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Continuous Gps Measurements And Co-Seismic Slip Observations : A Case Study From Imphal Continuous GPS Permanent Station.

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ABSTRACT
The continuously operating GPS permanent station at Imphal was installed in 2003. No major earthquake occurred in the region during the period of 2003-2020. Even the strong earthquakes which occurred in the region, had focal depth in the intermediate depth range (>70>150 km) and hence did not cause any coseismic offset in the coordinates. However, the 2004 Sumatra Andaman earthquake caused a coseismic displacement of about 3-5 mm predominantly towards SW and the earthquake of Mw 6.7 occurred near the Noney village of Tamenglong district, 30 km WNW of Imphal, Manipur on 4th January 2016. We have estimated co-seismic displacements of about 8.5 mm towards ENE.
KEYWORDS: *GPS, co-seismic slip, Indo-Burmese Arc,*

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I. INTRODUCTION

The Mw6.7 earthquake occurred on Jan. 4, 2016 in Manipur is largest event in last 60 years. Prior to this event, the region was visited by an earthquake of 7.3 in 1957 (Fig. 1). The local network of broad band stations, being operated by Manipur University has produced a very good data set to precisely locate this event. The epicenter of the event falls at 24.86oN and 93.65oE near the Noney village of Tamenglong district of Manipur. The focal depth of the event has been estimated to be 50 km. Manipur University has set up a continuously operating GPS permanent station at Imphal (IMPH) was installed in 2003 (Fig.2). This station is located in the Indo-Burmese Arc (IBA) region. The epicenter of recent Mw6.7 earthquake occurred on Jan. 4, 2016 in Manipur is located near the Noney Village of Tamenglong District on the west of IBA.

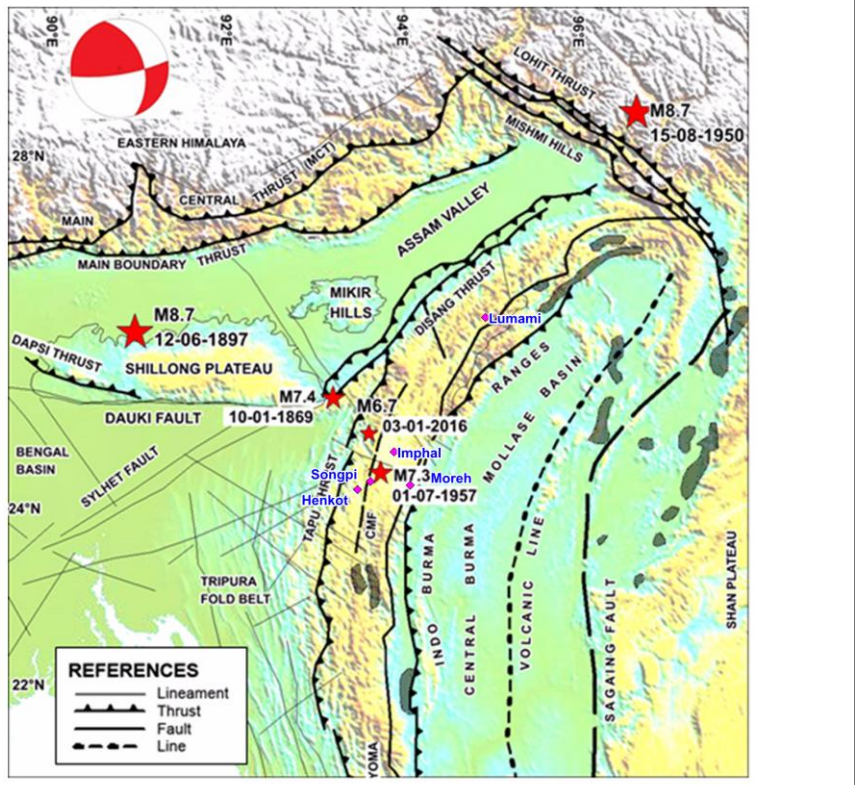

Fig.1 General Tectonics in the Indo-Burmese region

Fig.2. GPS permanent station at Imphal

GPS DATA PROCESSING AND ANALYSIS

GPS data of the Permanent station of IBA are used to determine the quasi-static displacement associated with the Mw = 6.7. The GPS data obtained from the site have been converted into RINEX observation files and quality check was performed using TEQC (Translation, Editing and Quality Checking Software). The quality check plots of all the GPS data were carefully examined and the data with high cycle clips, multipath and of duration with <18 hours observation were removed from the analysis.

The processing of the GPS data from station is routinely performed at Department of Earth Sciences Manipur University using the GAMIT/GLOBK software (Herring et al., 2010a,b). Data from IGS (International GPS Service) sites, namely, BAHR, IISC, HYDE, LHAS, KIT3, KUNM and POL2. These data were processed on daily basis producing loosely constrained station coordinates and satellite orbits. These were further combined with loosely constrained solutions of globally distributed nearby IGS station data available from the Scripps Orbital and Positioning Analysis Centre (SOPAC; http:garner.ucsd.edu). Using the GLOBK software (Herring, 2005), position estimates and velocity stabilization in ITRF08 were achieved. And Coulomb 3.3 software (Toda et. Al. 2005: Lin & Stein, 2004) is used for calculating stresses changes at any depth caused by fault slip.

INTERPRETATION

For our analysis, the Imphal permanent stations is deeply anchored in bedrock and have proven to have predictable motions that can be adequately modeled as a constant velocity over several years. Because this IMPH permanent station has more than 10 years old.

Time series of IMPH site is shown in Fig. 3. In the time series north component shows deformation 20.9 ±0.5 mm/yr, east component shows deformation 29.7 ±0.5 mm/yr and up components shows the deformation 0 ±19 mm/yr. In ITRF2008 reference frame the IMPH site shows a velocity of 36.3 mm/year towards N55°.

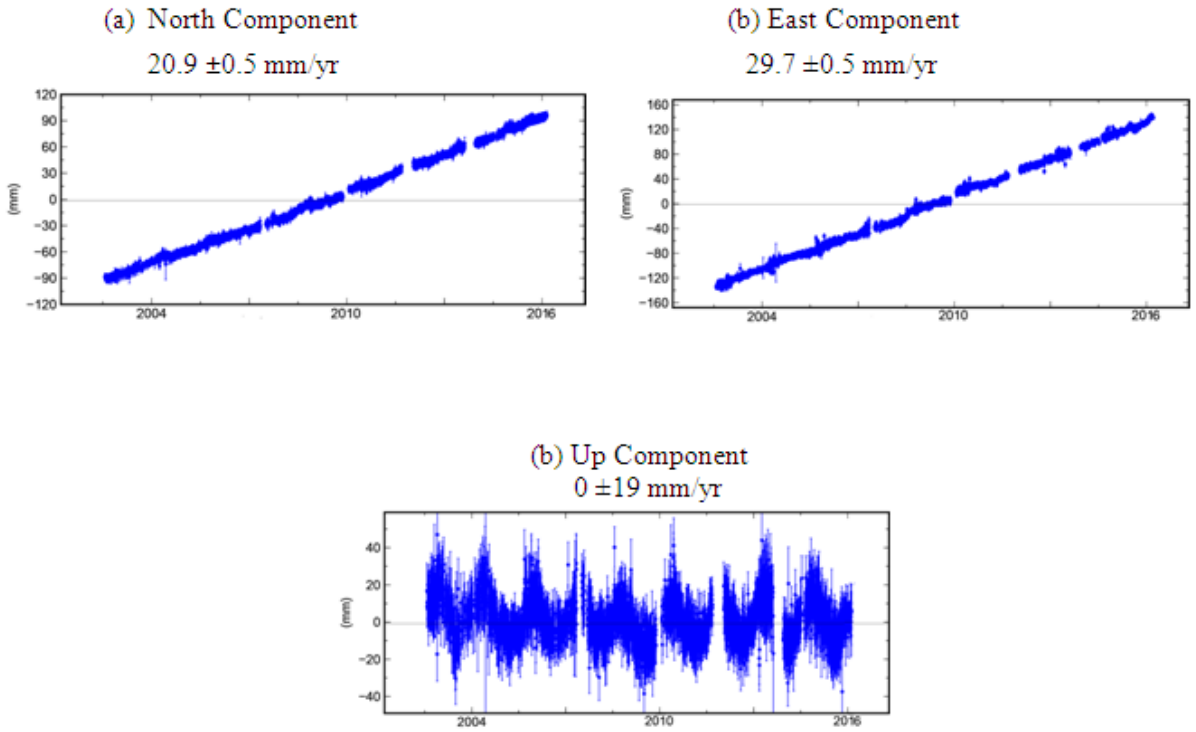

Fig.3 Time Series at IMPH in ITRF 2008. The estimate slope for east component is also given.

Table 1. Co-seismic displacement at Permanent GPS Stations.

GPS Station	Distance from Epicenter (Km)	North Measured (mm)	East Measured (mm)
IMPH	30	3 ± 0.5	8 ± 0.4

Co-seismic displacement is observed very clearly from the permanent GPS station IMPH (Table 1).

At the time of the shock Time series of IMPH a co-seismic displacement is evidenced of about ~ 8.5 mm in ENE (Fig.4) . The offset in the North component is not obvious, however it is quite distinct in the East component. In the North component the offset is ~3 mm and East component is ~ 8 mm.

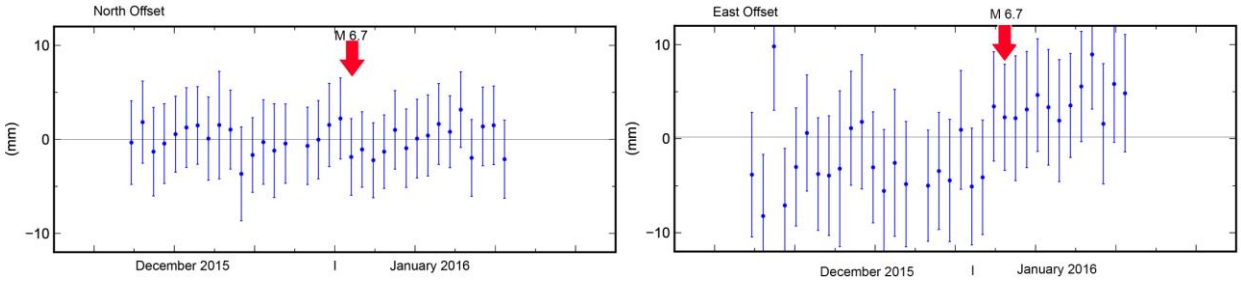

Fig.4 Time series at IMPH showing coseismic offset due to the 2016 Manipur earthquake.

The time series of the observed displacements shows that the main shock is followed by a significant post seismic signal occurring in the same direction as the co-seismic movement period lasting 10 days shows a rate of about 2 mm/day (during this period the strong aftershock (Mw= 6.7) of January 4, is seen as a step of about 4 mm on the time series.

A slight preseismic displacement (1-2 mm) is detectable during the 2 weeks before the main shock. It is particularly evidenced as a change in the slope of the time series during the 30 days.

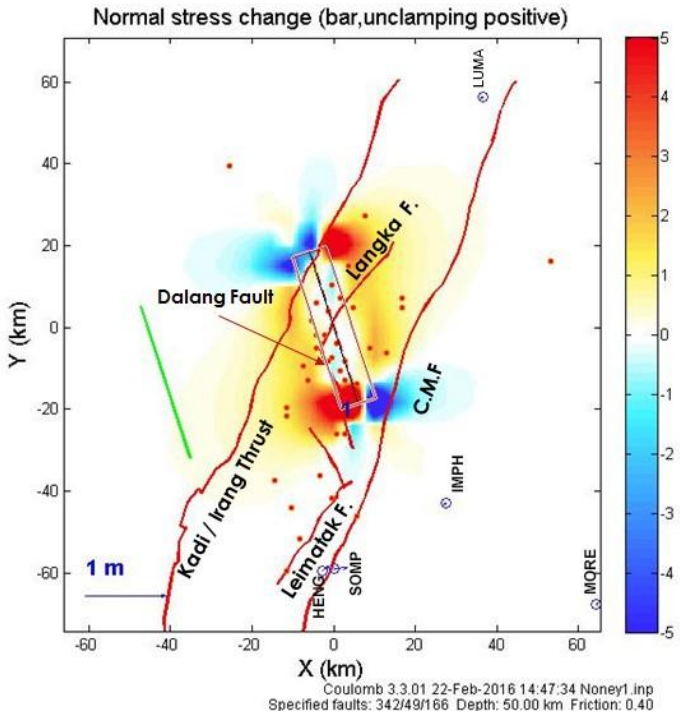

Fig 5. Preliminary results showing Normal stress change along the fault plane

Again the coulomb stress change values were compared with the earthquake focus distributions which were obtained from USGS between the years 1950-2016 (Fig 5). It is noticed that the earthquakes which occurred near the modeled fault are seen on high stress region (red colored areas).The earthquake were coherent with the high stress region at the North and South boundaries of the modeled fault.

II. CONCLUSIONS

The daily analysis of GPS data from Global Positioning System (GPS) data from permanent station IMPH along with three newly established stations, one month before and after 4 January 2016 Manipur Earthquake shows a co-seismic displacement is evidenced of about ~ 8.5 mm to ~ 8.5 . A weak pre-seismic signal is emerging from the background noise during the month preceding the main shock and is evidenced by a change in the slope of the time series. The mainshock is characterized by an abrupt change of the time series. A significant afterslip movement is seen for the month following the co-seismic rupture.

The estimated seismic moment and stress drop suggest that the hypocenter location of recent earthquake lies within the interplate region of IBA, where a number of past earthquakes, propagated with strike slip faults, exist.

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