Swami Ramanand Teerth Marathwada University

Seismic Observatory

at

School of Earth Sciences

Seismic Observatory

Initiation

The Founding Vice-Chancellor initiated the establishment of a Seismic Observatory in the School of Earth Sciences in the aftermath of the Killari earthquake (M ~ 6.3) of 1993. The Seismic Observatory is one of its kind in the State Universities of Maharashtra State. The Killari earthquake has changed the perception of Earth scientists about the Deccan province and a new branch of seismology stable continent earthquakes has evolved. The University had built an Observatory building at Killari and Nanded. The Killari observatory is operated in collaboration with CSIR-NGRI, Hyderabad with VSAT connectivity whereas the Nanded Observatory is operated by the University and linked to the LAN network enabling operation and data acquisition globally. The Seismic Observatory has been established to understand the seismicity of the region and to decipher the seismic structure of the region. Though the region does not show any historical seismicity, the recent micro seismic activity in the region has generated interest scientifically and also for general public.

The broad band Seismological data is being recorded continuously in a digital recorder. The data is being continuously analysed for understanding the seismicity of the region. The data of local earthquakes recorded on the network of stations are used to locate the epicentres and magnitudes. The data is being reported to the local District administration as and when the earthquake occurs, which will be forming the base of disaster management in mitigation in the event of a disaster.

The continuous data monitoring and analysis has resulted in understanding the seismic activity of the region and also has resulted in one major project (State Government fund) and a minor project (University funds). The output generated through the seismic data analysis along with other geological, geophysical and structural investigations has resulted in hazard assessment of Nanded city and regions in and around. Hazard reports have been submitted to the Nanded District Collector Office, ZP office and Hingoli Collector Office for planning for hazard mitigation. The data generated from the Seismic Observatory has also resulted in scientific publications.

Scientific and Societal work carried out

The research findings are based on the broad band digital seismic Data acquired from multiple stations with a sample rate of 100 samples. The data has been continuously recorded on a Flash card and these flash cards were replaced regularly as and when they get filled. On an average per day 40 MB of data gets recorded; it also depends on the inherent cultural noise at a site. The data downloaded were further converted to SEISAN format for processing. The events were identified by browsing the data set for each station during the entire operation period. Depending on the magnitude, distance of the epicentre and the inherent noise at site the events get recorded either clearly or feebly. These events are segregated and merged with data from all the stations and then used for picking P and S arrival and marking the amplitude and coda for magnitude calculations.

Using the three component broadband seismic data, the azimuth of the event recorded is measured using the ratio of amplitudes on the vertical and the horizontal components and the azimuthal angle is used to place the direction of the event from the recording station. Then the S and P arrival times are measured at the recording station, using the S-P arrival time the approximate distance is calculated using the following formula.

$$T_S - T_P = \frac{D}{V_P}\left[\frac{1}{V_S} - \frac{1}{V_P}\right] \text{-------(1)}$$

We used the Hypocenter algorithm to fix the location parameters. This program calculates the theoretical arrival time values for different stations based on an initial location and using the local velocity model. The program then calculates the best possible location with minimum rms error and this solution is taken as the final solution. If there is any inconsistency in the analysis one can always change the arrival time marks on the seismogram using SEISAN. All the analysis is being carried out using free domain software called SEISAN. The coda magnitudes are calculated using the following formula.

$M_c = 2\log_{10}L + 0.00365$ (□□□□□□□□□

Where L is the coda length of the earthquake and □ is the epicentral distance computed from the S and P arrivals of the event.

The Peninsular India is characterised by low to moderate seismic activity (magnitude less than 3) which has been episodic in nature except for the Koyna-Warna region of Maharashtra. Moderate seismicity in the past has occurred along well known geological

faults like Kinnerasani-Godavari, Gundlakamma etc (Srinagesh et. al. 2012). The other notable source region in the vicinity of the study region is the Killari earthquake of 1993 which had a magnitude of 6.3. The present study assumes importance in the wake of its spatial proximity to a Major earthquake source region Killari. Nanded district is experiencing seismicity and/or subterranean sounds since 1993, 1995, 2006 and the activity occurred is observed (recorded) since 2007-08 and later it reoccurred during last week of October 2010. The digital seismic data is being acquired continuously since 2007-08 from the seismic stations positioned in the SRTM University campus and other temporary network of stations that were setup in collaboration with NGRI, Hyderabad in 2007-08. However the 2010 seismic activity during the project period is being monitored and recorded by a local network managed by SRTM University. The seismic stations SRTM, SCN, MGM, TRDA, and GSDA are owned by SRTM University, Science College, Nanded. MGM college of Engg, Nanded and GSDA by Nanded Waghala Municipal Commission, Nanded. SRTMU operates its two stations, one located at SRTM campus and the other one is placed at Taroda (TRDA) (now being place at Yeshwant College, Nanded). The digital seismic data from the local network is collected and then processed.

The data acquisition from the Broad band seismic stations is being continuously being done from stations sited at SRTM, TRDA (SRTM's Station at Taroda), GSDA (NWMC station at Workshop) and SCNG (Science College's station at Science College). The complete data set from Oct 2010 to Dec 2011 has revealed that around 350 events have been recorded at Nanded with a maximum magnitude of 3.17 recorded on 2nd March 2011. The events have been short listed and being analysed for its hypocentral locations. The recording of data will be continuously done even after the project period. A list of 325 events is located for hypocentral parameters with the Origin time of the event. The hypocentral locations estimated for 2010-11 displays that focus of the events have migrated upwards.

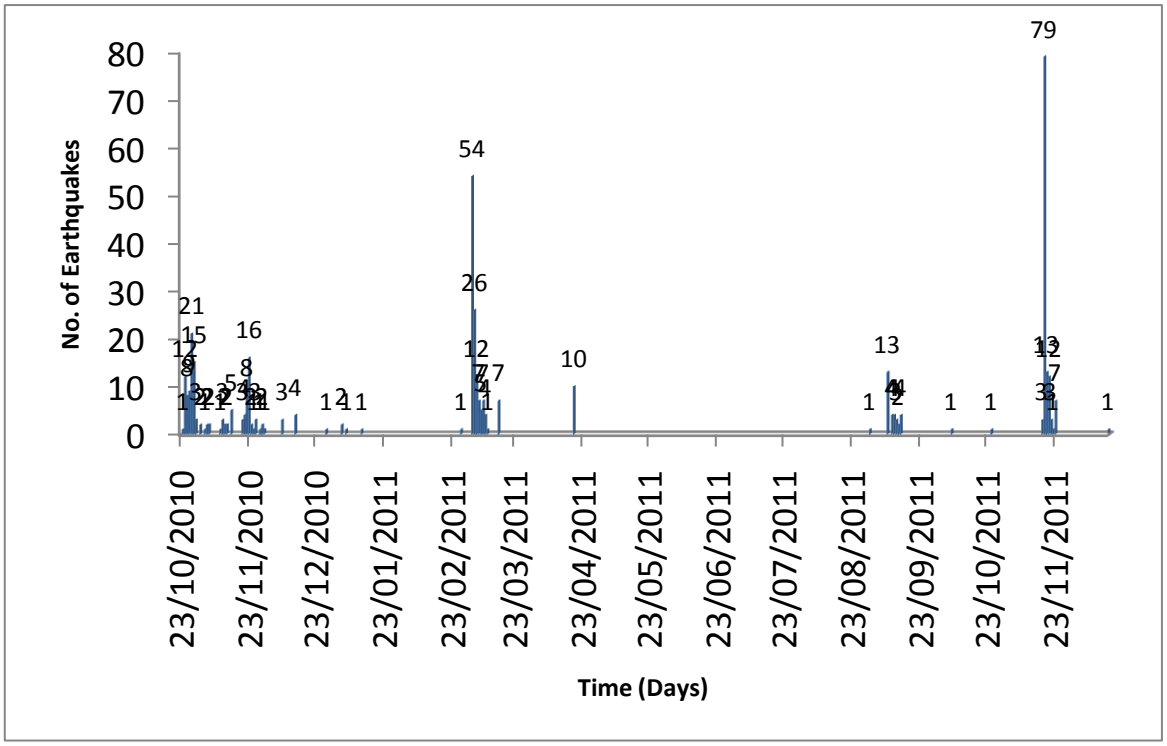
Two Accelerometers purchased from the project have been checked and found working, one of the Accelerometers has been installed at Science College Observatory, Nanded. The other accelerometer has been installed at SRTM University Campus observatory and is working well. The Accelerometer at SRTM is operation with 200 samples in continuous recording mode. The Accelerometer sited at Science College, Nanded is operational at 200 samples in a trigger mode.

Research Findings

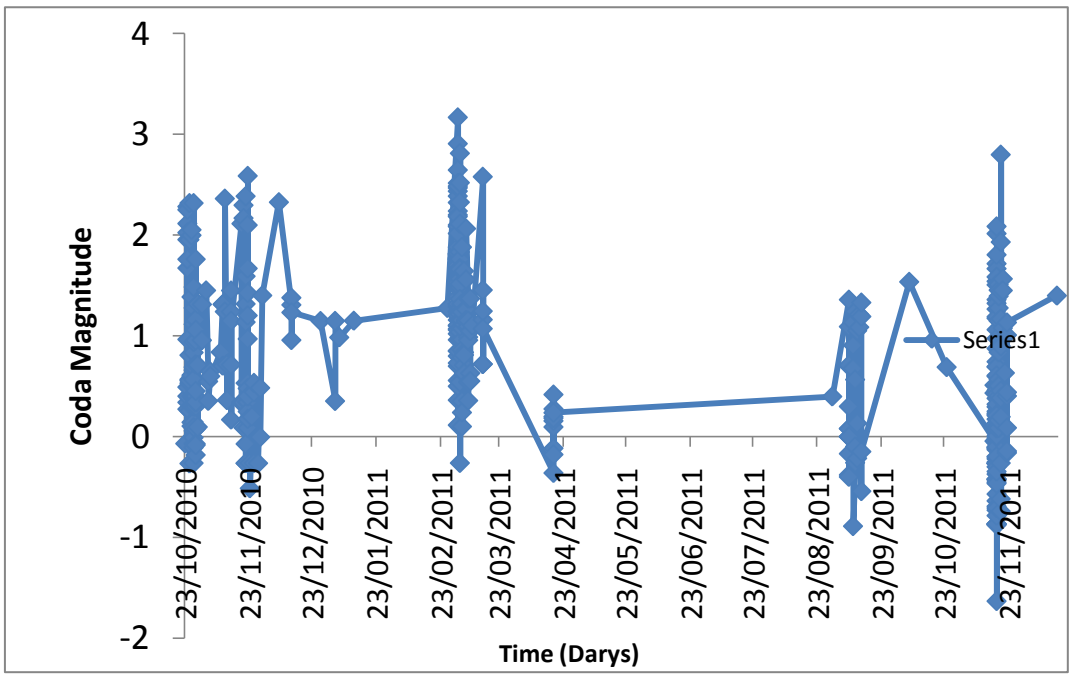
A total of 425 odd events were shortlisted of which many have been discarded as local blasts and noise based on the consistency of its recording at other stations and its characteristics. For final analysis a list of 324 events were analysed for magnitude and epicentral locations. The accuracy of the locations are determined by the azimuthal gap of the event, which depends on how many stations recorded the event and how well the event is azimuthally covered by stations. Those events which had an azimuthal gap of > 180 were not considered for final analysis as the hypocenter locations are not well constrained in this case. A total of 131 events were shortlisted as well constrained events for its locations based on its azimuthal gap and also after analysing the error in location parameters. The rms errors for these events are less than 0.08s. The temporal variation of occurrence and magnitudes of earthquakes are plotted and they bring out two observations; 1. The events occur as clusters and with a gap of few days (events are less) and again a cluster is observed. 2. Magnitudes plots also show that maximum magnitude so far recorded in 2010 is 3.1. Based on the figures plotted from the analysed data the following conclusions are drawn. The event depths vary from near 0.0 to 2.0 km with reasonably good resolution. The stable continental region earthquakes have been observed to occur in region of fault intersections, buried plutons and rift pillows. The present studies indicate the presence of fault in the region, however detailed geophysical studies would further help us in understanding the deeper subsurface structure of crust.

Seismic Observatory in the School of Earth Sciences

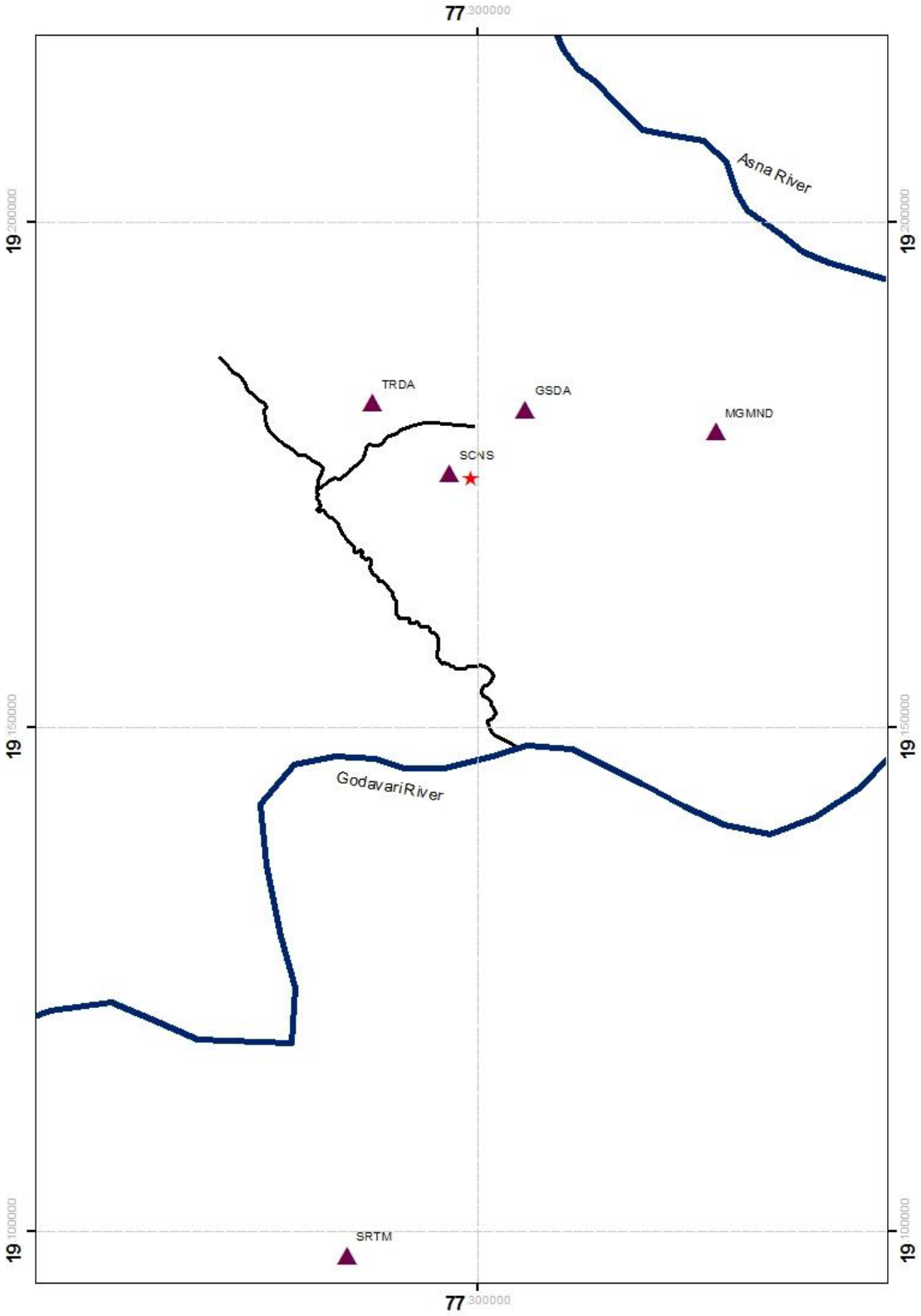
Accelerometer for Basaltic Terrain



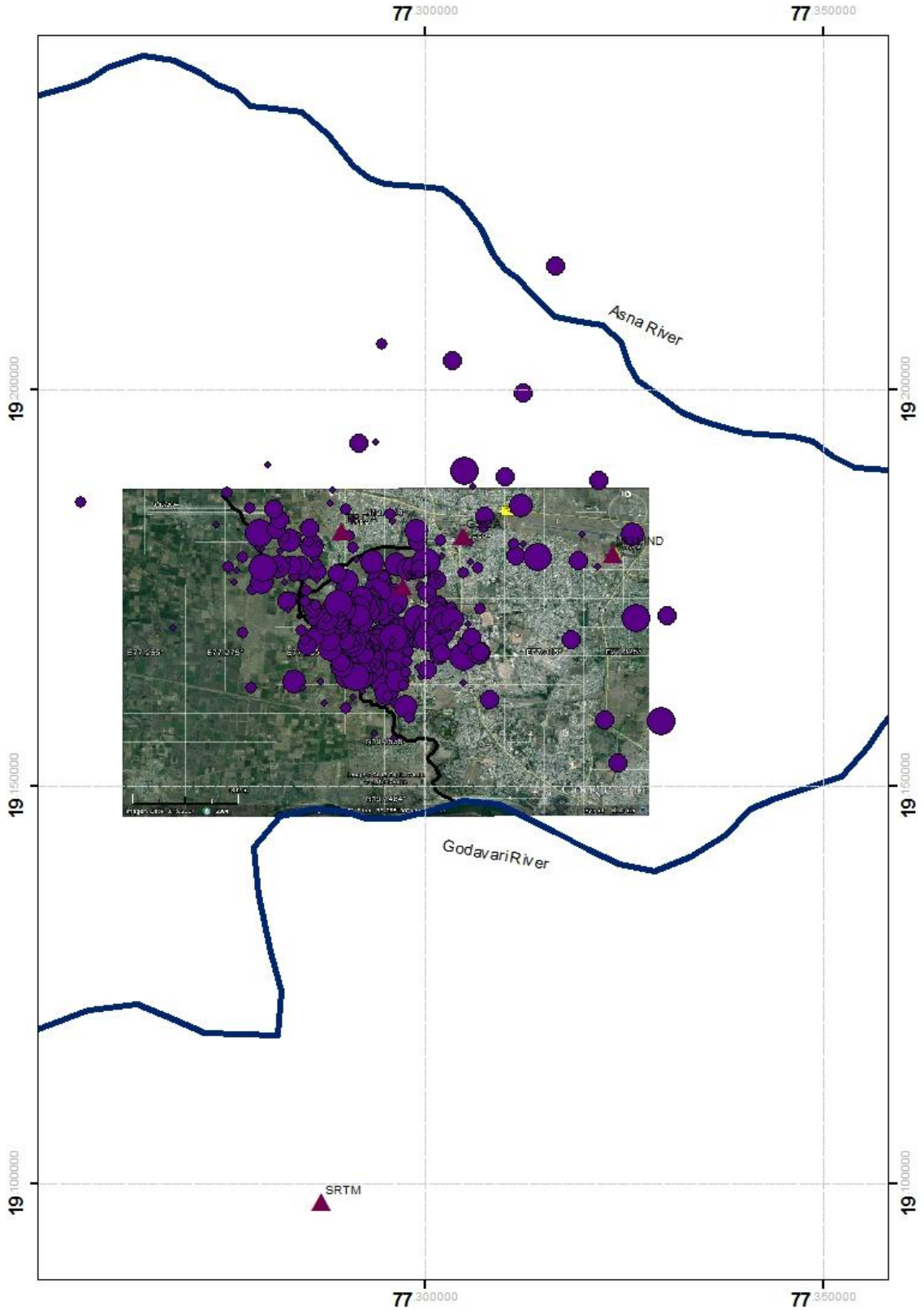
Temporal variation of occurrence of local Earthquakes



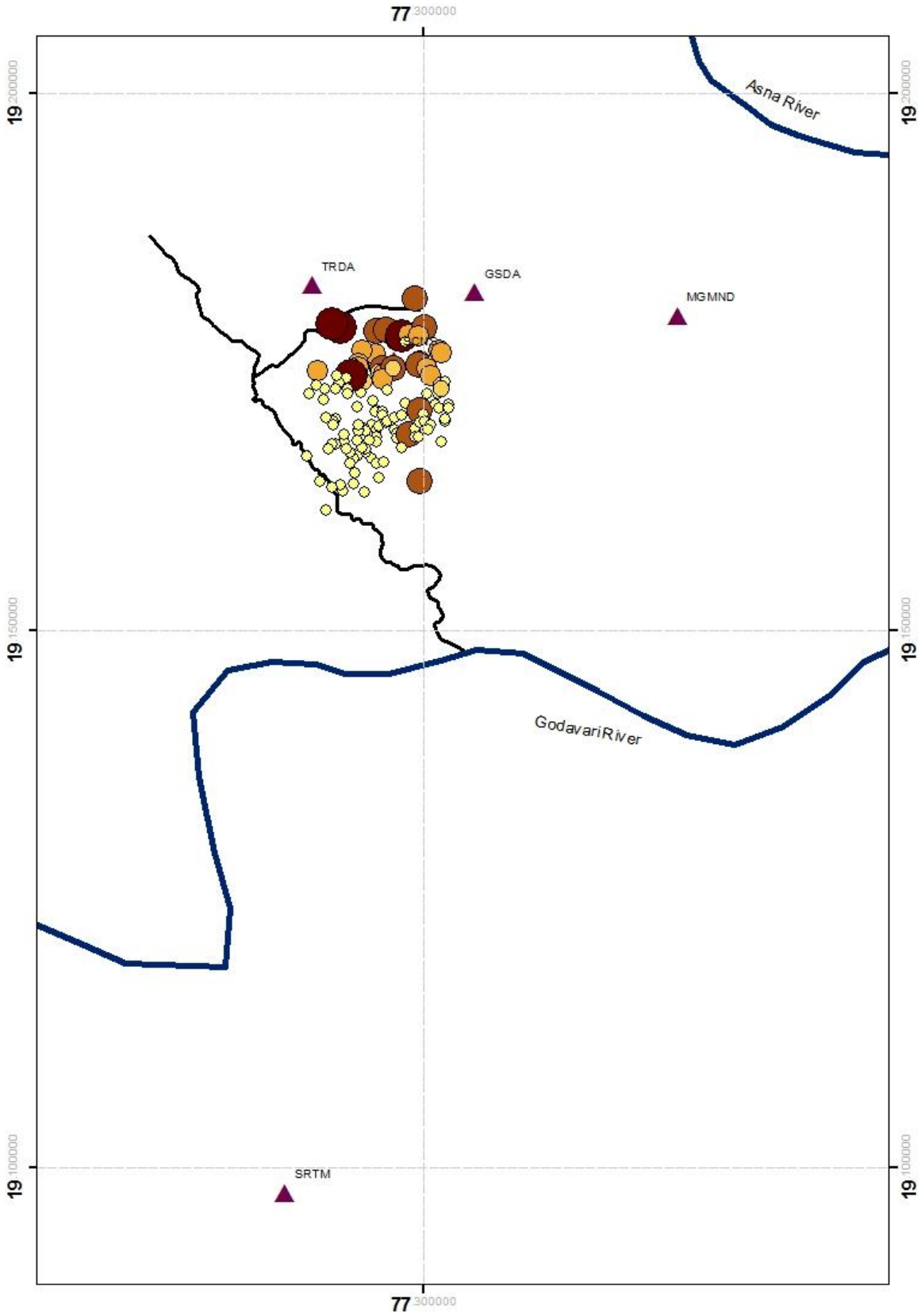
Temporal variation of Magnitude of local Earthquakes



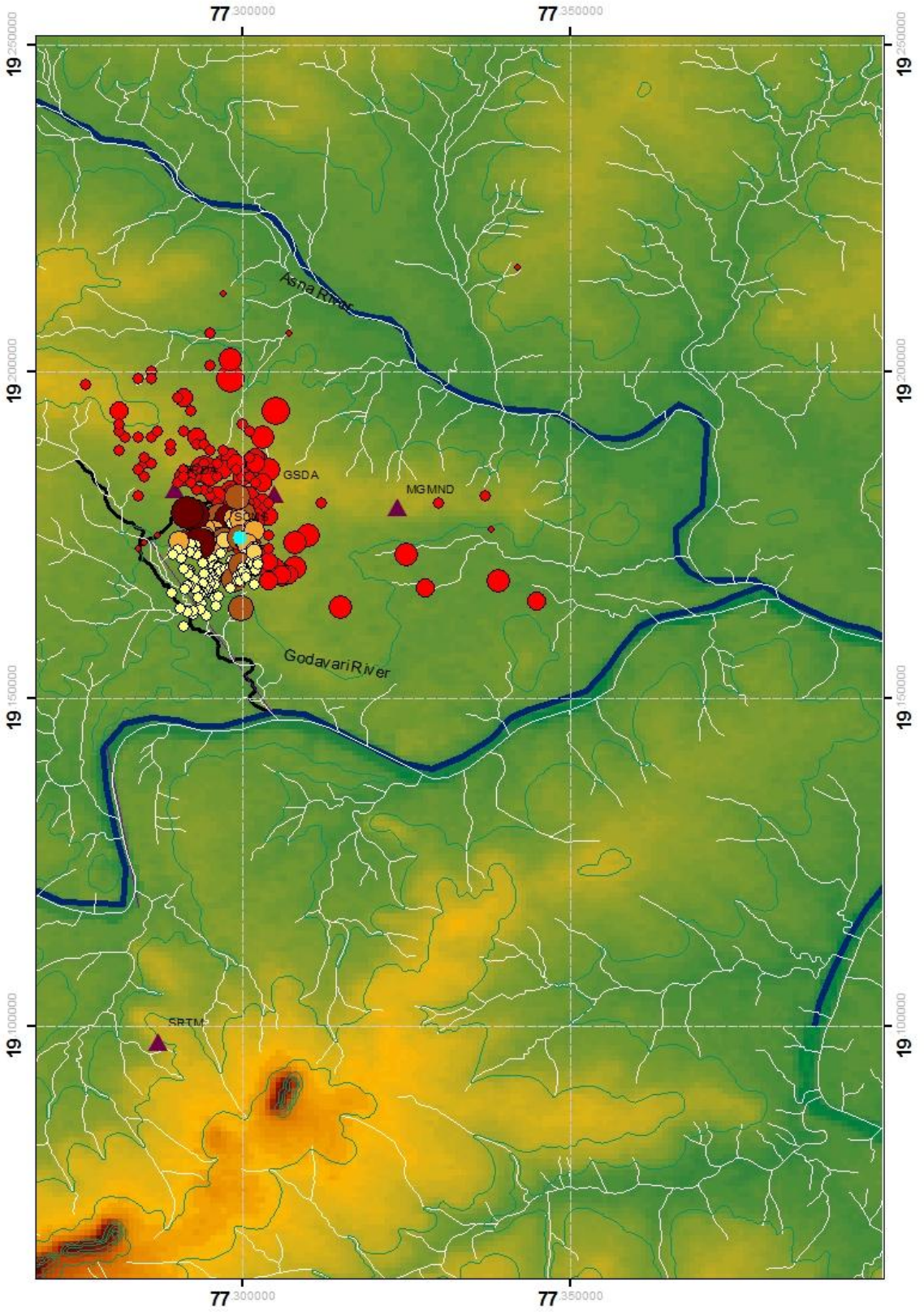
The epicentral location largest magnitude event so far in the Nanded City (Mc-3.17), the site is nearer to the cluster of events of 2007-08 and also in the region where the residents of Nanded feel the smallest of small tremors.



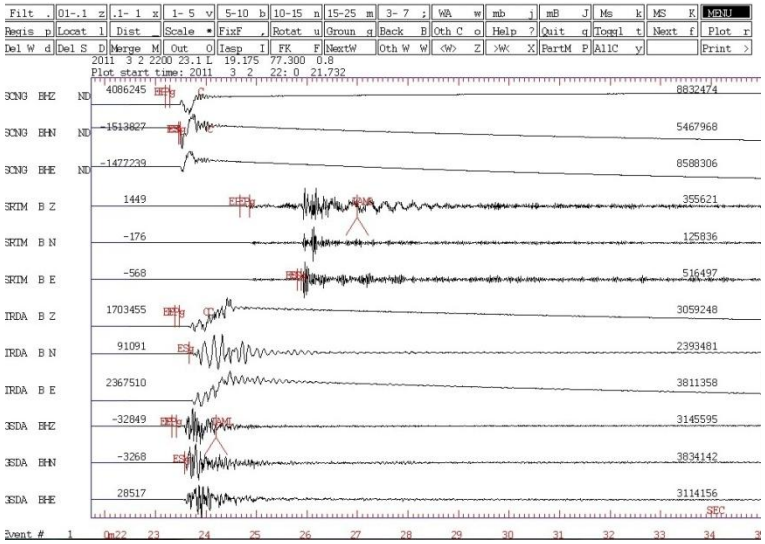
Total Seismicity plot of Nanded during 2010-2011 size of the symbols are proportional to the magnitude of the event. Maximum magnitude being 3.1.



Epicentral Locations of resolved events with azimuthal gap less than 180° of 2010-2011.

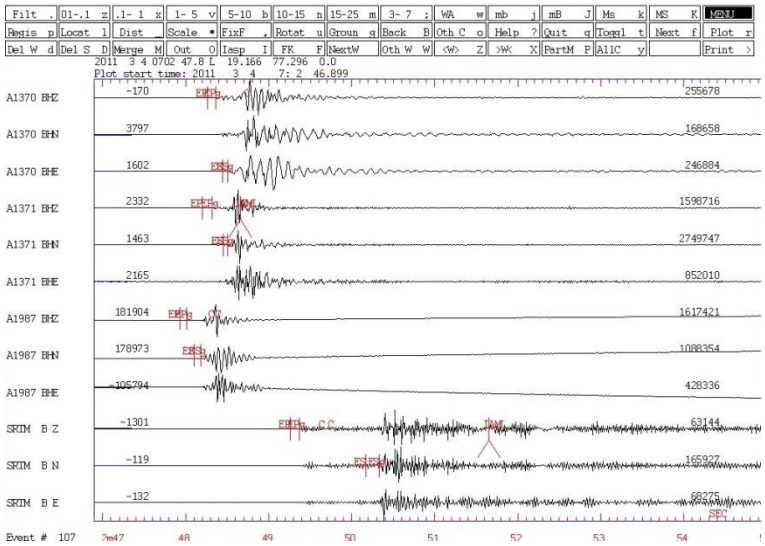


The plot shows the seismicity pattern of events during 2007-08 in red and resolved events of 2010-11 in shades of brown size proportional to the depth of earthquake. The maximum magnitude event has been marked as a bright spot in aquamarine plotted with DEM and drainage.



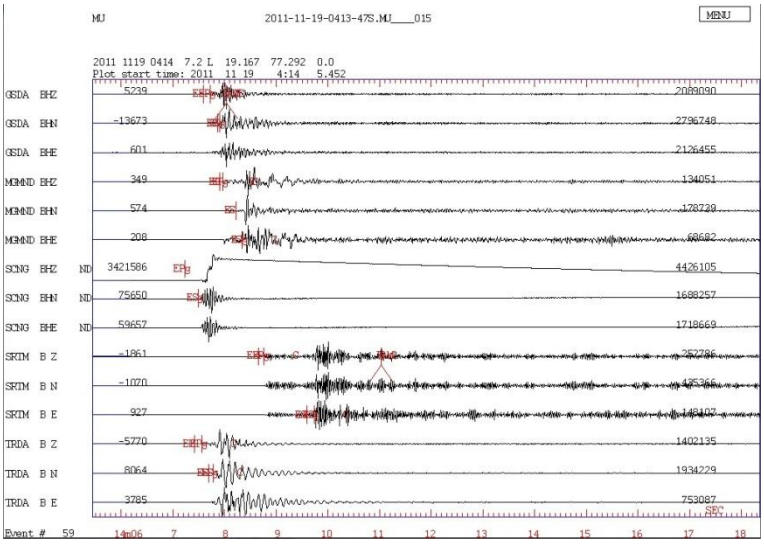
An event from 3rd March 2011 occurred with a magnitude of 3.1

With arrival phases marked



An event from 4th March 2011 occurred with a magnitude of 2.1

with arrival phases marked



An event from 19th Nov. 2011 occurred with a magnitude of 2.2

with arrival phases marked

Seismicity Characteristics deduced from the data

1. Seismicity has occurred after heavy rainfall, above the average rainfall of 1000mm during 2006-07 and 2010-11.
2. Events occur as small clusters temporally usually during October to May usually post rainfall.
3. Deeper focal depth earthquakes are away from the seismic fault suggesting a dipping fault with a dip angle of ~ 60° (Srinagesh et. al. 2012).
4. Seismicity of 2010-2011 shows a migration of events from deeper focus to more events of shallow focus when compared to 2006-07. Suggesting that the same fault is causative for the seismicity in both the seasons.
5. The seismically active region is around 2.5 Km along the geomorphic drainage pattern from Wadi Bk in Northwest to Godavari River which displays a linear path indicating that it is following a lineament. The seismic activity is restricted to 2km in depth from the surface for the season 2010-11.
6. The total energy release of the seismically active fault has not exceeded a 4 magnitude earthquake cumulative of the energy release of all the small shocks put together.
7. The seismic data will form the basis for preparing a disaster management plan at district level.

We would like to make the observatory of international standard data quality wise and are also working on the modalities to make the data a part of National repository to make the data available throughout the country. We are already in collaboration with National Geophysical Research Institute, Hyderabad, IIIT, Hyderabad, Ground water Survey and Development Agency, Govt. of Maharashtra, Science College, Nanded. We are operating a network of stations in Nanded. We are also extending scientific support in operating a seismic station of Nanded Waghala Municipal Corporation, Nanded.

Publications

1. D. Srinagesh, T. V. N. Srinivas, P. Solomon Raju, Suresh G., Y.V.V.B.S.N. Murthy, Satish Saha, A.N.S. Sharma and **T. Vijay Kumar,** (2012) Causative fault of Swarm activity in Nanded City of Maharashtra, ***Curr Sci*., V 103**, pp 366-369 **. (Impact Factor: 0.935)**

2. Kaplay, R.D., **Vijay Kumar T** and Ravi Sawant, (2013) Field evidence for deformation in Deccan Traps in microsesimically active Nanded area, Maharashtra, ***Curr. Sci***. **V 105**, pp 1051-1052. **(Impact Factor: 0.935)**

3. Kaplay, R.D., **Vijay Kumar T,** Patode, H.S., Wesanekar, P.R. and Shelke Nitin, (2014) Physical Evidences of Past Earthquake Activities and sustainable development of houses in Micro-seismically Active Nanded City of Maharashtra State, India. 3rd Annual international conference on Sustainable Energy and Environmental sciences, Singapore (SEES 2014 Proceedings). ISSN: 2251-189X

4. Wesanekar, P.R., **Vijay Kumar, T**., Sangnoor, H.M., Potdar, S.S.,(2012). Impact of swarm activity on groundwater of Nanded city, Maharashtra, India. *Proceedings Fifth International Groundwater Conference (IGWC-2012), Aurangabad, pg103-104*

5. Kaplay, R.D., **Vijay Kumar T** and Ravi Sawant, (2013) Field evidence for deformation in Deccan Traps in microsesimically active Nanded area, Maharashtra, ***Curr. Sci***. **V 105**, pp 1051-1052. **(Impact Factor: 0.935)**

6. R. D. Kaplay, Md. Babar, Soumyajit Mukherjee & **T. Vijay Kumar**, (2017) Morphotectonic expression of geological structures in the eastern part of the South East Deccan Volcanic Province (around Nanded, Maharashtra, India), Journal Geological society of London, doi.10.1144/SP445.12, pp 317-335 **.(Impact factor = 2.808)**

7. R.D. Kaplay, **T. Vijay Kumar**, Soumyajit Mukherjee, P.R. Wesanekar, Md. Babar and Sumeet Chavan, (2017) E-W strike slip shearing of Kinwat Granitoid at South East Deccan Volcanic Province, Kinwat, Maharashtra, India, Indian Journal of Earth Sciences Published by Indian academy of sciences**.(Impact factor = 0.808)**

Reports

1. Report On Preliminary Geoscientific Studies On Rumbling Sound/Fountain Activity In A Bore Well At Borgaon (Nadri), Tq. Mudkhed, Dt. Nanded, Maharashtra. By Dr. S.K.G Krishnamcharyulu, Dr. D.B. Panaskar, Shri T. Vijay Kumar in July 2008 to District Collectors office.

2. Preliminary report on Seismic Activity at Nanded City, Maharashtra region, by Srinagesh D, Bhasker YVBSN, Thandan babu Naik R, Solomon Raju P, Sarma ANS, Vijay Kumar T and Yedekar submitted to Municipal Corporation in July 2008.

3. Nanded Microzonation studies submitted to District Collector's Office as a part of multi-institutional consultancy project sanctioned by Government of Maharashtra. T. Vijay Kumar, D.B. Panaskar, R.D. Kaplay, S.K.G. Krishnamacharyulu, K. Vijay Kumar, H.S. Patode

Projects

1. Monitoring of Seismicity pattern and magnitudes around Nanded City, Maharashtra a minor project sanctioned by S.R.T.M. University with an outlay of 1 lakh rupees 2009-2012. PI: Dr. T.Vijay Kumar, School of Earth sciences, SRTMU)

2. Groundwater studies for earthquake forecasting in Nanded region funded by UGC with an outlay of Rs. 6.83 lakhs (PI Dr. Wesnekar P. R, Associate Professor, Science College Nanded, Co PI: Dr. T. Vijay Kumar, School of Earth sciences, SRTMU) 2011-14.

3. Nanded Microzonation multi institutional Project with an outlay of 20.7 lakhs Co-ordinator: Prof. D. B. Panaskar and Dr. T. Vijay Kumar, School of Earth sciences, SRTMU funded by Government of Maharashtra. (2011-13)