



# Crustal movement of North-East India and its impact on climate change : a micro-seismic study using Global Positioning System (GPS)

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## Abstract

The Earth's crust is divided into a number of plates. Due to the earth's movement, all plates are moving relative to each other with different velocities. The long term climate change has played a great role on the movement of these plates. But the changes happened very slowly, at about in millimeters per year. Climate change can cause seismic shift, which make some regions seismically very active. The more rainfall in North-East India has a small effect on the movement on the plate. The Brahmaputra Valley is built by the deposition of more than 1000 m thick alluvium formed during the period of the rise of the Himalaya. The Brahmaputra Valley is a relatively narrow valley bounded by two mobile young mountain belts, Mishmi block to the northeast and Meghalaya Plateau to the south. The north east part of our country is known to be one of the six most seismically active regions of the world. There is crustal deformation in this region and the area is prone to natural calamities like earthquakes.

The average velocity of Indian plate and the velocity of North-Eastern Region are slightly different. This can work the opposite way too. The different velocity of the plate of this North-East has an effect on climate of this region. For this we have studied the different part of this region for four years (2007-2011) with the help of GPS. We also see the change in climate of this region for these periods. All these are analysed in this paper.

**Keywords :** GPS, Plate Tectonics, Climate Change, Velocity

## 1. Introduction

The whole North-East is geologically an unstable area comprising rocks of Precambrian to Recent alluvium. The affect of thrust and faults in the Himalayan region, the high rising plateau of the Meghalaya, the low lying Brahmaputra Valley at the centre, the mobile subduction zone in the east, the deep basin in Bangladesh bordering Meghalaya, all there had its enervating effect on shaping the seismic character in the region. Its peculiar geologic setting, its plate movements in different directions, the presence of a number of active faults and related pro-active symptoms of

surface rejuvenation signify more unstable condition in future. Because of its complex geology and geographical setting, the climate of the North-East India is peculiar. The region falls under high rainfall zone with more than 300 cm of rainfall annually, which makes the region unique. Now a day, some scientists are engaged in correlating rainfall and tectonic movement of plates. They find that the speed of a plate gain movement due to rainfall of the region (Iaffaldano, G.). But, North-East India, which is adjacent to world's highest Himalayan Mountain and encompassed by distinct geologic features,

the relationship of rainfall and plate movement is likely to be most prominent in this region. To understand the actual picture, we have installed twelve (12) GPS campaign stations and collected data for four times (2007-2011) in the region. Taking into account the complex geological framework of North-East India, this paper makes attempt to project as to how crustal movement in North-East India is influenced by climate change.

## 2. Plate Tectonics

The earth is a dynamic plate whose surface is constantly undergoing change. The drifting of continents and sea floor spreading come together as parts of plate tectonics. When the surface of the earth are believed to be composed of a number of thin slabs of plates that moves across the surface. These plates follow a distinct boundary outlined by the location of earthquake epicenters. The plates are formed at the mid-ocean ridges and returned to the earth's interior at convergent plate boundaries such as the volcanic island arcs. Our

continents are made of granite, a rock that is less dense than the ocean floor rocks. The continents stand above the ocean floor basalt, and, so, as the plates move they carry the continents with them. In this way the same mechanism that causes sea floor spreading is also the cause of continental drift.

It is known to all that the earth Lithosphere is divided into six large and several small plates which are bounded by three fundamental types of zones that form the plate boundaries (Fig.1). The basic concept of plate tectonic is that Lithosphere is created at spreading axes, slides horizontally part itself along transform faults, and plunges into the mantle at subduction zones. The rate of subduction of Lithosphere must approximately balance the rate of formation of Lithosphere, as there is little evidence to support significant expansion or contraction of the earth during the present episode of sea floor spreading, which extends back at least 180 million years (Burchfiel, *et al.*).

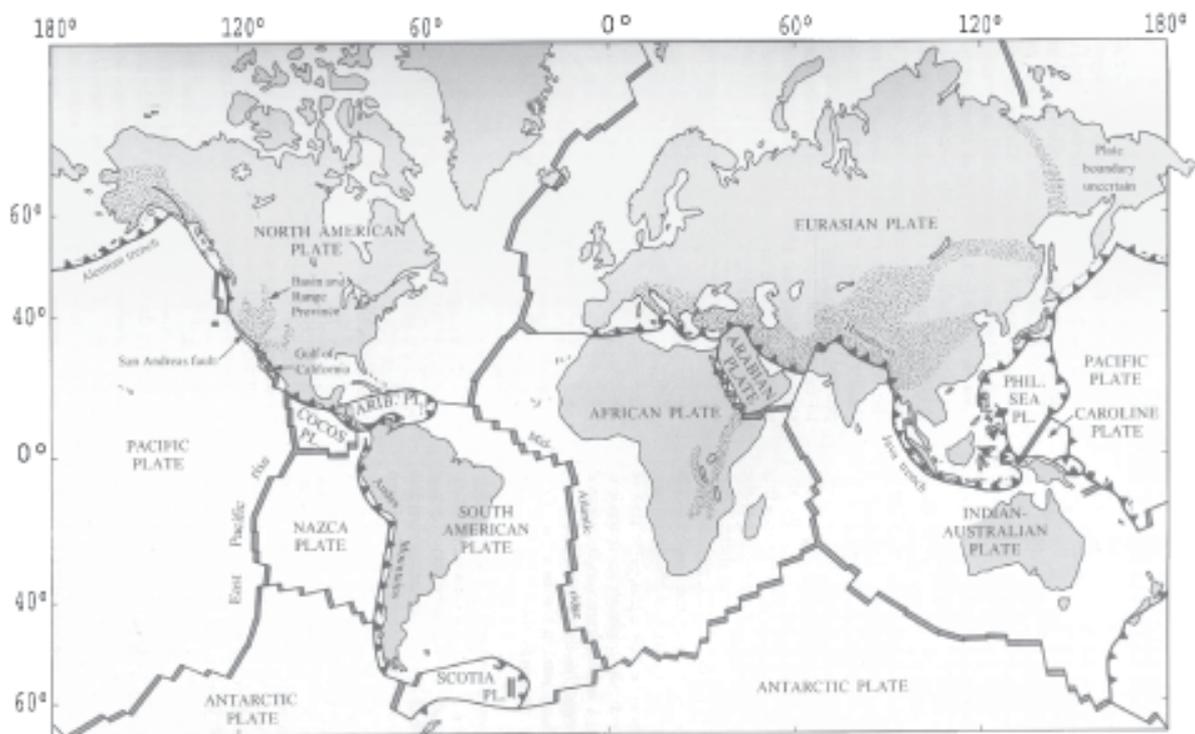


Fig. 1 : Lithospheric plates of the world

Human desires to understand the phenomenon of earthquake, the eruption of volcanoes, through various perspectives. Scientists have developed a number of interesting theories on origin of earth and movement of continents. Mention may be made of the theories of Kober, Jeffreys, Hall & Dana and others. But it was Alfred Wegner, who revolutionaries the concept of one ocean-one continent theory and exemplified the reality of continental drift which at present forms the concept of plate tectonics. The matter that plates move relative to each other in convergent or divergent form causing earthquake and sea floor spreading is being viewed in different perspective by a team of scientists from French and Germany. The Australian based study team is of the view that the strengthening Indian monsoon had accelerated movement of the Indian plate over the 10 million years by a factor of about 20 percent (Iaffaldano, G.). For the first time in world's history, scientists have succeeded to bring a linkage between intensifying climate events and tectonic plate movements, which could open up a window for understanding the occurrence of mega thrust earthquake.

In the North-East India region, the crustal movement causing enormous strain on the active Kopili Fault region. Added to this, the findings of the Australian scientists that crustal movement is correlated with rainfall implies that this region is actively prone to seismic catastrophic. As such the paper makes a determined attempt to understand the mechanism of fault movement in this tectonically volatile region and also desires to find linkage between the high amount of rainfall in the North-East India (as in Fig. 2) and also the movement of plates.

### 3. North-East Region

North-East India with an area of 2,55,089 sq. km. or 7.75% of India's total area encompassing ~3.748% of the country's total population is situated in a corner of the Indian Union with natural frontiers on three sides. The region is located between latitude 29° and 22° North and 89°46' to 97°45' East longitude, is literally boxed by China, Myanmar and Bangladesh.

Physiographically, 59.2% of the region is covered by mountains, 28% plain and the rest 12.8% is made up of plateau region. The entire area of Arunachal Pradesh, the biggest of the seven states of the North-East is constituted of a mountainous belt comprising spurs radiating southward from the crest line. Gori Chen (6,339 m or 21,450 ft.) is the highest peak of the territory. South of the Indo-China (Tibet) international boundary in Subansiri district, the altitude of peaks varies between 18,000 ft. to 21,000 ft. (5,487 m to 6,401 m). The Crestline forms India's northern and north-eastern boundary with China (Tibet). But around the north-eastern syntaxial curve, there is a gradual fall in altitude till the crest line, dips as low as 9,000 ft. (2,744 m). Towards the east, along the Indo-Myanmar border, it descends to 15,000 ft. (4,573 m) and even less until it averages about 6,000 ft. (1,828 m) in the northern Patkai Hills. The areas above 6,000 m (19,680 ft) remain snow covered for most part of the year and the presence of a number of waterfalls signifies the youthful topographic nature of the region (Acharyya, 1982).

Geologically, North-East India and its adjoining region display tectonically distinct geological domains occurring in intimate spatial association. Rocks representing the entire geological span i.e. from Archaean to the Recent occur in this very small region. Geologically, the Brahmaputra Valley is built by the deposition of more than 1000 m thick alluvium upon sag formed during the period of the rise of the Himalaya. The Brahmaputra Valley is a relatively narrow valley bounded by two mobile young mountain belts, Mishmi block to the northeast and Meghalaya Plateau to the south (Das Chowdhury, 2005).

### 4. Climate in India and its North-Eastern region

According to Koppen, Indian climate is divided into six major climatic subtypes. The world's highest and massive Himalayan mountain system regulates both the South-West and North-East monsoon climate of India. India is home to an extraordinary variety of climatic region ranging from tropical in the South to temperate

and Alpine in the Himalayan North, the desert in the West to the heaviest rainfall region in the East.

Against the backdrop of the geology and geographical setting of North-East region, the climate also plays an important role. The climate of the North-East region is unique, compared to the rest of the country. In the Northern Arunachal Pradesh the high rising Himalaya determines the pattern of climate there because of velocities in altitude region is very cold whereas in lower altitude and valley areas the climate is highly hot

and humid. In Assam, the climate is marked by extreme humidity. From the first week of June, south-west monsoon starts bringing rainfall in Assam. Whereas in Meghalaya, because of its plateau character, the climate is uniquely pleasant all throughout the year. The Cherrapunji-Maushingram area records world’s heaviest rainfall regions. In Tripura the climate varies from subtropical monsoon climate to temperate condition in the hilly areas with temperature varying from 10°C to 35°C. Nagaland on the other hand experienced heavy monsoon rainfall from June to September.

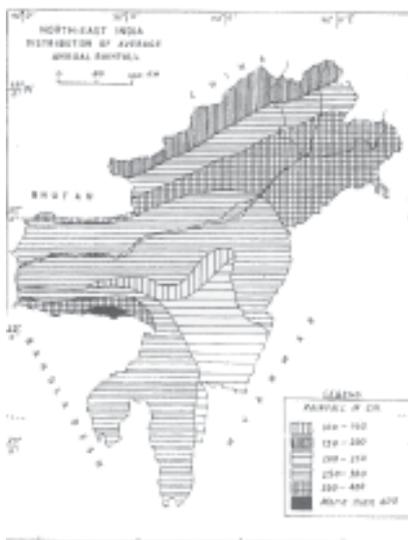


Fig. 2 : Distribution of average annual rainfall

Monsoon in India gives enormous amount of rainfall from June to September every year. India is also the land of world’s heaviest rainfall. Scientists who are recently engaged in correlating rainfall and plate movement on Indian tectonic plate have discover that the speed of the plate gain movement by about 20 percent due to rainfall (Iaffaldano, G.). As the whole North-East India receives more than 300 cm of rainfall annually, it is to be studied whether the plate margin in North-East India acquiring faster velocity compared to the whole Indian plate due to heavy rainfall or in vice versa whether rain act as an agent to strengthen the velocity of crustal plate.

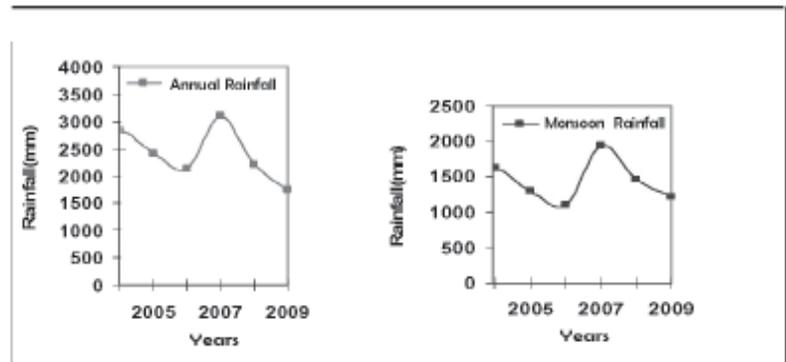


Fig. 3 : Annual and Monsoon Rainfall Distribution Pattern at Barapani over the last 5 years (2004-2009) (Das *et al.*, 2010)

**5. Methodology and Data processing**

To understand the crustal deformation in North-East India and its impact on climate change, the work has been carried out on the latest technology using Global Positioning System (GPS). In this study, twelve (12) points in different locations of Kopili Fault region have been selected for campaign study. The first field study was initiated in 2006-07 and then after it was continued for sequent four years up to February, 2011. These GPS campaign stations are studied with Trimble 5700, Leica500 and Leica1200 receivers with choke ring and Zephyr geodetic antennae. The selection of twelve sites

was based on granite and feldspar rock formations or on hard stable rocks. All the points were selected in an open area without having any disturbance to the antenna. The machines were installed in all the campaign sites at least for continuous 72 hours, so that we can collect 48 hour data without break. The GPS data so collected has been converted into RINEX observation files and quality check has been conducted using TEQC (Translations, Editing and Quality Checking) software. All these processes of quality check plots were carefully examined and data with high cycle slips, multi-path were removed from the analysis (Sunil and Kumar, 2008). The data collected for the last four epochs (2007-11) processed along with the selected

permanent stations like Tezpur (TZPR) and Bomdila (BOMP) and IGS (International GPS Service) stations KUNM, LHAZ, HYDE, IISC, POL2, KIT3. In the processing, we have used GAMIT/GLOBK software developed by Massachusetts Institute of Technology (MIT), USA and a reference frame ITRF 2005 is used for all time series. Ambiguity free and ambiguity fixed solutions were performed with ionosphere free linear combination to account for carrier phase ambiguities and signal delay due to ionosphere (Sunil and Kumar, 2009). The horizontal errors ellipses are calculated by GAMIT/GLOBK software from the uncertainties in the North and East coordinates/velocities using the correlation between the baseline component estimates.



Fig. 4 : Installation of a GPS machine in Raja Gaon, Nagaon, Assam.

## 6. Results

The analysis of data gives a clear picture that the Kopili Fault region is moving in North-North-East (NNE) direction traversing the Kopili Fault at an average angle of  $84.041^\circ$ , causing enormous stress and strain at various levels.

GPS has revolutionaries the scientific methodology of estimating crustal velocities all over the earth. It is used as scientific and most reliable to determine the crustal movement in the earth's surface, we perceived different in

velocities in different IGS (International GPS Services) stations. The average velocities of KIT3 and POL2 in Eurasian plate is  $5.19N (\pm 0.310mm)$  and  $27.37E (\pm 0.525mm)$  which show almost similar velocities. The IGS stations in India IISC and HYDE have the average velocity of  $35.06N (\pm 0.425mm)$  and  $40.54E (\pm 0.635mm)$ . In North-East India the average velocity of the all campaign sites with permanent stations is  $27.70N (\pm 1.091mm)$  and  $40.47E (\pm 1.092mm)$  (Table 1 & 2 and Fig. 5).

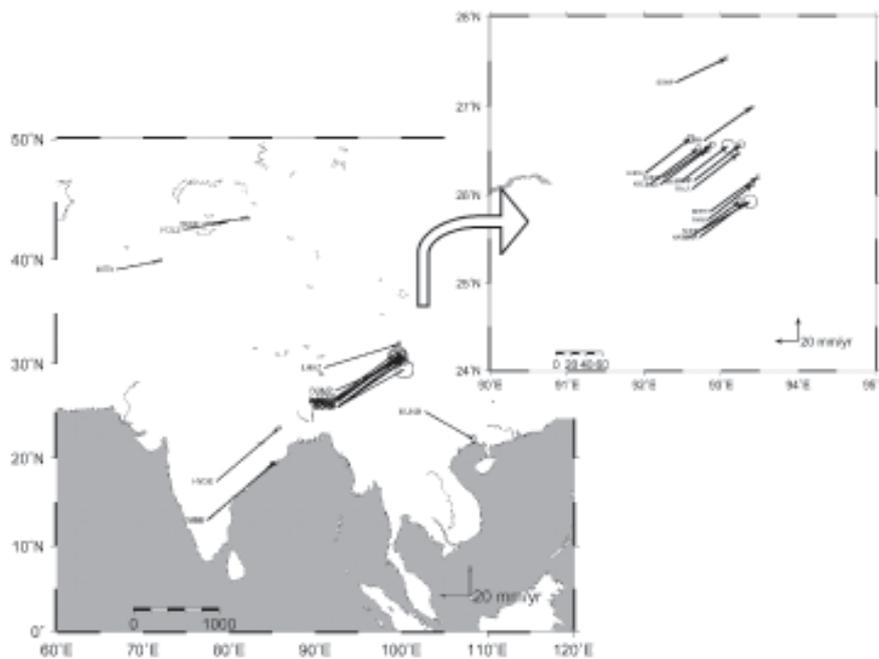


Fig. 5 : Velocity plot of various campaign/permanent sites along with IGS stations (Mahanta *et al.*, 2012)

**Table - 1** : Estimated velocities of campaign and permanent sites of North-East India

Sl. No.	Name of the Stations	Station Code	East (mm/yr)	North (mm/yr)	H Rate (mm/yr)
1	Natun Bazar	NATU	42.42 ( $\pm 1.06$ )	29.53 ( $\pm 1.06$ )	-0.24
2	Umrangsho	UMRA	38.10 ( $\pm 0.73$ )	27.51 ( $\pm 0.77$ )	2.46
3	Sokra Pam	SOKR	42.04 ( $\pm 2.44$ )	23.88 ( $\pm 2.32$ )	51.16
4	Panimura	PANI	38.39 ( $\pm 0.70$ )	29.43 ( $\pm 0.75$ )	2.70
5	Raja Gaon	RAJA	38.93 ( $\pm 0.73$ )	28.97 ( $\pm 0.79$ )	-4.24
6	Kheroni	KHER	40.86 ( $\pm 0.67$ )	28.44 ( $\pm 0.73$ )	1.85
7	Kumoi	KUMO	41.72 ( $\pm 0.99$ )	27.21 ( $\pm 0.97$ )	3.37
8	Jagiroad	JAGI	40.37 ( $\pm 1.04$ )	28.73 ( $\pm 1.03$ )	2.92
9	Bura Mayong	BURA	38.92 ( $\pm 1.30$ )	28.88 ( $\pm 1.25$ )	-13.87
10	Amsoi	AMSO	39.73( $\pm 2.25$ )	29.27 ( $\pm 2.12$ )	-26.94
11	Kampur	KAMP	40.06( $\pm 1.31$ )	29.74( $\pm 1.24$ )	18.45
12	Khetri	KHET	41.19( $\pm 0.99$ )	29.18( $\pm 0.98$ )	1.46
13	Tezpur	TZPR	40.77( $\pm 0.53$ )	27.31( $\pm 0.63$ )	0.58
14	Bomdila	BOMP	43.12( $\pm 0.55$ )	19.79( $\pm 0.64$ )	4.36

**Table - 2** : Estimated velocities of IGS sites of Indian and Eurasian plates

Sl. No.	Name of the Stations	Station Code	East (mm/yr)	North (mm/yr)	H Rate (mm/yr)
1	Kunming	KUNM	30.71 ( $\pm$ .64)	-17.64 ( $\pm$ .84)	-1.25
2	Lhasa	LHAZ	47.70 ( $\pm$ .50)	14.99 ( $\pm$ .58)	3.36
3	Hyderabad	HYDE	39.82 ( $\pm$ .61)	34.06 ( $\pm$ .42)	-0.97
4	Bangalore	IISC	41.27 ( $\pm$ .66)	36.07 ( $\pm$ .43)	-0.33
5	Bishkek	POL2	26.64 ( $\pm$ .55)	4.64 ( $\pm$ .31)	2.18
6	Kitab	KIT3	28.10 ( $\pm$ .50)	5.75 ( $\pm$ .31)	-0.66

From the above findings we may come to the conclusion that the Eurasian plate is more stable than the Indian plate where as the eastern velocity of the Indian plate and also that of the North-East region is almost same, but Northern velocity of the Indian plate ( $35.06 \pm 0.425$ mm) is much more higher than the Northern velocity of the North-East region ( $27.70N \pm 1.091$ mm). Moreover the point that puzzles us is the stability of the Northern Eurasian plate. Because the Indian plate and the North-East region moves 7 times and 5 times more compared to the Eurasian plate respectively.

## 7. Discussion and Conclusion

The climate of North-East India will undergo a drastic change in near future, as because of the abnormal plate movement of this region (as mentioned above). Its temperature will rise and also rainfall will increase. According to Indian Network of Climate Change Assessment (INCCA), assessment, the temperature of the region will increase by  $1.8^{\circ}\text{C}$  to  $2.1^{\circ}\text{C}$  during the next two decades. In addition the mean annual rainfall is also likely to increase by 1mm to 6mm per day; however the number of rainy days in a year may decrease from 1-10 days. According to the assessment, the rise of temperature and pattern of changes in rainfall distribution is expected to affect ecology, especially the forests of the North-East region.

Moreover, there remains an enormous scope for the scientists to generate a model studying the variations in plate movements in this region and rate of erosion continuing because of prevailing monsoon climate in this region. The enormous monsoonal rain lightening the loads in this region, which affects the plate movement, is also another serious study material for consideration. Urbanisation is gradually rising open cast mining is prevalent in the region, continuous deforestation and construction of roads, railways, airports and more significantly, construction of big dams has its enervating effect on changing the landscape of the region. The report that China is constructing a dam on river Brahmaputra and her likely move to divert water from the river towards interior China would also create devastating ecological effect on this region. The North-East India in the long run would change its physical character. To understand the linkage between impacts of climate change on crustal movement in North-East India, we need to consider the effect of monsoonal rainfall on human changed topography and related crustal movement of the region.

As the region demands serious investigation for its complex geodynamic and geophysical characters, we hope to study- the extent up to which climate is responsible for triggering plate movement in North-East India based on our findings.

## 8. Acknowledgement

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