MODELLING FOR HAZARD QUANTIFICATION

South Indian Strain Measuring Experiment (SISME)

The application of Global Positioning System (GPS) measurements to precise surveys in seismogenic regions provides opportunities for studying geodynamic processes and for monitoring the development and release of strain associated with earthquakes. These processes demand measurement accuracies that are typically unobtainable in conventional mapping and control networks, although decimeter control accuracies are of value for monitoring tectonic processes, if they were undertaken sufficiently long ago, or if a substantial earthquake occurs near the network. The nineteenth century Great Trignometrical Survey of India (GTS) provides potentially an invaluable record of deformation in India in the past 100-150 years. Yet the current disposition of few of its original control points have been measured using GPS methods. As a test of the utility of the GTS network in applications related to seismic hazards, an experiment was designed to determine the current positions of several points of two of the earliest triangulation chains in India. The Madras-Mangalore-Cape Comorin measurements were first undertaken in 1805-8, and were repeated with superior instruments in 1864-74. In March 1994, the South Indian Strain Measuring Experiment (SISME) measured 18 trig points of the original network (Fig.10) of the Southern Trigon of the GTS. Six Trimble 4000 SSE GPS

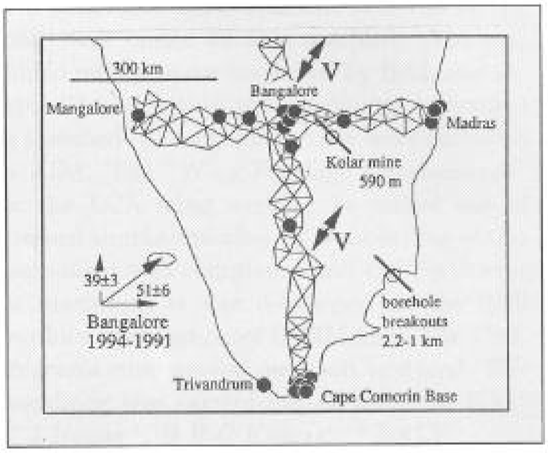

Figure 10: Original network of the Southern Trigon of the GTS

receivers were used in this experiment, which was conducted by scientists of C-MMACS, the University of Colorado at Boulder, the University NAVSTAR Consortium (UNAVCO), the Indian Institute of Science (IISc), Bangalore, the Wadia Institute of Himalayan Geology (WIHG), Dehradun and the Survey of India, Southern circle. These receivers were obtained on loan from UNAVCO, an NSF-funded US university facility, of which C-MMACS has become a member. This experiment was designed to reveal the potential accuracy of dilatational and shear strain in the original networks, and the amplitude of any changes of these values since their mid 19th century measurement. The experiment was conducted simultaneously

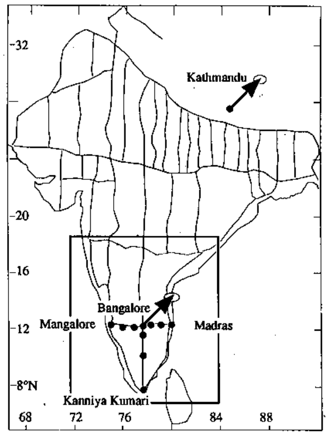

Figure 11: 6 cm/year NE displacement of India toward Tibet

with measurements near Kathmandu, Nepal, that had been first undertaken in 1991 by Chris Reigber. The SISME data were downloaded onto PC's, archived on floppy discs, converted to RINEX format, and processed on Sun computer at C-MMACS using BERNESE 3.5 software. The Bangalore fixed station data were corrected for cycle slips, time-varying solar radiation pressure and phase ambiguities.The day-to-day repeatabilities for several hundred kilometer long baselines in peninsular India are 5-7 mm. Three distinct data products were obtained from the 1994 SISME survey: translation and rotation information for India between 1991 and 1994, deformation rate estimates between Bangalore and Kathmandu for 1991-1994, and deformation rate estimates for peninsular India for the period 1864-1994.

In summary, an important finding is the 6 cm/year NE displacement of India toward Tibet, consistent with inferred plate motions, less than 0.003 microstrain/year deformation between Bangalore and Kathmandu consistent with assumed plate rigidity and insignificant strain in southern India (Fig. 11). Remeasurements of two 19th century GTS baselines reveal that these have not changed in length substantially since 1869. The mean shear strain rate of southern peninsula is 0.01 microstrain/year since 1869. The southernmost Peninsular India appears not to have significantly deformed either in dilatation or in shear strain since 1869, providing a lower limit for the renewal time for earthquakes in southern India of approximately 10,000 years.

The GPS station of Bangalore was monitored during July 1994 to March 1995 continously 24 hrs/day and the intercontinental baselines between Bangalore and global International Geodetic Service (IGS) stations in Australia, Taiwan and South Africa have been established. A few new points were measured in Bihar, Bidar, Andaman and Nicobar islands during Oct.94-Feb.95. The 18 trig point in Southern India were reoccupied in March 95 to determine the strain rate over the 12 month period (1994-95). The GPS data collected at these stations are currently being processed in C-MMACS to determine the strain rate in the Indian subcontinent in the last year. *(V K Gaur, J Paul, S Jade, Shankar Doraiswamy †, P S Swathi, V Kumar, R P Thangavelu, M B Ananda, R Bilham*, D Mencin*, R Burgmann* and B Namboodri**, * Univ of Colorado, USA; ** Survey of India, Bangalore, †presently at NIO, Goa)*

Modelling and Early Warning of Tropical Cyclones

The discovery of a preferred scale of incipient disturbance for intensification of tropical cyclones in the Bay of Bengal region was reported earlier (CM 26, C-MMACS Annual Report 1993-94). In particular, it was shown that given a number of incipient systems of varying size (radius) embedded in the same large scale environment, it is the vortex with radius about 250 km that generally intensifies to the most severe system. In the first phase of this study, this result was established for the Bay of Bengal region by using 20-year mean climatological data for the Calcutta station for the months of May and November. Such a finding opens up possibilities of significantly aiding early warning and monitoring of tropical cyclones through satellite identification of potential cyclones. It has been shown subsequently that the phenomenon of scale-selective intensification occurs in other conditions also. Using a composite study with the monthly mean station data for three stations in the Bay of Bengal region, namely, Calcutta, Madras and Visakhpattanam for seven months May-October, it was shown that the scale-selective intensification is a robust effect. However in this case, which includes results for 21 different mean thermodynamical states, the maximum intensification is not always at incipient vortex radius $r_0 = 250$ km but sometimes also occurs at $r_0 = 150$ km or $r_0 = 200$ km. This introduces a slight flattening of the intensification (maximum sustained low level tangential wind verses r_0 curve, shown in Fig.12. To further show the prevalence of the scale-selective intensification, annual mean station data for West Indies and zonal monthly mean data for 15 latitudes from Oort were used to investigate intensification and was found to give similar results.

To make the results obtained from this series of study to be operationally useful, an extensive diagnostic study of the model fields was carried out to identify observable parameters that showed good and consistent correspondence with intensification. It was found that intensifying systems are characterised by high

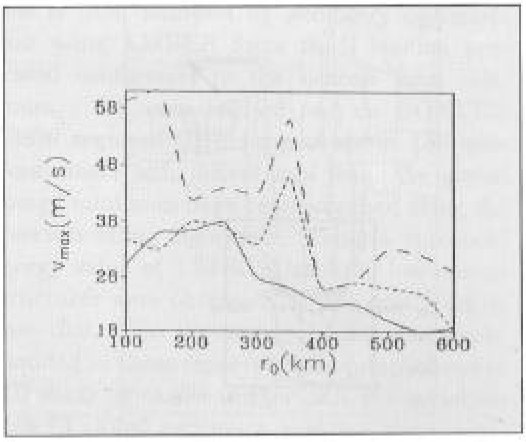

Figure 12: Maximum tangential velocity ($V_{\max}$) attained for Bay of Bengal (solid line), West Indies (small dash line) and for zonally averaged monthly mean data at 25° N latitude (large dash line) for incipient vortices of different sizes (r_0).

radial organisation (measured by autocorrelation as a function of radial lag) of the initial (3 hour) low-level convergence. Since tropical cyclones derive their energy from the release of latent heat from convective towers, an analysis of the organisation and evolution of the cloud fields was carried out for different values of r_0. It was also found that intensifying systems are characterised by high cumulative (upto 9 hours) total cloud activity averaged over 300 km radial distance. Thus satellite observation and estimate of central cloud activity in developing systems may be used to determine spatial organisation of the initial central cloud field. This in turn can help to identify potential cyclones at an early stage. *(P Goswami and R K Rao)*