GEODYNAMIC STUDY OF THE NORTH OF THE ANDES BLOCK (COLOMBIA, PANAMA, ECUADOR AND VENEZUELA) THROUGH GNSS-GPS: MODELS OF DISPLACEMENTS, MODELS OF DEFORMATION AND DEFINITION OF LOCAL AND REGIONAL GEODYNAMIC STRUCTURES.

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Abstract

The northwest of South America is conformed by the territories of Ecuador, Colombia and Venezuela. Great part of these territories make up the Northern Andes Block (BAN). The tectonic and volcanic activity in the northwest of South America is directly related to the interaction of the South American plate, and the Nazca and Caribbean plates, with the Maracaibo and Panama-Chocó micro plates. The high seismic activity and the high magnitude of the recorded earthquakes make any study necessary to define this complex geodynamic region more precisely.

This work presents the velocity models obtained through GNSS-GPS observations obtained in public continuous monitoring stations in the region. The observations of the Magna-eco network (Agustín Codazzi Geographic Institute) are integrated with models already obtained by other authors from the observations of the GEORED network (Colombian Geological Service). The observations have been processed using Bernese v.52 software using the PPP technique; obtaining topocentric time series. To obtain the speeds, a process of filtering and adjustment of the topocentric series has been carried out. Based on this velocity model, regional structures have been defined within the Northern Andes Block through a differentiation process based on the corresponding speeds of the South American, Nazca and Caribbean tectonic plates. Local geodynamic structures within the BAN itself have been established through cluster analysis based on both the direction and the magnitude of each of the vectors obtained.

Finally, these structures have been correlated with the most significant geodynamic elements (fractures, failures, subduction processes, etc.) and with the associated seismic activity.

Study Zone

The analyzed time series come from permanent geodetic stations located in the territory of the Northern Andes Block, BAN (fig. 1). The permanent GPS stations that make up this network belong to different organizations: MAGNAECO, GEORED, FUNVISIS, COCONet, REGME, IGS, IGNTG.

Las series temporales analizadas proceden de estaciones geodésicas permanentes ubicadas en el territorio del Bloque de los Andes del Norte, BAN (fig. 1). Las estaciones permanentes GPS que componen esta redes pertenecen a diferentes organizaciones: MAGNAECO, GEORED, FUNVISIS, COCONet, REGME, IGS, IGNTG.

Figure 2 shows the stations of which the BAN consists, classified by the networks to which each one belongs.

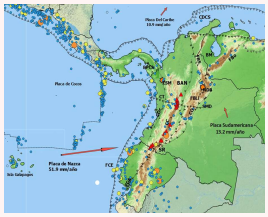

Fig. 1: Geodynamic Map: Delimitation of the territory of the Northern Andes Block (BAN) and its main faults.

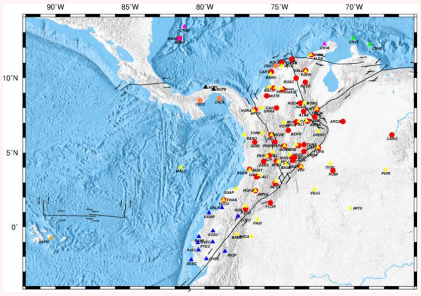

Fig. 2: Permanent stations of the networks located in the BAN.

The series under study have been obtained from daily GPS observations and processed using PPP positioning techniques. The time interval selected for the study is from the beginning of 2005 until 2016.

Methodology

❑ Time series filtering

In order to eliminate anomalous values, we first performed 1-sigma and 2-sigma filtering on the topocentric time series.

The following graphs show the eastern and northern components of the BUEN station, and the results obtained after applying the 1-sigma filter (figure 3), and the 2-sigma filter (figure 3).

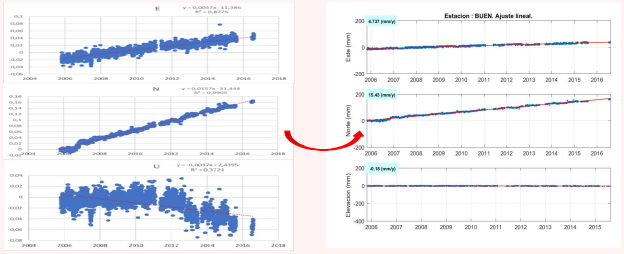

Fig. 3: Raw station series BUEN with 2-Sigma filtering and linear filtering.

❑ Cluster analysis

This technique allows data to be grouped based on the similarity between them. The groupings are based on the idea of distance between a studied parameter, in this case, the speeds of the GPS stations of the networks used in this work.
The Kmeans method has been used, which aims at dividing a set of n observations into k groups in which each observation belongs to the group whose mean value is closest (Martin et al., 2001).

Let be an initial set of k centroids m1 (1), ..., mk (1), such that:

$$S_i^t = \{x_p : \|x_p - m_i^t\| \leq \|x_p - m_j^t\| \forall 1 \leq j \leq k\}$$

Where x_p it goes exactly inside a S_i^t, and it`s true that :

$$m_i^{(t)} = \frac{1}{\left\|S_i^{(t)}\right\|} \sum_{x_j \in S_i^{(t)}} x_j$$

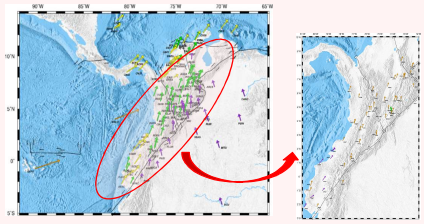

Fig. 4: Cluster with the Kmeans method of the GPS stations: MAGNA-ECO, GEORED, REGME-ESPONA, IGNTG, COCONet, FUNVISIS and IGS with their respective horizontal vectors of absolute speeds classified by similar behaviors in the variation of their coordinates that They are located in the northwest of South America.

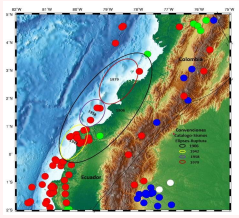

Fig. 5: Seismic zone of northern Ecuador-south-western Colombia where earthquakes of magnitude greater than 5 are shown (adapted from Kanamori and McNally, 1982).

Results

❑ Absolute displacement model

Figure 6 shows the horizontal model of the surface deformation of the GPS stations located in the northwestern region of South America. All the GPS solutions have been obtained with respect to the ITRF2008 reference system.

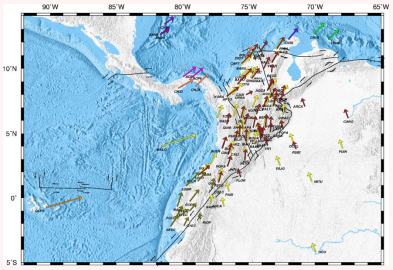

Figure 6. Absolute horizontal velocity field for the northwestern area of South America.

❑ Residual displacement model

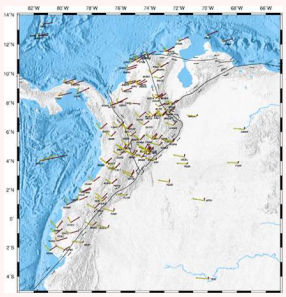

Figure 7. Residual models obtained from subtracting the theoretical model MORVEL2010 CA (NNR) and MORVEL2010 SA (NNR), respectively from the model of GPS absolute speeds (PPP) of all the networks under consideration. Vectors (yellow) are the residuals relative to the Caribbean plate and vectors (red) are the residuals relative to the stable South American plate.

Using GPS station data from the CASA project from the mid-1980s and early 1990s, Trenkamp et al., 2002 estimated that the NAB is moving northeast driven by the rapid collision of the Panama block with Chocó at an escape velocity 6.0 mm / yr. The direction of movement of the NAB continues to the northeast, but its speed of movement has increased. Nocquet et al., 2014 estimate an escape velocity of 4.2 mm / yr relative to the stable South American plate, but only consider two stations located in Colombia. Pérez et al., 2018 estimate a speed relative to the South American plate of 15.0 mm / yr taking into account stations located in Venezuela and 4 stations located in the northern part of Colombia. Mora-Páez et al., 2019 estimate a speed of 8.6 mm / yr. We estimate an average velocity relative to the stable South American plate of 14.6 mm / yr.

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