

# Crustal deformation rates in the Indian region from continuous GNSS measurements from 2013 to 2018 and sensitivity of plate velocity with reference frames

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## ABSTRACT

The Indian plate velocity for six IGS (International GNSS Service) stations was re-estimated by processing the GNSS datasets for the period January, 2013 to December, 2018 in International Terrestrial Reference Frame 2008 (ITRF2008) using long baseline GNSS scientific software Bernese 5.2. Out of these six IGS stations, two stations IISC in Bengaluru and HYDE in Hyderabad are located on the Deccan plateau, two stations LCK3 and LCK4 in Lucknow are located in the Indo-Gangetic plain and the remaining two stations, PBRI and PBR2 are located in the Port Blair area of Andaman Islands. Totally, 13 IGS sites data have been used as reference stations; 6 sites being located in the Indian plate and the remaining 7 sites in the adjacent plates (Eurasian plate, Arabian plate, and Australian plate). The result indicates that Indian plate is moving with a velocity of  $54 \pm 0.6$  mm/year at Hyderabad,  $55 \pm 0.8$  mm/year at Bengaluru,  $48.5 \pm 0.95$  mm/year at Lucknow and  $21.5 \pm 1.2$  mm/year at Port Blair. The results confirm that Southern part of India is moving as a rigid plate at velocity of 48 to 55 mm/year and the Andaman area, at a velocity of 21 to 22 mm/year in North East direction. The sensitivity of the velocity estimates with reference to the different Terrestrial Reference Frames namely ITRF2005, ITRF2014 has also been analysed.

**Keywords:** Bernese software, ITRF (International Terrestrial Reference Frame), Indian plate velocity, earthquakes, IGS

## INTRODUCTION

The change in the earth's surface caused by tectonic forces is called crustal deformation. The crustal deformation rates are very useful in understanding the earthquake phenomenon. The precise plate velocity is a key parameter in estimating the crustal deformation rates. Different techniques like Satellite Laser Ranging (SLR), Global Navigation Satellite System (GNSS), Very Long Baseline Interferometry (VLBI), Doppler Orbitography and Radio Positioning Integrated by Satellite (DORIS) etc. are there for estimating the plate velocity. Particularly, the geodetic methods like GNSS technology are very effective tool in studying the crustal deformation. Previously several research groups have studied the crustal deformation using GNSS technology. DeMets et al., (1990) observed that Indian plate moves with a velocity of approximately 5 cm/year. EC et al., (2000) used GPS data for studying the crustal deformation and observed that the motion of Indian Plate at Hyderabad (37 mm/year) is smaller than the NUVEL-1A model (45 mm/year). Southern peninsular India moves as a rigid plate with the velocity of Indian plate (Jade, 2004; Mahesh et al., 2012; Krishna et al., 2014; Rajewar et al., 2021). In the Indian Plate interior, there is no segmentation and observed residual velocity is 1 to 3 mm/yr (Jade et al., 2017; Sharma et al., 2021). The angular velocity for Indian plate was  $0.5205 \pm 0.002^\circ/\text{myr}$ . (Rajewar et al., 2021). The advancement in GPS geodesy makes it possible to understand the crustal deformation of Indian plate with better accuracy (EC et al., 2000; Jade, 2004). According to the Indian seismic zone map (BIS, 2002), seismically, there is no safe zone within India. Hence, it is required to monitor the crustal deformation of Indian region continuously to

understand the earthquake process. In this paper, we have studied the crustal deformation of Indian region by using 6 IGS stations lying within the Indian region and 7 IGS stations lying in different tectonic plates around the Indian region as reference stations. In addition to that, we have analysed the effect of reference frames on plate velocity.

## DATA

Continuous GNSS data from 13 IGS sites (International GNSS Services, Source: <ftp://cddis.gsfc.nasa.gov>) for the period of five years (Jan 2013 to Dec 2018) were used in this study. IGS is an international consortium involving more than 200 participating organizations in over 80 countries (Dow et al., 2009). The IGS sites were installed with geodetic receivers and calibrated antennae for high precision geodynamic studies. Among 13 IGS sites (Table 1), 6 sites are in the Indian region and the remaining 7 sites are located adjacent to the Indian region.

6 Indian region sites are Hyderabad (HYDE-Indian Plate), Bengaluru (IISC-Indian Plate), Lucknow (LCK3 and LCK4-Indian Plate), Port Blair (PBR2 and PBRI-Indian Plate) and the remaining 7 sites are Cocos (COCO-Australian Plate), Diego Garcia (DGAR-Australian Plate), Kitab (KIT3-Arabian Plate), Lhasa (LHAZ-Eurasian Plate), Quezon city (PIMO-Eurasian Plate), Bishkek (POL2-Eurasian Plate) and Yibal (YIBL-Arabian Plate), which are located adjacent to the Indian Plate. The daily based GNSS data in RINEX (Receiver INdependent EXchange) format for all the stations with sampling interval of 30 seconds were used in this study. The data used in this study have completeness above 90% and the multipath/cycle slips are within the acceptable range.