Crustal Deformation Studies Using GPS

SISME: South Indian Strain Measurement Experiment

In continuation of the South Indian Strain Measurement Experiment (SISME) reported in 1994, repeat measurements were made to look for possible deformation of a few E-W and N-S baselines using Global Postioning System (GPS) receivers, in April 1995 at Chenimalai (CHEN), Ponnarkulam (PONN), Mijar (MIJA), Krishnamakonda (KRIS) and Arasakulam (ARAS). Data was collected at each station for three days (24hrs each day) to check on the repeatability of the baseline length estimate. A baseline length repeatability of 3 to 8 *mm* was obtained (Table 3).

It is seen that the N-S IISC-CHEN and IISC-PONN baselines are extending although the Indian Plate is generally compressed in N-S direction. Interpretation of these results together with the local short wavelength geoid map and geological inferences about plate buckling are in progress. It is possible that plate buckling, a phenomenon observed in central Indian ocean, is also present in the Indian continental lithosphere. *(J. Paul, V. Kumar and V.K Gaur)*

Establishment of C-MMACS GPS station at IISc

In September 1995, a continuously operating GPS receiver was installed in the Indian Institute of Science campus in Bangalore on an unfractured gneissic rock exposure to provide a reference for GPS measurements elsewere in the country. The station consists of a fenced enclosure (20x20m) with a pillar in the centre on which the antenna is mounted, and a small bunker in the corner to house the receiver, communication and power equipment. The receiver is hooked directly to the computer in the ECE department of IISc through a pair of short haul modems. This computer is connected to the internet which facilitates C-MMACS to download the data every day at 00:00 UTC. Downloaded data is RINEXed and archived at C-MMACS on Convex hard disk with backup on floppies and data cartridge. Precise orbits and weekly coordinates of the station are also obtained from the International GPS Service (IGS) and archived at C-MMACS which in turn are made available to other scientific organisations and universities in India. *(Sridevi Jade, P.S. Swathi, R.P. Thangavelu and V. Kumar)*

GPS Measurements in Central and North India

GPS measurements were also carried out at a number of points in central and North India to study the deformation along the various

BASELINE	1870(EVEREST) (m)	1994(WGS84) (m)	1995(WGS84) (m)
IISC-DEVA	44192.7900	44192.6870	
N-S		± 0.008	
IISC-CHEN	206218.7994	206218.9336	206218.9403
N-S		± 0.003	± 0.004
IISC-PONN	535210.0910	535211.0618	535211.0716
N-S		± 0.004	± 0.004
IISC-ARAS	530259.8666	530260.8170	530260.8175
N-S		± 0.001	
IISC-MIJA	285776.3630	285776.0022	285775.9987
E-W		± 0.003	± 0.008
IISC-KRIS	102727.7954	102727.5850	102727.5855
E-W		± 0.005	± 0.006

Table 3: Comparision (1870-1994-1995) of few baselines in the Southern Indian Peninsula suggests extension of the N-S baselines (save IISC-DEVA) and compression of E-W baselines

tectonic boundaries that partition the Indian plate interior. A base station was established in JNU campus, New Delhi, to monitor it simultaneously with C-MMACS station at IISc and the stations at various parts of central and north India. The coordinates of this point were determined in the International Terestrial Reference Frame (ITRF) to use as refernce for GPS measurements in north and central India.

In May 1995, GPS control points were also established in Bhopal and Sonegaon (Wardha) to determine strain accumulation along the Narmada-Son lineament. GPS measurements were also carried out at one GTS (Great Trigonometrical Survey) point in Shillong.

In October 1995, measurements were carried out at five GTS points in North Bihar to study the post rupture strain field in some potentially revealing areas notably the miezoseismal region of the 1934 Bihar earthquake, a small part of which was again ruptured locally in 1988. These GTS points are Dipai, Masaha (both Motihari), Bulakipur (Sitamarhi), Beria-Bishanpur (Madhubani), and Diwanganj. However, since all these stations have been reconstructed by the Survey of India, comparison of GTS-GPS coordinates could not be made but repeat measurements in the future should shed useful light.

At all these stations GPS measurements were carried out for three days continuously for 24 hours using TRIMBLE 4000 receivers. The data thus collected has been processed using precise orbits and Bernese3.4 software. Data was processed with reference to NAGA (Nagarkot, Nepal) as well as IISC. Baselines thus obtained are given in Table 4. These baselines would be monitored regularly to check for the rate and style of deformation in this region. *(G.K. Sharma, V. Kumar, J. Paul and V.K. Gaur)*

Strain Measurements in Bidar District

Development of ground cracks in some parts of the Homnabad taluk of Bidar district in Karnataka and the evolution of subterranean sound in Basavakalyan taluk during July/August 1994 have caused considerable concern amongst the inhibitants of the area and the district and state administration.

BASELINE	Length in m	Repeatability		
		North	East	Vertical
NAGA-DIPA	112576.6436±0.0008	1.5	1.5	2.8
NAGA-MASA	125153.7325±0.0002	0.6	1.8	16.1
NAGA-BULA	112271.3985±0.0079	8.6	7.9	7.1
NAGA-BERI	158020.5658±0.0064	5.8	4.3	3.0
NAGA-DEWA	208115.0088±0.0009	0.7	0.8	4.3
IISC-NAGA	1816850.2896±0.0077	9.1	11.6	38.3
IISC-BERI	1723939.6463±0.0054	6.2	7.0	23.7
IISC-DEWA	1757052.4676±0.0041	1.1	11.1	18.7
IISC-BULA	1715944.6412±0.0029	6.7	0.3	19.9
IISC-ALUR	293850.0965±0.0085	2.1	19.5	16.1
IISC-BHOP	1134736.6211±0.0054	5.3	7.9	8.5
BHOP-SONE	324664.9948±0.0037	5.6	3.1	0.8
JNUC-IISC	1714071.3765±0.0065	6.5	6.6	6.6
JNUC-BHOP	582918.5415±0.0018	1.6	4.7	13.1
IISC-SLNG	2030641.8644±0.0107	0.7	13.9	8.5

Table 4: Repeatablity of baselines measured in central and North India

Since no plausible explanation could be found except their logical connection with ground deformation, it was considered desirable to experimentally determine the evolving nature of ground deformation and strain in the region. An experiment was accordingly designed to measure baseline lengths between points shown in Fig. 6, at periodical intervals using high precision GPS receivers.

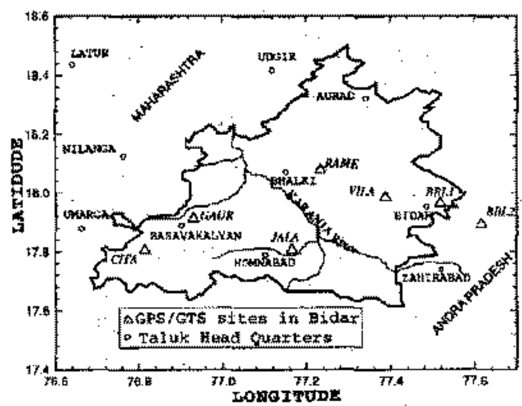

Fig. 6: Locations of GPS sites in Bidar district

A Trimble 4000SSE receiver was used for making these measurements which C-MMACS had obtained on loan from Colorado University/UNAVCO. For both epochs of measurements, the IISC station was treated as the fixed reference station whose precise coordinates were obtained from IGS using ftp facility. Bernese GPS software was used for the data processing and analysis.

The first set of measurements was made during Dec-Jan 1994/95 at about seven control stations covering Bidar, Bhalki, Basavakalyan and Homnabad taluks of the Bidar district. Repeat measurements were made during Dec-Jan 1995/96 but only at four out of the seven stations owing to limited availability of GPS receivers (Fig. 6). The results of these measurements are presented in Table 5.
(V. Kumar and V.K. Gaur)

Baselines	1994-95 length (m)	Repeatability (mm)	1995-96 length (m)	Repeatability (mm)	Change in length mm
IISC-RAME	560631.4181	1.3	560631.4115	3.1	-6.6
IISC-CITA	535400.7647	3.8	535400.7341	6.5	-16.4
IISC-VILA	549560.0140	0.8	549560.0068	0.3	-7.2
IISC-JALA	531072.2844	0.8	531072.2801	7.4	-4.3
IISC-BBL2	539050.6644	8.1	-	-	-
IISC-BBL1	546886.0580	4.8	-	-	-
IISC-GAUR	545531.4179	8.1	-	-	-

Table 5: Comparison of 1994-95 and 1995-96 GPS measurements in Bidar

Slider Block Models in Earthquake Studies

Slider block models for the generation of earthquake sequences show chaos. These were quantitatively studied earlier with a view to compare them with the sequence of empirical earthquakes. The notion of compounding of chaotic systems was also introduced earlier, in a general context. It was, therefore, natural to consider the effect of compounding the slider block model by coupling it with some other physical process which has been neglected in the simple slider block models. Compounding consists of making some parameter of the compoundee system vary in accordance with some variable in the compounder system. Convection in the mantle is modelled as the thermal-buoyancy induced motions of a fluid confined in a base-heated box of large aspect ratio. This is, in effect, Rayleigh-Benard convection. In the hard turbulent regime convection is chaotic for high Rayleigh and Prandtl numbers. The driver in the simple slider-block model moves with a small constant velocity. In the compound slider-block model studied, this velocity is related to the chaotic mantle convection.

It has been observed that the compound slider block models can represent a wider variety of earthquake sequences. For example, the compound slider block models with just two blocks can exhibit quiscence or event-swarms, which do not occur in simple models. The foreshock- main- shock- aftershock incident ratios are more realistic in the compound slider block models. However, it was found that many different parameter sets of the compound slider block model can give reasonable fit with the catalog data in terms of the fractal dimensions. That is, nonuniqueness of fit is not removed by compounding. Further, this fit in terms of the matching of the spectral correlation dimensions does not imply simultaneously good fit of the spectra or the point processes themselves. The study constitutes a use of fractal measures for quantitative characterization and the adequacy of the slider block models. *(R. Singh*, V.M. Maru* and P.S. Moharir*, * NGRI, Hyderabad)*