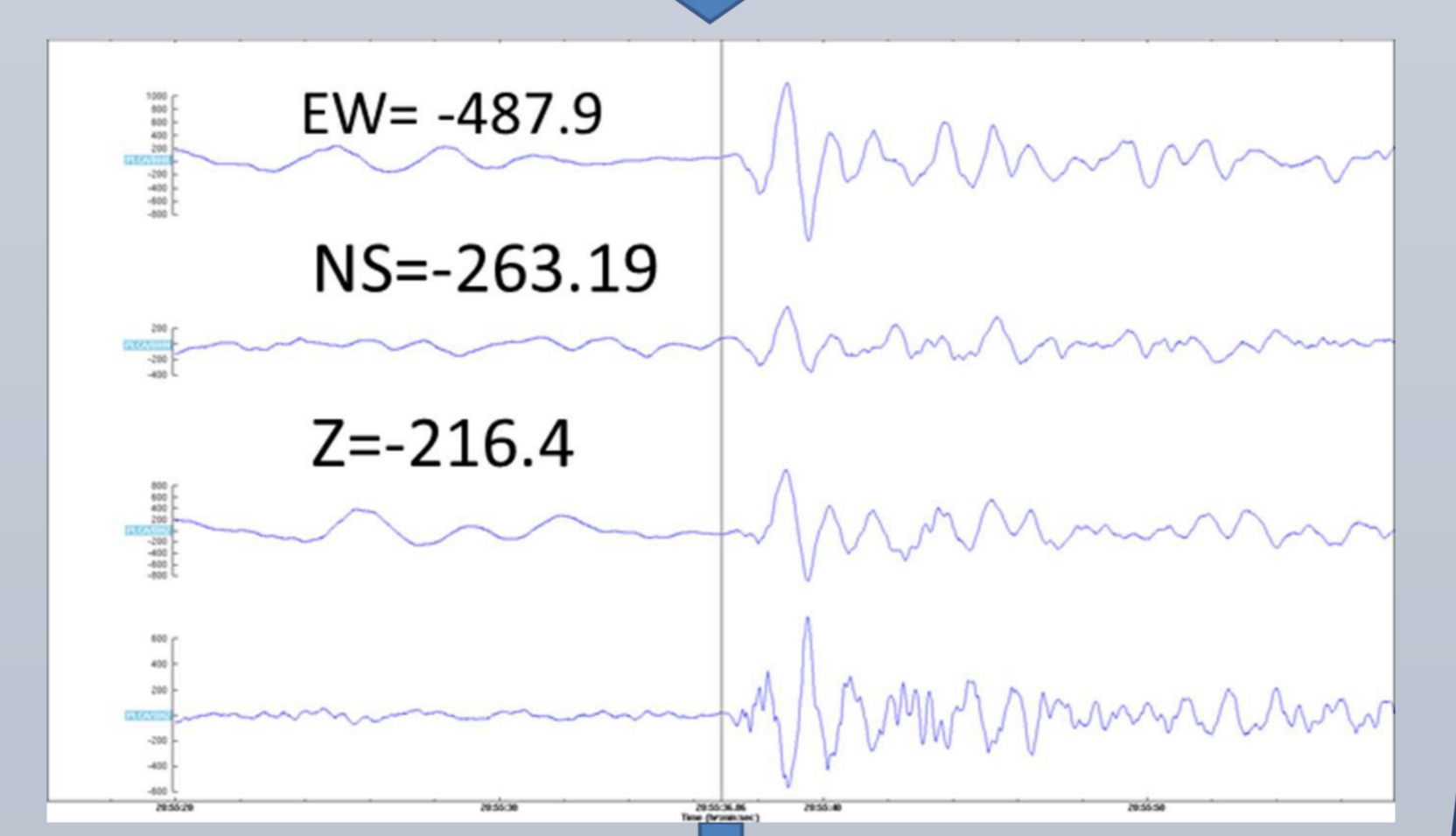
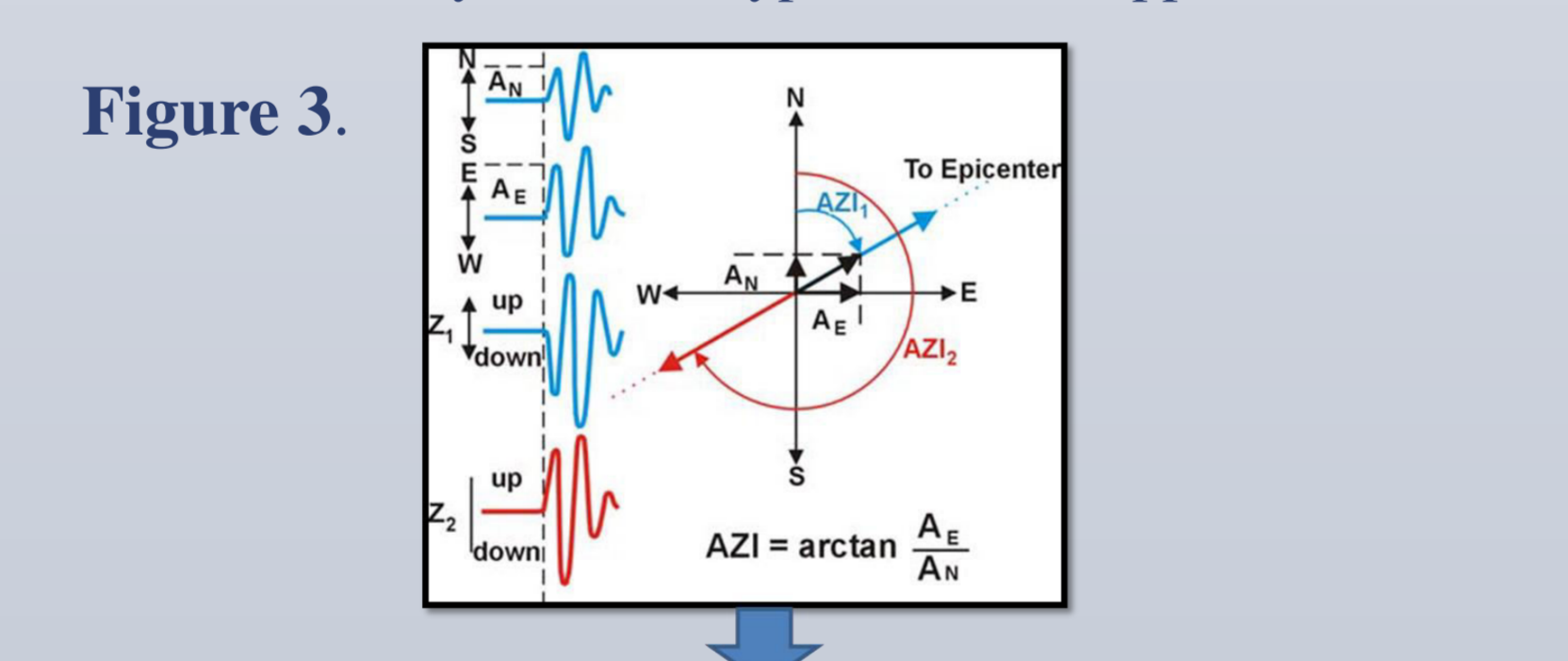
Long period (LP): Very emergent P onset, S is not visible. Frequency between 1 and 3 Hz, very shallow (≤ 2 Km). Locations could be deduced mainly by amplitude distance curves and from particle motions recorded on a broad-band seismometer network. The source is related to fluids that are pushed up toward the surface by the magma ascension, filling cracks and producing short resonance periods.

Hybrids (HB): A combination between VT and LP starting with high frequency and clear onset but with a fast decay in to low frequencies(3-8 Hz). No clear S phase normally with shallow source related to a crack that is filled immediately by a fluid, this could mean that a lot of pressure is under the cone.

Tremors (TR): Normally related to magma movement, is always a sign of high activity. However, since the exact mechanisms are still theme of controversy, the importance and timing between the first appearance of tremor and possible eruptive activity is still a matter of discussion (McNutt, 2000). Frequencies between 1-3 Hz with emergent starting and duration about hours or days. In general there are two types of tremor, the spasmodic or drum beat which can fluctuate with strong and short-pulsed amplitude variations and the harmonic that shows in the spectral analysis a dominate frequency with one or more overtones. Locate tremors is not easy the most close efforts compute the back azimuth of the wave field and using velocity models like a complex superposition of Lg and Rg surface waves.

Back azimuth, distance to the source and magnitude parameters.

An REB event (OrigID 11915135) with first station PLCA (PS01) recorded before the eruption of Calbuco volcano (22/05/2015) was taken like example. Since the P-waves are vertically and radially polarized, the vector of P-wave amplitude can be used to calculate the back azimuth to the epicentre (Fig 3). The radial component of P will be recorded on the 2 horizontal channels north and south and the ratio of the amplitudes AE/AN on the horizontal components can be used to calculate the back azimuth of arrival $\phi = \tan^{-1} AE/AN$. If the first motion on the vertical component of the P is upward (+), then the radial component of P is directed away from the hypocenter, the opposite is true if the P polarity is negative.



Z	+	-	+	-	+	-	+	-
N	+	+	-	-	-	-	+	+
E	+	+	+	+	+	-	-	+
Add	180	0	0	180	0	180	180	0

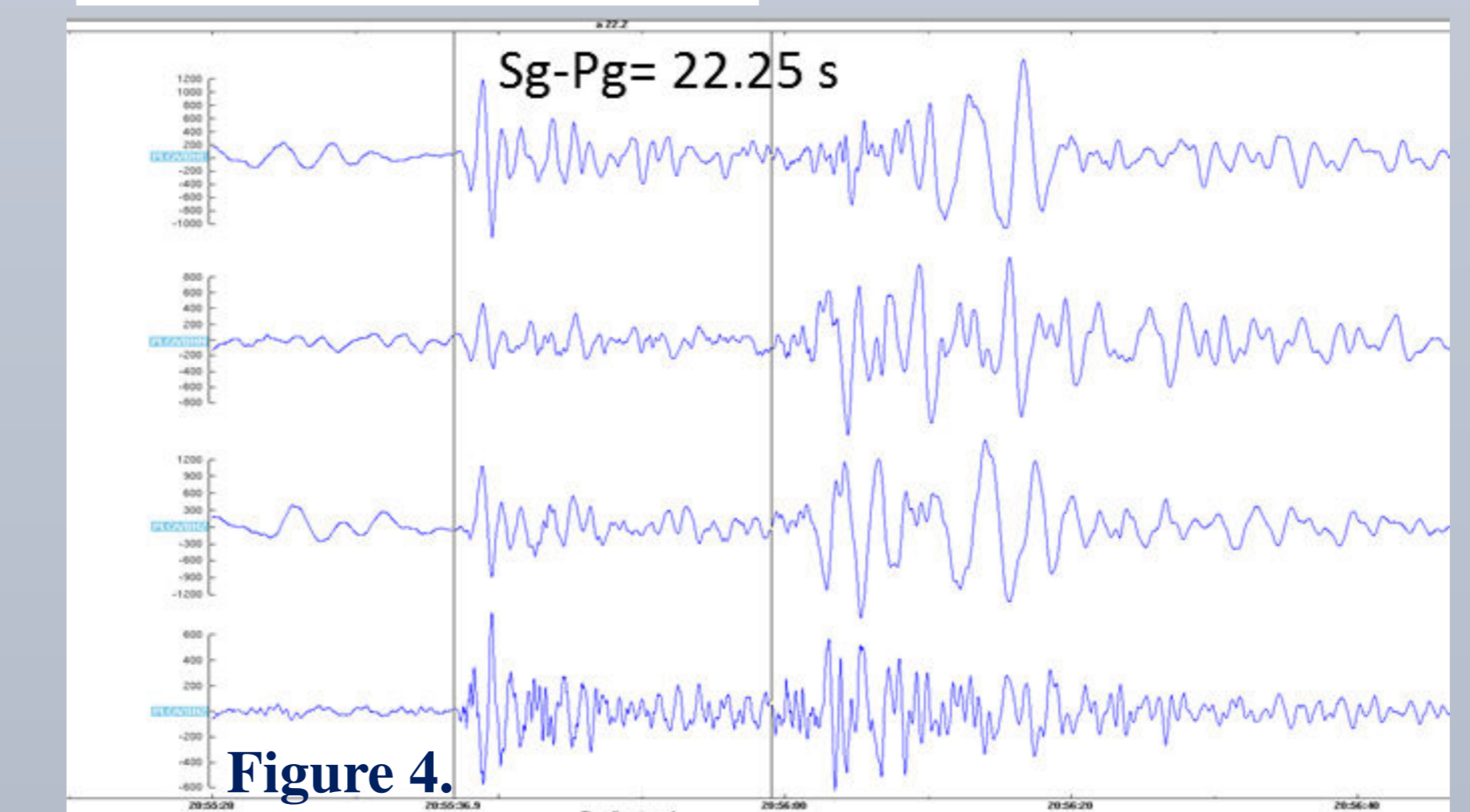
$$\phi = [\tan^{-1}(-487.9/-263.19)] + 180$$

$$\phi = 241.63^\circ$$

In the absence of local travel-time curves for the area under consideration Δ can be used for approximate distance determinations from travel-time differences Sg-Pg. For an ideal Poisson solid $v_s = v_p/\sqrt{3}$. This is good approximation for the average conditions in the earth's crust and assuming that the layers in the volcano are relative new and first arrivals are under a distance of 220 Km (~2 degrees). With this follows assumptions, the data Sg-Pg measured in PLCA station (Fig 4) and replacing them in Δ :

Normal crust, $v_p = 5.9$ km/s (km) and $v_s = v_p/\sqrt{3}$

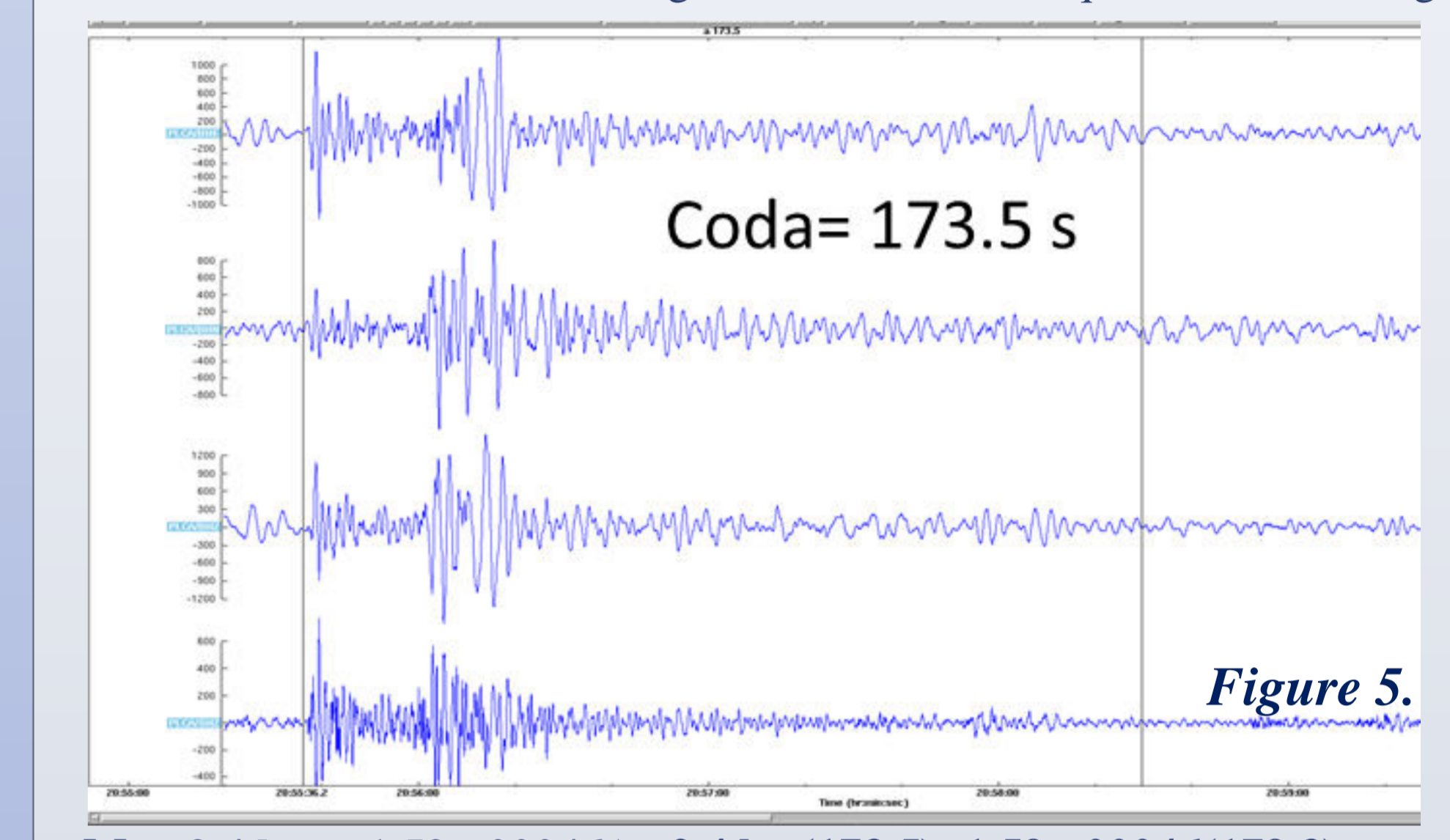
$$\Delta = (t_p^{arr} - t_s^{arr}) \frac{v_p v_s}{v_p - v_s} = (t_{Sg} - t_{Pg}) \times 8.06 = (22.25)(8.06) = 179.3 \text{ Km}$$



For the magnitude calculation was used the algorithm proposed by Lee et al. in 1972 and recalculated by Havskov and Macias in 1983 for volcano-tectonic events during the activity of Chichon volcano eruption.

$$M_c = 2.4 \log \tau - 1.59 + 0.00046 \Delta \text{ where } \tau = \text{coda}, \Delta = \text{distance}$$

Named coda magnitude because is in function of the signal's duration. This magnitude is good for small events that are not exceeding the dynamic range of the sensor and with low background noise. From equation M_c and Fig. 5:

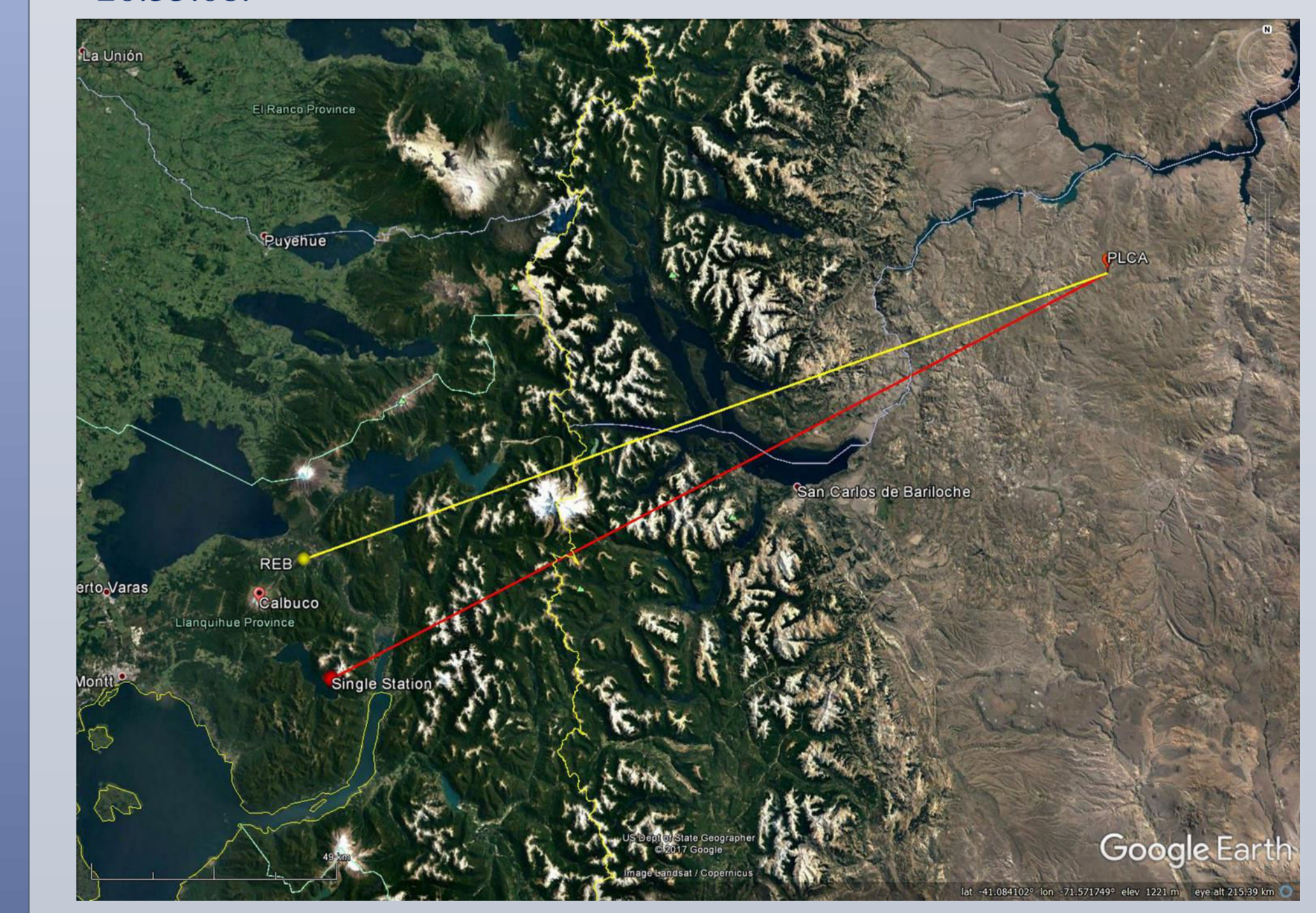


$$M_c = 2.4 \log \tau - 1.59 + 0.00046 \Delta = 2.4 \log(173.5) - 1.59 + 0.00046(179.3)$$

$$M_c = 3.86$$

Results

In compare with the REB event with 4 stations and using the IASPEI91 model, the single station location has a difference in back azimuth of -7.99 degrees and +5.04 Km variation in distance to the source. The magnitude. (M_c) was 3.86 versus the $M_b = 4.2$ reported in the REB. The first arrival in PLCA was at 20:55:36.7 in compare with the REB at 20:55:08.



This method seems to be archaic but is very useful in case of no more of one station available and can be implemented for a pre-automatic location in a software of interest for further manually review. The discrepancies were not huge and the precision can be improved with specific local velocity models and a local magnitude algorithm also can be approximated with the analysis of several events.

References

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