# High rate GPS and seismological data to monitor coseismic deformation of the Peninsula of Baja California, Mexico

Carlos Moraila[1], Gilbert Feraht[2], Clara de Lacy[3]

[1]Universidad Autonoma de Sinaloa, Mexico cmoraila@uas.edu.mx
[2]INSA Strasbourg and IPGS Strasbourg, France Gilbert.ferhat@insa-strasbourg.fr
[3]Universidad de Jaén, España mclacy@ujaen.es

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**ABSTRACT**

The evolution of the Global Positioning System (GPS) allows to be used in monitoring long periods of the plate geotectonic. The continuous observations of GPS (cGPS) are similar to the seismogram in a range of frequency, providing differences, like the reference frame, likewise, the type of specific measure of each instrument. This differences present advantages which allow us to complement the GPS and seismological measurements. One of the problems of the seismograms is the sign saturation, it does not present equal in the GPS observations. With the definition presented previously, the use of GPS of high rate as a seismological instrument result fundamentally efficient to the study of earthquakes. In the present project, it is processed and analyzed time series generated with GPS data, for earthquakes occurred in the region of the Gulf of California, over the period of 2008-2010. In this way it is obtained the coseismic movement associated to displacements of these events. It performed an analysis of the quality of the observations and a filtering which, be necessary, remove the effect caused by the movement in the reference station upon to the cinematic stations. The analysis of the cGPS time series and the integrated accelerometers, shows that, to lower frequencies 0.1.Hz, due to similar response. Otherwise, the domain of the accelerometer in the high rate and GPS in the low rate make them to be complementary instruments capable to yield relevant information in the analysis of seismic events.

## I. Introduction

At present, the advance in satellite positioning technology has enabled the acquisition of data systematic at high sampling interval, converting the GPS into a viable tool for study earthquakes, providing additional information. Traditionally, the Global Positioning System (GPS) has been used to study displacements at very long periods, making it one of the few instruments capable of measuring displacement in the crust produced by long period earthquakes.

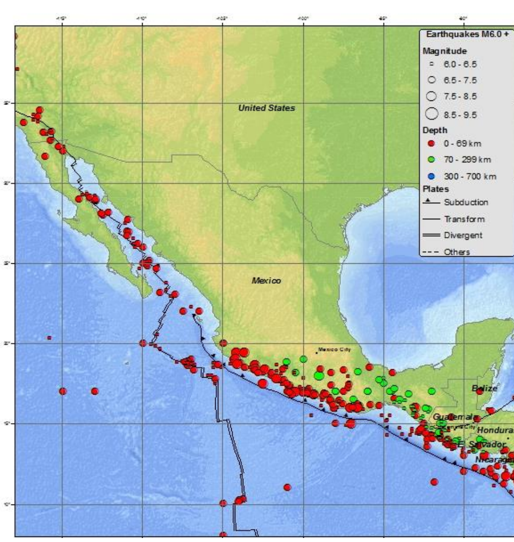


*Figure 1. Earthquakes of at least M6.0 in Mexico (USGS report)*

An important number of earthquakes in the world have been registered with GPS of high sampling period San Simeon, 2003 Mw6.5; El Mayor Cucapah, 2010 Mw 7.2 Crowell et al., 2012, TokachiOki, 2003 Mw 8.3All These studies have shown that the high frequency GPS is transformed into a powerful tool capable of representing a wide spectrum of the field of seismic waves in a similar way to the Seismograms and accelerograms.

The area of our investigation is the Gulf of California, extending 1400 km approx. from the fast spreading mid-oceanic ridge system of the East Pacific Rise to San Andreas Transform Fault. The continental rift is extensively exposed in the conjugate margin present in the Mexican states of Sonora and Sinaloa, where there is a zone of active basin-and-range type extension. Crustal deformation within the Gulf itself ranges from ridge transform structures in the south to minimal deformation in the north.

*GPS network analyzed*

Several permanent GPS stations exist in the studied area. SOPAC network of continuous GPS sites exists throughout the field area, but CORS network and GPS sites operated for INEGI (Mexico), are concentred in Sonora, Sinaloa, Colima and Baja California states. We delimit our study region as described above to complement survey networks operated by other Institutions (USGS Geological Survey, TLALOC network, Universidad Autónoma de Mexico).


*Figure 2. CGPS Stations*

## II. Metodology

*GPS Data processing*

TRACK is a GPS data processing program derived from GAMIT that allows calculating the movement of one or more stations with respect to one or more assumed fixed, this is called relative positioning. This calculation is much faster than the absolute positioning of a station that makes GAMIT, because it is only necessary to obtain the relative movement between stations. The principle of TRACK is simple, consists inconstructing the theoretical phases of the signals registered by the GPS stations, knowing their position a priori and position of the satellite and then compared with observed phase calculating the residue (RMS) for both, adjust the position of the stations along with other parameters that intervene in the process in order to minimize the residue. It Is because of this that it is advisable to choose a station reference for which will travel the same way as for the mobile stations, and therefore, the alterations present in the trajectory of signal are diminished at the moment of forming double differences.

TRACK has main components in the analysis of data:

- Calculation of the cinematics trajectory u sing the values of ambiguities.
- Reading of RINEX files and assignment of ambiguities a priori. Resolution of ambiguities to integer *integrated*values

*Accelerometer with GPS data*

The continuous and rapid development of the GP S and the improvement in the strategy of data processing have been such, that estimating the seismic displacement from GPS of high frequency has been con-poured in a topic of investigation known as GPS seismic Bock et al. 2004; Langbein & Bock,2004 . Recent studies have shown that large static displacement in the Near field can be obtained from post acceleration records to a correction in base line Graizer, 1979;

Iwan et al., 1985; Boore, 2001;Wang et al. Bock et al. (2011) showed how GPS and accelerometer work well as a complement to displacement obtained with GPS instruments, allowing to solve the problem of the double integration of acelerometer, due to this, the installation of a accelerometer together with a GPS receiver, or in its defect use of acelerometer and GPS observations located at a distance of not more than 4 Km (Emore et al.,2007), allows to make a good combination, delivering a precise record of the displacement through complete frequency range of the ground movement. An important utility of the networks composed by GPS high frequency and accelerometer, is to be able to deliver seismic records in the Near field, useful to constrain process kinematics of the source of an earthquake. In practice, the low frequency band of waveforms is very useful for the invertion of the so Cucapah, 2010 Mw 7.2 registered by the station installed in Mexicali, source time function.

Figure 3 shows the displacement of the earthquake of El Mayor Cucapah, 2010 Mw 7.2 registered by the station installed in Mexicali, BC, Mexico obtained from the GPS and also from the accelerometer integrated twice. It Is possible to observe the good adjustment of the accelerometer integrated twice when making a correction of the lınear base, obtaining to reproduce the static displacement.

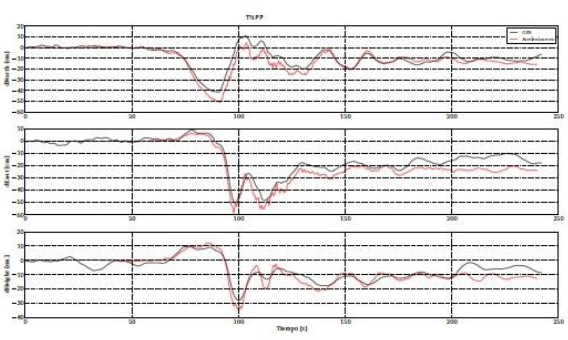

*Figure 3. Comparison between motogram (black) and integrated accelerogram*

There are some differences in the low frequencie s in North component that are ratified by observi ng the spectraof both signals, that is due to the accelerometer fail to effectively reproduce that frequency range.

We compared the data obtained from the GPS and accelerometer showing the content of its signal in speed, in order to know, as is the behavior of the signal cGPS in high frecuency that some component of the GPS was not entirely resolved during the process.

## III. Conclusions

To obtain the speed or displacement from accelerogram, it is necessary to apply to those which can be obtained directly from the GPS. When not making a correction, apply a high pass filter or pass-band to conducing record to a loss of information in the low frequencies, as of the static deformation that is important when calculating magnitude for the moment. As a whole, GPS and accelerometer are highly complementary instruments, since they will obtain a close field record of an earthquake of great magnitude in a range of frequencies wider than that obtained by each instrument separately. In the last time, techniques have been developed both to obtain a correction of automatic base for of GPS The study of earthquakes with high frequency GPS, offers possibility of observing the carrying of the signal like a seismogram, reproducing the movement coseısmic to registered in displacement.

The displacement associated with long periods, p articularly static deformation is well resolved. However, in high frequency it is unknown until the period is able to adequately reproduce the earthquake signal. Because of this, the signal obtained from the GPS was compared with with an accelerometer signal located in the same site.

The sensitivity to the movement of the GPS is different to of sismometers and accelerometer, for this reason, GPS is not able to register minor events.

However, the frequency range in which the GPS register is limited (less than 0.1 Hz), losing information with respect to arrival of the first seismic wave that can be of little amplitude (Meneses et al., 2015). This could be a problem for an early warning system

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