

## **Scientific Activities of National Geophysical Research Institute at Maitri Station during 27th Indian Antarctic Expedition**

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### **ABSTRACT**

National Geophysical Research Institute is carrying out two long- term ongoing scientific projects at Maitri, Indian Research Base Station in Antarctica. (1) Sophisticated Seismological Observatory and (2). Permanent GPS Tracking Station. These research activities at Antarctica were successfully carried out during 27th Indian Antarctic Expedition. The GPS station continues to contribute to Scientific Committee on Antarctic Research (SCAR) and International Earth Rotation Service (IERS), the seismological observatory continues to contribute to NEIC (USGS) and ISC (UK) and plays a pivotal role in the Global Seismographic Network. Global positioning system (GPS) measurements at Maitri, Indian Antarctic station have been carried out from 1997 till date. The International GPS Service for Geodynamics (IGS) stations, in different plates, such as Casey, Davis, Kerguelen, Seychelles, Coco, Hartebeesthoek, Yaragadee, and Tidbinbilla have been chosen in the global network. The GPS data from 1997 to 2010 from all these IGS stations in and around Antarctica, along with Maitri, were used to estimate the time series, baseline lengths and velocity vectors of individual sites. The results have enabled to obtain a deeper insight into the driving mechanism and the causative factors for Indian plate kinematics. During the 27th expedition continuous seismic data has been recorded and the same has been archived and stored in DVDs for further processing and analysis. Using SEISAN software, the final analysis work of this data has been completed and reported to International Seismological Centre, United Kingdom as per their time schedule.

**Keywords:** Antarctica, Maitri, Seismic Observatory, GPS Tracking.

### **1.0 INTRODUCTION**

The India–Eurasia collision zone has been the focus of intense studies by the Space Geodetic community for Indian Plate Motion. So far space geodetic studies by GPS have been made in southern and central India that bears on the rigidity of the Indian plate, whose velocity data for 2 sites fit the rigid plate model within uncertainties, estimated at about 3.7 cm/yr. for Hyderabad and 3.9 cm/yr. for Bangalore, respectively. Since Space geodesy

can test many otherwise untestable predictions and boundary conditions, GPS-Geodesy is extended to envelop the large Indian Ocean lithosphere and observations are extended to the Indian Ocean and Antarctica. Despite the extensive studies to date, major issues remain unresolved. Motions across some of the plate boundaries seem well constrained, as implied by good agreement between space geodetic and geologic models. In others, apparent discrepancies exist. Very few studies have been conducted on the larger oceanic part of the Indian plate using space geodesy. To holistically determine the kinematics of the Indian Ocean Basin between Antarctica and India, the data available are very sparse and characterization and the delineation of the plate boundaries, especially in the Indian Ocean, are poor. This study addresses several of these issues mentioned as follows:

- (1) How rigid is the Indian Plate and Indian Ocean Basin?
- (2) Does relatively high level of intraplate seismicity on the oceanic part of the Indian Plate indicate internal deformation in excess of other plates? and,
- (3) Is this related to Indo-Eurasian collision and the uplift of Himalayas?

Therefore, GPS geodesy is used to improve the understanding of the complex plate motions, diffuse and poorly located plate boundaries, and striking intraplate deformation that characterize the Indian Ocean basin.

### **1.1 Work carried out during the Expedition**

During this 27<sup>th</sup> expedition, the new TOPCON System was installed, the existing Astech X-XII GPS Geodetic receiver also simultaneously recording the data with the sampling rate of one sample per 15 secs. Daily about 5 Mb Topcon data and 4-5 Mb Ashtech data is collected. This is then converted to Rinex format and transferred to CDs in 2 copies. The data was processed using Bernese software at NGRI.

A new Reftek Broad Band Digital Seismic System was installed. The stand by BB system the Geotech Broad Band Seismic Digitizer, Smart-24R and KS-2000M Seismometer is also simultaneously recording the data. Un-interrupted good quality seismic data acquisition is going on till now in this observatory. The new Reftek Broad Band data is acquired continuously and the Geotech Broad Band data acquisition is also being continued in the 27<sup>th</sup> expedition. It is very useful to provide valuable control on global Hypo-Central determinations, specifically the earthquakes in the higher latitudes in the Southern Hemisphere. This data has been sent to

NEIC, USGS for inclusion in the global data archives, as well as for accurate epicenter parameters estimation by this, elevating Maitri seismic observatory to the global scenario. We are also contributing the data to ISC, U.K. And AnSWeR (Antarctic Seismic Web Resource). To improve the system performance we have opened the seismic vault and completed the sensor leveling and mass centering by locking and unlocking. The entire seismic system was refurbished for satisfactory operation. After doing this, we observed that the daily file size improved to 20-25 Mb (as it was earlier). There was significant improvement in the signal level.

## **2.0 GPS DATA ACQUISITION AND ANALYSIS**

Global positioning system (GPS) measurements at Indian Antarctic station (Maitri) have been carried out since 1997 to study the temporal evolution of baseline length between Hyderabad and Maitri, and to understand the tectonic and geodynamical processes taking place in Indian Ocean. The Global network of GPS stations includes Maitri (MAIT), Casey (CAS1) and Davis (DAV1) in the Antarctic plate, Seychelles (SEY1) in Somalian plate, Cocos (COCO) on edge of Indo-Australia diffuse plate boundary, Yaragadee (YAR1), Tidbinbilla (TID2) and Australian plate and Hartebeesthoek (HRAO) in African plate. GPS data are processed and analyzed using Bernese software. Data processing resulted in the estimation of all site coordinates and the baseline lengths from Kerguelen to all other stations. The estimation of very long baseline lengths and their changes between India and Antarctica give insight into the signatures of crustal deformation and strain accumulation in the south of Indian peninsula.

## **3.0 SEISMOLOGICAL OBSERVATORY AT MAITRI**

Focused study on the Indian Ocean Region and South Sandwich Islands Region becomes very important in the present scenario of interplate and intraplate earthquakes that do occur frequently in India and nearby regions, forcing us to re-evaluate the rigidity of the Indian plate, as well as Indian Ocean Margin. GPS- Geodesy and Seismic Studies are extended to envelop the large Indian Ocean lithosphere. Permanent GPS station is continuously operational since 1998. In order to monitor the seismic activity in and around Antarctica and Indian Ocean, a reconnaissance survey for site selection and feasibility of operation of seismological observatory in Antarctica was initiated during 16<sup>th</sup> Indian Antarctic Expedition and a Digital Short Period System has been installed during the 17<sup>th</sup> expedition. The station was fully commissioned on 26 January 1998, with analog and short period digital systems. This observatory was further upgraded with the installation of Broadband seismic system in the 20<sup>th</sup> expedition,

comprising of a Broadband Sensor CMG-3ESP (GURALP make with 50 Hz to 100 sec flat response). In this expedition, the Modern Reftek Broad Band digital Seismic System was installed.

The seismic station at Maitri is also a member of AnSWeR. (Antarctic Seismic Web Resource) and can be seen in Figure 2b, with the code MAIT. After final analysis of seismic broad band digital data, the complete phase data is reported to ISC, U.K. to be included in the global data center for global access by any other agency and can be accessed at: <http://www.isc.ac.uk>

Using SEISAN software, the final analysis work of this data has been completed and reported to International Seismological Centre, United Kingdom as per their time schedule. The data acquisition during wintering period, the Preliminary Determination of Epicenters (PDE) reports by NEIC are referred to while processing the data using SEISAN, PCSUDS and REFTEK software. After completion of the analysis, the arrival times, origin times and the corresponding hypo central data of the processed events have been used to compile the MAITRI Seismological Bulletin.

#### 4.0 DISCUSSION

##### 4.1 Results from the GPS Station

Figure 1 shows the velocity and the direction of movement of stations. Estimated site velocities are given in Table-1.

**Table 1— Estimated site velocities**

Site	N-VEL (mm)	E-VEL (mm)	N-Error (mm)	E-Error (mm)
MAIT	11.3	2.3	1.009	1.768
CAS1	-12	7.6	2.222	4.019
DAV1	-2.9	-6.4	1.495	2.542
YAR1	50.8	27.9	5.59	2.49
TID2	43.5	-22	9.399	3.472
COCO	40.3	48	5.696	3.694
SEY1	3.9	17.8	22.794	11.718
HRAO	15.8	23.6	6.087	2.703

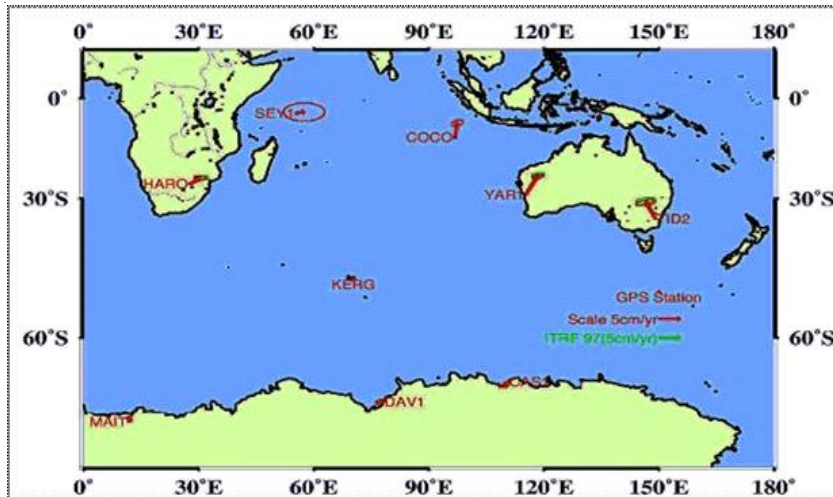


Fig. 1: GPS Velocity vectors of Global Network Including Maitri GPS station

The overall analysis is that the estimated baseline lengths between Kerguelen and Maitri and other IGS stations; namely Casey, Davis in Antarctica Plate are indeed shortening at the rates of 5.9mm/yr, 4.4mm/yr and 1.9 mm/yr, respectively. The rate of change in the order of mm in the base line lengths between these stations indicate no significant change at the one standard deviation level and may be construed as the stations in the same plate are moving together. The increase in baseline length between Kerguelen (KERG) and Seychelles (SEY1) at the rate of 5.6mm/yr clearly indicates that Seychelles (SEY1) is moving away from Kerguelen (KERG). The velocity vector of Seychelles (SEY1) shows the movement towards the Indian peninsula and this also agrees with the plate model. If this rate of movement is verified, this may result in the increase in the strain accumulation in the southern Indian peninsula. GPS data at COCO suggests the high rate of movement, that could be the result of excessive strain accumulation due to the Indo-Australian diffuse plate boundary forces acting upon this region.

#### 4.2 Results from the Seismic Station

During the 27<sup>th</sup> expedition, uninterrupted good quality Seismic analog Record & Digital Broad Band data were acquired. The data acquired was processed and analyzed at NGRI. For the Digital Broad Band seismic data, SEISAN software is used for the final processing and analysis. The total number of earthquakes recorded from January to October 2008 was 453. Fig. 2a shows that the epicentral map of the events recorded during 2008.

**Epimap of 453 earthquakes recorded at NGRI Seismic Observatory, Maitri, Antarctica during 27<sup>th</sup> IAE during 2008**

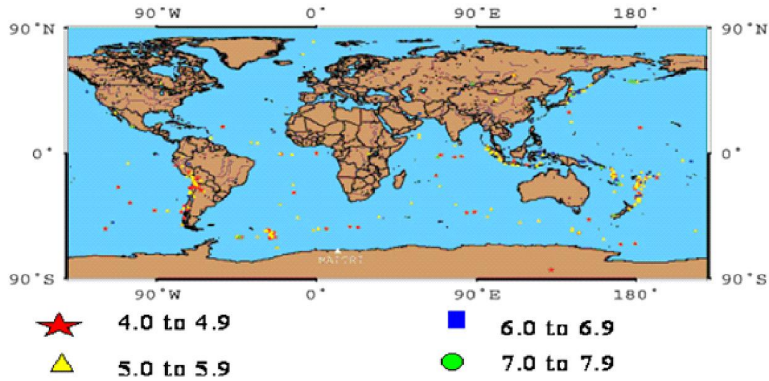


Fig. 2a.

**Maitri in Antarctic Seismic Web Resource (AnSWeR)**

Antarctic Broadband Seismic Observatories

Filled triangles = Existing stations, Open triangles = Proposed stations

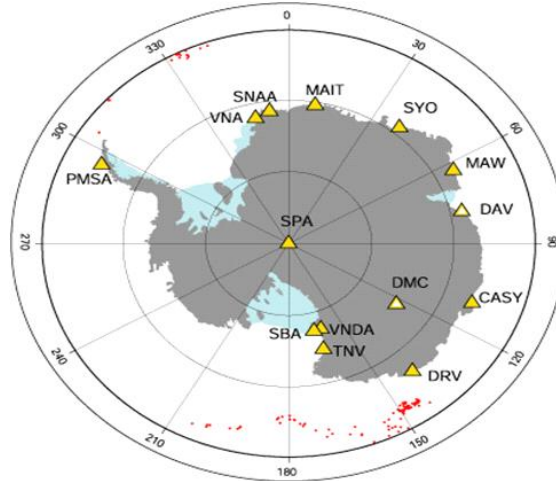


Fig. 2b

CODE	NAME	INSTRUMENTATION	VAULT/ SITE	WHERE TO GET DATA
MAIT	Maitri Station	CMG3ESP	Underground vault, bedrock	ISC

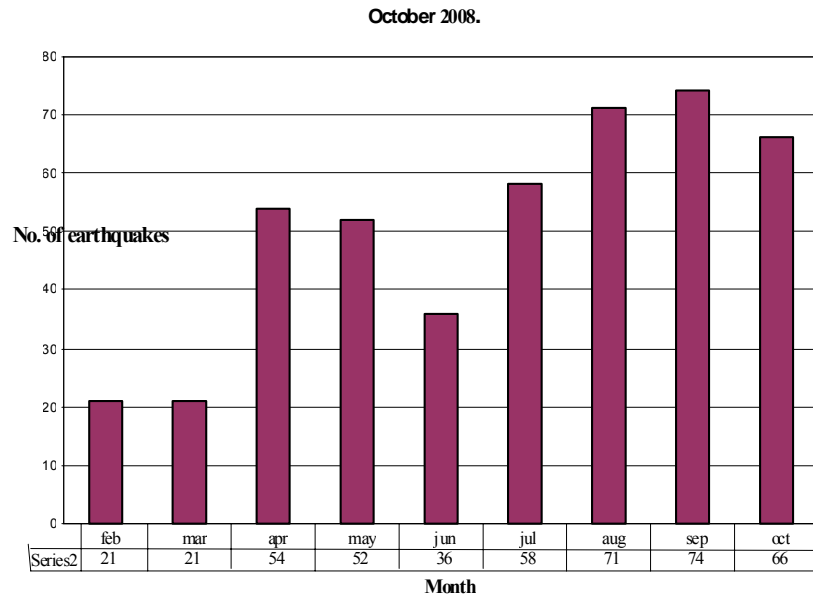


Fig. 2c : Month-wise distribution of 453 Earthquakes recorded at Maitri observatory from February to October 2008

**5.0 CONCLUSIONS**

This collocated GPS and Seismic study enabled a deeper insight into the driving mechanisms responsible for Indian plate kinematics. Islands Seychelles and Coco are converging toward Indian plate. The station Yaragadee in Australian plate is moving away from Indian plate, confirming the drifting of Indo-Australian plate, especially the western Australia and the emergence of a diffuse plate boundary between India and Australia. The GPS and the seismic results show the strain accumulation and deformation processes towards the Indian plate. The Stations Maitri, Casey, Davis show a consistent movement within the Antarctic plate. The net result of these complexities is that the plate kinematics of the region remain less well described compared to other regions, and the issue of plate kinematics is inextricably linked to the question of plate rigidity.

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