

# Three-dimensional crustal movement and the activities of earthquakes, volcanoes and faults in Hainan Island, China

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## ABSTRACT

Hainan Island is a seismic active region, where Qiongsan M7.5 earthquake occurred in 1605 and several seismic belts appeared in recent years, especially the NS trending seismic belt (NSB) located in the northeast part of the island. Here is also a magmatic active region. The lava from about 100 volcanoes covered more than 4000 km<sup>2</sup>. The latest eruptions occurred on Ma'anling–Lei Huling volcanoes within 10,000 years. The neotectonic movement has been determined by geological method in the island and its adjacent areas. In the paper, the present-day 3D crustal movement is obtained by using Global Positioning System (GPS) data observed from 2009 to 2014 and leveling observations measured in 1970s and 1990s respectively. The results show the horizontal movement is mainly along SEE direction relative to the Eurasian Plate. The velocities are between 4.01 and 6.70 mm/a. The tension rate near the NSB is less than 1 mm/a. The vertical movement shows the island uplifts as a whole with respect to the reference benchmark Xiuyinggang. The average uplifting rate is 2.4 mm/a. The rates are 2–3 mm/a in the northwest and 3–5mm/a in the northwest. It shows the deformation pattern of the southwest island is upward relative to the northeast, which is different from the result inferred from the coastal change and GPS. Haikou and its adjacent region present a subsidence in a long time. The southern part of the middle segment of the Wangwu-Wenjiao fault uplifts relative to the northern. Meanwhile, the western part uplifts relative to the eastern NSB. The vertical crustal motion and the two normal faults nearly correspond to the terrain. The NSB is located along the Puqiangang-Dazhibo fault, which is assessed as a segmented fault with a dip of 80°–90° and partly exposed. The 3D deformations and other studies reveal the present activities of

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earthquakes, volcanoes and the faults. The small earthquakes will still occur in the NS belt and the volcanoes are not active now.

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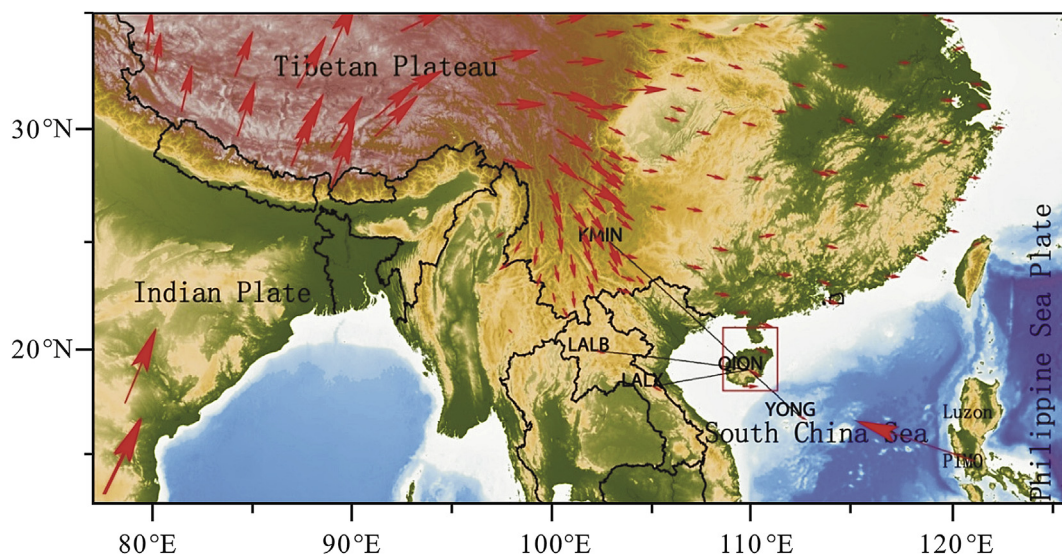
## 1. Introduction

As a continental island, Hainan Island is located in the southern edge of China. The island and its adjacent regions are not only affected by the forces transmitted through the Tibetan Plateau that originates the continuous compressing from Indian Plate, but also the NWW squeeze from the Philippine Sea Plate and the lateral pressure of the N expansion and push from the South China Sea (Fig. 1) [1,2]. Especially the tectonic stress field adjusted locally in the inner island cannot be neglected. Seismic tomographic images indicated a mantle plume may exist beneath and around the island [3]. A sub-vertical low-velocity column is imaged beneath the Hainan and the South China Sea, and extends from shallow depths to 660 km seismic discontinuity and continuously to a depth of 1900 km [4]. The synthetic plumes are even extending down to 2800 km depth [5]. The vertical deformation field has been impacted greatly by the force which originates from the uprising material of the midmantle, even the lowermost mantle. Due to the mantle material upwelling, it caused Yunlong block uplifting. The formation of the geological landforms, the occurrence of earthquakes and other phenomena are closely related to the hot mantle materials [6–8].

Qiongbai depression is one part of the Leiqiong fault depression, and its south boundary is Wangwu-Wenjiao fault

(WWF) (Fig. 2). The neotectonic movements of the fault depression are intense. Earthquakes, volcanoes and faults are all very active. Especially in the NS trending seismic belt (NSB) in the northeastern island, 1605 Qiongsan M7.5 earthquake (QSE) and several small earthquake swarms occurred (Figs. 2 and 3). The lava erupted from about 100 volcanoes covered an area of more than 4000 km<sup>2</sup>. The latest eruptions occurred on Ma'anling–Lei Huling volcanoes (MLV) about 4000–10,000 years ago. The island mainly developed the approximate EW, NW, NE and SN oriented faults [9]. The WWF and some NE, NW oriented faults are active in modern history which affected the formation of the NW oriented uplift and depression directly in the northeast island. The active faults are also associated with the seismic and volcanic activities.

The horizontal and vertical movements were estimated by using geologic method in Hainan and its adjacent areas. The horizontal movement of the island can be found on geomorphologic aspects such as the developed fold, a large number of faults with horizontal shear and the dislocated Quaternary in horizon [2]. For example, the quaternary profile incised by Changliu-Xiangou fault shows a left lateral horizontal slip and slightly distorted formation in some segments [10]. The vertical motion is significant in the north area since the Cenozoic. The crustal movement was inferred by coastal change, Global Positioning System (GPS), leveling and Interferometric Synthetic Aperture Radar (InSAR). The



**Fig. 1 – GPS velocities relative to Eurasia in the period from 1999 to 2013. The red small box in the inset map shows the study region. Black lines between the two stations are the baselines in Table 1.**

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