CSIR-SUMMER RESEARCH TRAINING PROGRAM(CSIR-SRTP)2020 ONLINE

Course Completion Requirement (to Obtain Training Certificate)

INSTRUCTIONS

- **Mentees should submit the following summary sheet along with the final project report.**
- **The project summary (ANNEXURE I) must be limited to 2000 words plus a maximum number of 6 figures, tables and schemes together. The total report should be within 6 pages in Times New Roman font with 12 font size and 1.5 spacing.**
- **Projects involving survey works should be submitted along with the data from the survey form, questionnaire and/or consent form as "ANNEXURE V".**
- **Feedback form must be submitted as "ANNEXURE VI" along with the final report.**
- **"Self Evaluation Sheet" (ANNEXURE VII) and "Mentor's Recommendation" (ANNEXURE VIII) must be submitted along with the final report.**

Name of the mentee	Name of the mentor	Project no. and summary of the project	Summary of selected five Eminent Scientist Lecture	Lectures attended	SRTP videos watched by the Mentee
Aditya Sengupta	Dr. Debasis D. Mohanty	(Annexure I)	(Annexure II)	(Annexure III)	(Annexure IV)

ANNEXURE I

Project summary

Annexure 1 - Project Summary for Project-1 Group-9 Frequency Magnitude Relations and Hazard Estimation

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17/08/2020

Abstract

This project seeks to explore b-value estimation and study of the spatio-temporal variations of the b-value of the Gutenberg-Richter Law for the Andaman Region for all earthquakes, 1980 onwards. The main objective of the project is to determine the Hazard estimation of the region using the spatial and temporal variations of the b-value in the region, and the seismic history as well as the geo-tectonics of the region and to determine the most hazardous zones or areas in the Andaman Region. The study has been carried out using the ISC catalogue in the Zmap software for b-value estimation. The plots thus obtained have been analysed and conclusions have been drawn about the stress in the Andaman region.

Contents

1 Introduction and Background

The present study is focusing on determination of the b-value as a function of time and space for events in the Andaman region. Earthquake data for time period 1/1/1980-13/07/2020 from the International Seismological catalogwas used. (Wiemer 2001) The frequency of earthquake occurrence in a given area during a specific period of observation can be expressed as a function of magnitude through a relation given by Gutenberg and Richter. (Gutenberg 1956) But first we must understand the importance of b-value as a seimsological parameter.

b-value and its Importance

One of the basic seismological parameters used to describe an ensemble of earthquakes is the *b-value* in the famous Gutenberg-Richter frequency magnitude relationship relationship/law.

It charaterizes the distribution of earthquakes over the observed range of magnitudes. The *b-value* is usually 1.0, but for shorter time windows it varies significantly depending on the tectonic features of the seismically active region (Prasad and SInGH 2015) (Pacheco, Scholz, and Sykes 1992). In order to understand the concept of b-value in terms of seismology, we need to understand the Guteneberg Richter law and its significance -

Gutenberg-Richter Law ~

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> In seismology, the Gutenberg–Richter law (GR law) expresses the relationship between the magnitude and total number of earthquakes in any given region and time period of at least that magnitude. (Gutenberg 1956)

The corresponding Gutenberg-Richter Frequency Magnitude Relation is given by,

$$\log_{10} N = a - bM$$

Or

$$N = 10^{a-bM}$$

Where, N is the number of events having a magnitude $\geq M$, also called the cumulative Frequency, and a and b are constants which are always same for a given value of N and M.

The significance of the GR law lies in the values of these constants. The relationship between earthquake magnitude and frequency is fairly common, but the values of a and b vary significantly from region to region giving seismologists significant amount of information regarding the seismo-tectonics/geo-tectonics of the region under study. When we say that the parameter b i.e. the *b-value* is close to the value 1.0 (in seismically active regions)we mean to say that for a given frequency say 4.0 or larger events there will be 10 times as many magnitude 3.0 or larger quakes and also 100 times as many magnitude 2.0 or larger quakes. But the *b-value* can vary significantly from 0.5 to 2.0 or even higher depending upon on the region's seismic activity. A good example of this is Earthquake swarms which can have a *b-value* as high as 2.5 which indicates a high proportion of small quakes to large ones.

The GR Law and specifically the measurement and interpretation of the spatial and temporal variations in *b-values* can provide significant information about the evolution of the seismicity of the region under study. By analysing anomalies in the spatio-temporal variation in the *b-value* of a region with respect to major quakes we can obtain spatio-temporal constraints that can used to create, modify and/or improve earthquake forecasting models for that particular region as done by Nuannin et. al. (Nuannin, Kulhanek, and Persson 2005) for the Andaman-Sumatra region.

Now, the ***a-value*** represents the total seismicity rate of the region. This is more easily seen when the GR law is expressed in terms of the total number of events:

$$N = N_{TOT} 10^{-bM}$$

where $N_{TOT} = 10^a$, is the total number of events. Also it is interesting to note that since 10^a is the total number of events, 10^{-bM} is the probablity of those events.

This is the importance of b-value and the GR law as seismological Parameters.

2 Objective

The main objective of the report is to do hazard estimation using the b-value obtained from the Frequency-Magnitude distribution curve and infer the Geological implications of the b-value estimated from the said FMD-curve as well as infer about the stress and heterogeneity of the region using the spatio-temporal ditribution of b-value and its variation with depth.

3 Methodology

b-value estimation and Spatio-temporal variation.

The b-value estimation for the defined study area has been carried out using zmap7 software and MATLAB. The data was obtained from the ISC catalogue online bulletin (Centre 2001). The following Map of events was obtained for the given data. -

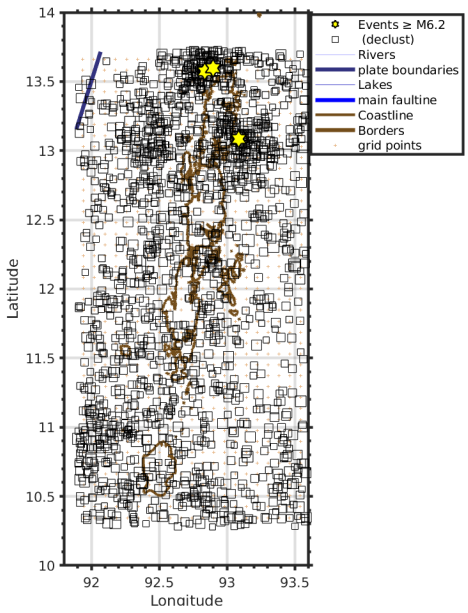


Figure 1: Seismicity map of the studied area. The stars show the epicenters of the maximum magnitude events in the catalogue

Declustering of the Earthquake catalogue

In order to analyze the expected anomalies in the spatial and temporal distribution of the seismic activity, the catalogs were declustered to remove "dependent" events. In our hazard analyses, we are interested in modeling a process where each possible event is independent of any other. Foreshocks and aftershocks are both temporally and spatially dependent on the mainshock. When we speak of declustering, we mean removing these dependent events. Declustering an earthquake catalog results in a catalog composed of independent events. Here Reasenberg's decluster method (Reasenberg 1985) for aftershock identification was applied. In this method, events within time and distance windows are associated to form clusters and the cluster is replaced with an equivalent earthquake. Any earthquake that occurs within the interaction zone of a prior mainshock is classified as an aftershock and considered as a dependent event. Several parameters have to be chosen for the declustering procedure. A detailed description is given in Ref. (Reasenberg 1985) and in the ZMAP program manual (Wiemer 2001)

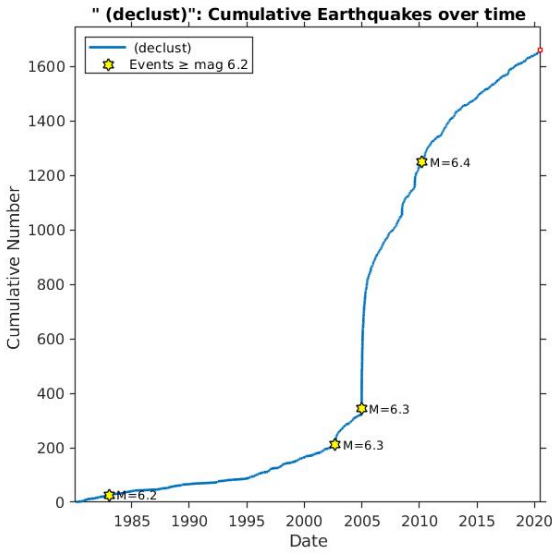


Figure 2: Cumulative Number of original and declustered data-set for ISC Catalogue of Andaman Region over time

The *b-value* estimation and value of the Magnitude of Completion i.e. M_c was done using the Maximum Likelihood method.

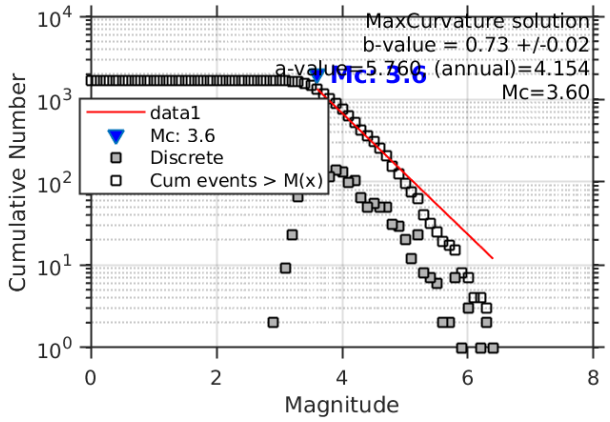


Figure 3: Frequency Magnitude Distribution

The *b-value* thus obtained here is 0.73 ± 0.02 and the value of M_c is 3.6 from the declusterd ISC catalogue.

An assessment of the minimum magnitude of complete recording, the so-called threshold magnitude, M_c , is an important part of data quality control. M_c is defined as the lowest magnitude for which all events in a studied space-time volume are detected. M_c varies with space and time. For most catalogs it decreases with time, because the number of monitoring seismographs continuously increases and the analysis methods improve (Wiemer and Wyss 2000). The magnitude of completeness of the declustered catalogs was determined by the Best Combination method in the ZMAP software. Figure 4 on 13 shows the variation of M_c as a function of time and as expected the minimum threshold is decreasing with time as detected events has significantly increased over the years.

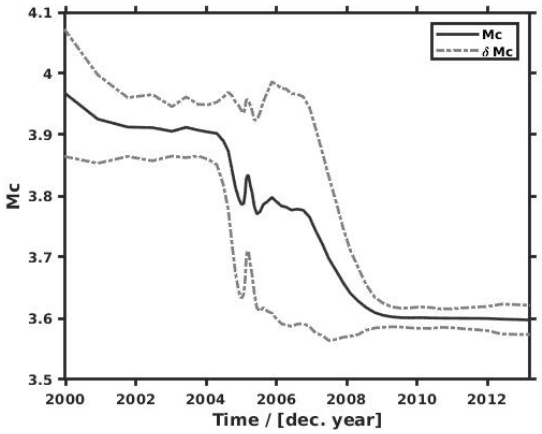


Figure 4: M_c time series

THe figure 3 shows the magnitude -frequency distribution as a function of spatial position which has been mapped by projecting earthquake epicenters on a plane. The *b-value* has been estimated at every node of the plane grid. using the N (N = constant) nearest earthquakes, or a varying number of events located within a chosen (constant) distance, R, from the node. When N is constant, it is usually in the range of 50-500 events, and the nodal separation is 0.1^o - 1^o, depending on the density of epicenters. To visualize the variation, b-values are translated into a color code and plotted for each grid node. (Nuannin and Kulhánek 2012)

From the bval grid it is clear that Andaman-Nicobar region can be broadly categorised into two seismic zones, one in the norhtern andaman and the second, southern andaman region. The southern andaman region has very low *b-value*, whereas, the northern region which has high *b-values*. We know that higher *b-values* mean a greater proportion of low magnitude earthquakes to higher magnitude earthquakes and vice-versa for lower values of the constant *b*. Hence we can say that,

- High *b-values* $\rightarrow$ low stressed region; small to moderate earthquakes,
- Low *b-values* $\rightarrow$ high stressed region; moderate to large earthquakes.

4 Main Findings

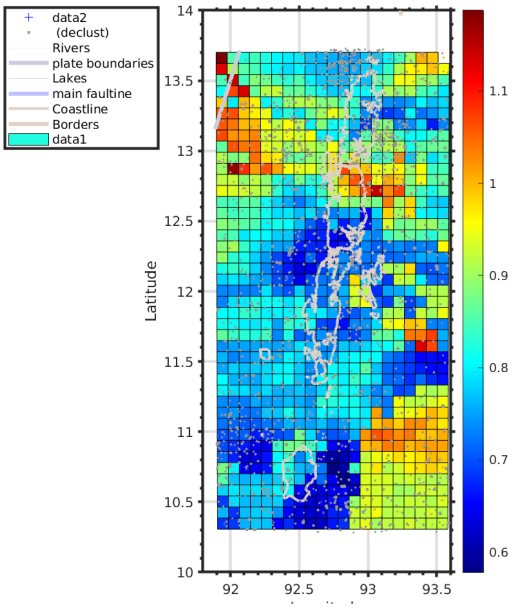


Figure 5: Spatial Variation of b-value

From figure 1 and figure 5 above, we can easily say, that all major earthquake events of magnitude ≥ 6.20 occured in the regions/nodes of relativly low *b-values*, clearly supporting the expections from the Gutenberg-Richter Law. These regions of low *b-values* are the hazardous regions as these are the areas where a large number of the high magnitude earthquakes have occured or may occur in the near future. The regions of extremely high *b-values* are essentially earthquake swarms of fairly low magnitude quakes.

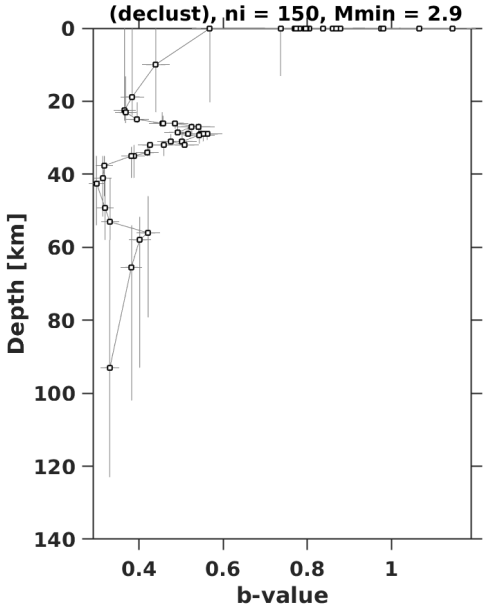


Figure 6: Variation of b-value with depth

The Gutenberg–Richter b-value is thought to reflect the stress conditions in the crust; therefore, spatial and/or temporal variations of the b-value can provide important information regarding crustal tectonics. But, the variability of b with depth is often not statistically significant and that the decrease of b with depth should be interpreted with caution as shown by many research groups including Amorese et. al. (Amorese, Grasso, and Rydelek 2010).

In this case, the variation of *b-value* with depth indicates a steady decline in the value of b with depth. There is a sharp increase in value of b at $\approx 30km.$ and $58km.$ This indicates that the higher magnitude quakes are generally occuring at

larger depths small quakes have their epicenter at/near the surface. These variations with depth indicate the stress among the earth's surface layers in those depths. The depths at which b-value is high, are less stressed regions, whereas the opposite is true for depths with higher b-values and hence there are gerater chances of high magnitude earthquakes to have epicenters in these depths.

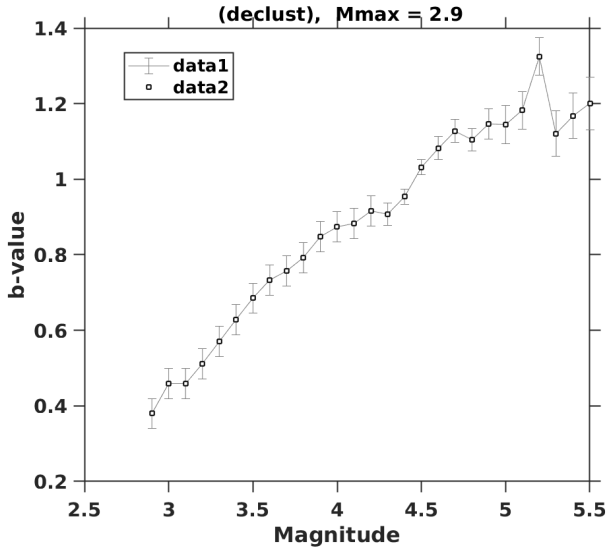


Figure 7: Variation of b-value with magnitude

The Figure 7 above shows the variation of *b-value* of the Andaman region with the magnitude of the quakes. This is in accordance with the Gutenber-Richter law. The larger the magnitude of the quake, the larger will be the corresponding *b-value* and thus the smaller will be the correspiding cumulative frequency as seen from the following equation.

$$N = N_{TOT} 10^{-bM}$$

The opposite is true for smaller magnitude quakes.

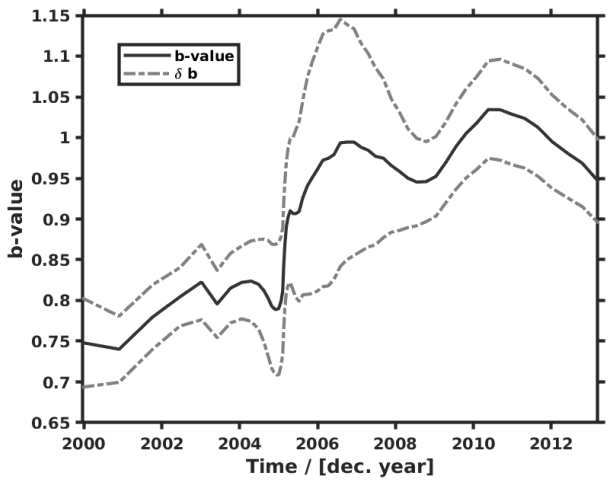


Figure 8: Temporal variation of b-value

The temporal variations of the *b-values* shown in the above figure give us a great insight into the potentially hazardous regions in the greater Andaman region. We can correlate the temporal variation with the Seismic history of the region to identify the changes in *b-value* before/after major earthquake events.

- From the figure it is clear there was a sharp decline in the *b-value* before the major quake in North Andaman in the year 2002 of moment magnitude $M_w = 6.5$[1]

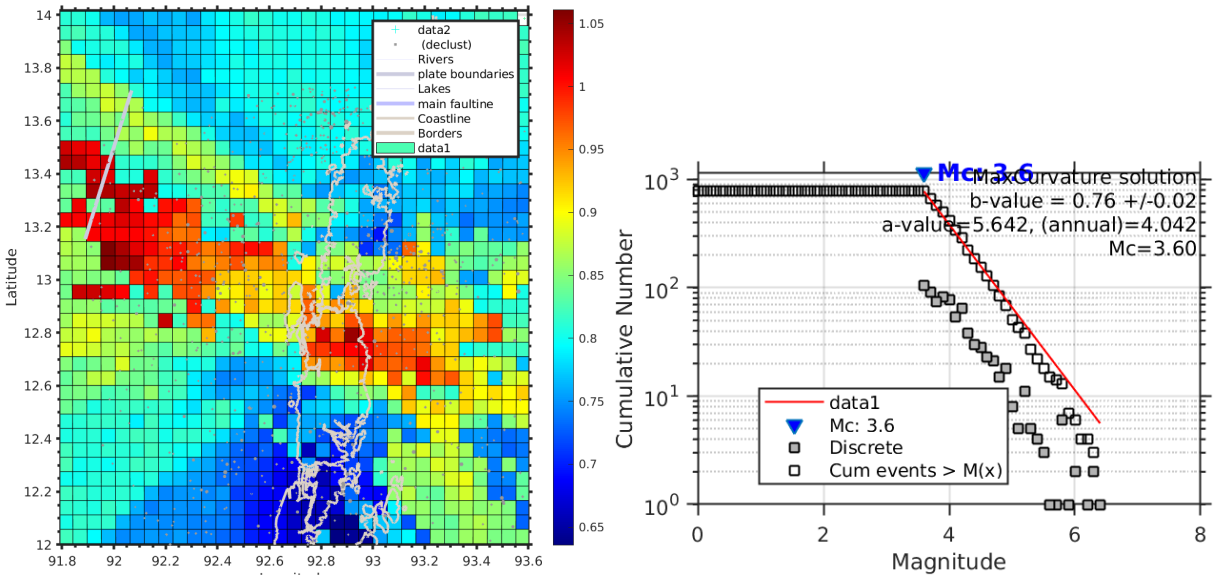
[1]Note that the magnitudes used from the ISC catalogue for analysis are body wave magnitude i.e. M_b

- After this, there was a steady increase in the *b-value* with time before a sharp decrease in the value of b right before the devastating Sumatra-Andaman quake in 2004 of $M_w = 9.1$
- Then there was another significant decline in *b-value* prior to the major quakes in 2005 and 2006 followed by many years of steady incline in the value of b.
- Then there was another sharp decline before the major quake in June, 2010 off the shore of Nicobar islands with a moment magnitude of $M_w = 7.5$ and then there was a steady rise before a another steady decline.

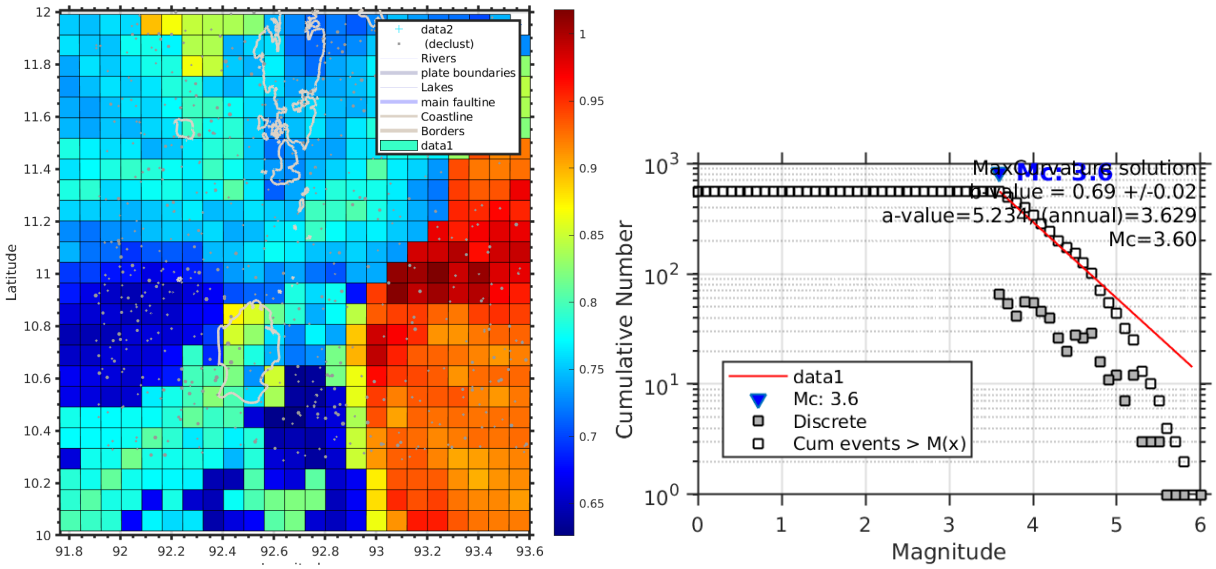
It is clear from these observations that there has been a steady decline in the b-value of the Andaman region before major quakes have occured and this time between the sharp decline in the *b-value* in the analysed data-set and actual occurence of the quake (also called the Precursor time) can be used to predict the time until the next major quake by using *b-values* as a precursor for predicting earthquakes of specific magnitudes depending on the decrease in *b-value* in the data gathered from the Seismology catalogues.

The two Seismic Zones -

The Northern seismic zone was chosen from 14 deg. latitude to 12 deg. and the following spatial variation of b-value and FMD was obtained.



The overall b-value of the Norhthern seismic zone is higher than that of the entire Andaman region indicating that it is a relatively low stress region and is less prone to hazard in the near future. The Southern seismic zone was chosen from 12 deg. latitude to 10 deg. and the following spatial variation of b-value and FMD was obtained.



The overall b-value of the Southern seismic zone is lower than that of the entire Andaman region and also lower than the Northern region indicating that it is a relatively high stress region and is more prone to hazard in the near future.

5 Conclusion

b-values characterizing the spatial and temporal variation of seismicity in the Andaman region during a span of 40 years were calculated using earthquake data from the ISC catalogue. Data from the catalog have been carefully selected and analyzed. Completeness of the catalogs is an important parameter that has to be taken into consideration in the determination of b. The results have been obtained -

- The b-value of the entire Andaman region was found to be 0.73 ± 0.02 with $M_c = 0.36$
- The b-value of the Northern seismic zone of Andaman region was found to be 0.76 ± 0.02 with $M_c = 0.36$
- The b-value of the entire Andaman region was found to be 0.69 ± 0.02 with $M_c = 0.36$
- The temporal and spatial variations of b-value were analysed and it was tested against the Seismic History of the region to check for the years in which major quakes happened and it was found that before each major quake, there was a gradual drop in the b-value.
- The b-value variation with depth was analysed and the depth at which the stress is maximum was determined.

6 Future perspectives

Frequency magnitude distribution curve and spatial and temporal variations of b-value can be used as a precursor to exisiting seismic history of a region to loosely predict the time and magnitude of future quakes. The study has been carried out by several research groups including Smith et. al. (Smith 1981) and Nuannin et. al. (Nuannin and Kulhánek 2012). The $b(t)$ variation can be used as a precursor to model to existing data on major quakes to obtain precursor times for each quake. These precursor times can be plotted and the data can be extrapolated to obtain the time duration between the last major quake and next major quake. This particular application isn't always accurate in prediction, however modifications can be made to check the validity of this method and improve the accuracy.

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ANNEXURE II

Summary of selected five Eminent Scientist Lectures

Annexure - 2 - Summary of selected five Eminent Scientist Lectures

Lecture 1 – Importance of Early Questions

by Prof. Eluvathingal D. Jemmis, Indian Institute of Science, Banglore.

The session was one of the most inspiring talks that I have ever had the priviledge of attending. The main theme of the talk revolved around the importance of asking questions especially in the field of science. Prof. Jemmis said in the talk,

> "Success of nations depends on the ability of its citizens to ask original questions."

He also focused on the idea that one need not be a genius to ask questions but aks intriguing questions and as the experience and academic knowledge of an individual increases, the quality of questions also improves and questions become less generalised. But generalised questions are not bad, instead they are fundamental and quite more important as well as interesting.

Another major aspect of the talk was to understand the importance of interdisiplinary sciences and Prof. Jemmis gaves us example of Edward Witter who was studying history and instead went on to do a PhD in Theoretical Physics and went on to become one of the pioneers of String Theory. Similar cases have happened where students have found their interests in subjects and fields other than the ones they were studying during their undergraduate or high school years. He also gave us insight into his PhD thesis on the study of Borophene and it was quite engaging and informative.

Lecture 2 – Igniting Minds: Spurring Innovations

by Dr. Renu Swarup, Secretary to the Govt. Of India, Dept. Of Biotechnology, Ministry of Science and Technology

The talk was centred around the provisions and steps taken by senior scientists and the government of India has taken to help ignite young minds in the country and push forward the envelop of innovation in the near future and what steps we can take in the future as students in doing the same. Some of the main focuses are team work, hard work as well as focused and targeted outcome. Dr. Swarup also focused on the importance of international collaboration.

One of the major aspects of the talk was the concept if translating our ideas into research and then into a tangible product or service and make it widely availble to the end-user. The talk focused on how knowledge driven enterprises, academia as well R&D departments in both public and private sector along with Start-Ups can help take science and innovation ahead.

Lecture-3 – Investing in Science, Technology, and Innovation: A way towards an Atmanirbhar Bharat

by Prof. Alok Dhawan, CSIR-IITR, Lucknow

The lecture was centered on the importance of investments in scientific innovation and research for the formation of a self-reliant nation and it is even more important for a nation as big as ours. The key, as Prof. Dhawan stated is for students to be Critical, Creative and Innovative. The lecture also focused on the role played by CSIR as a pan India research instituion to foster as a link between entrepreneurs, industry and academia and thus increase the development of Science and Technology (S&T) in India. One major aspect of the lecture was also on how CSIR-IITR and other institutions are using drug development and other methods to combat COVID-19 and eliminate SARS-CoV-2 virus in India. Prof. Dhawan talked about the use of Digital and Molucilar Surviellance to study the sequencing of the corona virus and development of rapid and economical diagnosis for at various facilities and also on the repurposing of drugs and development of new drugs and vaccines.

Lecture-4 - Science of Climate Change

by Dr. Madhavan Nair Rajeevan, Secretary at the Ministry of Earth Sciences, Govt. Of India and Chairman at ESSO and Earth Commision

The lecture was focused on the understanding of all the factors responisible for climate changes and the study of the earth system for understanding as to how we can model and quantitatively understand how the different factors lead to climate change and to what extent.

Climate change maily occurs due to

- Internal causes and
- External Causes

External Causes are generally comprise of changes of solar irradiance incident on the upper atmosphere, changes in the orbital parameters of the earth such as eccentricity of the orbit or obliquity of the ecliptic and other reasons might be a change in the rate of rotation of the eath about its own axis.

Internal causes are further classified into 2 categories mainly, natural variability such as volcanic eruptions or changes in atmospheric composition or continental drift, etc., and second due to anthropgenic (human) activity such as deforestation, desertification, etc. The lecture further focused on data and using qualitative as well as quantitative data to study how these different factors and causes can effect mean climate in different regions on the planet. Dr. Madhavan focused on both global as well as Indian trends of Surface air temperatures and how it has evolved.

Lecture 5 – Manage your Career Journey

by Dr. Julie Franklin, MSc CChem MRSC MCMI, Career Management Specialist.

This lecture was one of the most productive, informative and interesting lectures till now as Dr. Franlin focued on very important topics such as finding career opprtunities and also what skills are employers looking for in todays demanding enterprise sector as well as the marketable skills needed in Industry. Further she emphasised on techniques to make one's CV and application stand out, perform in interviews and develop as a professional.

Dr. Franline emphasised that a career is a lifelong leaning journey and it is not linear. It is flexible and dynamic and will change as we evolve as professionals and individuals. She focused on the importance

of choosing a profession in a filed which we enjoy to study and work on as individuals to create a proper work-life balance.

One major aspect of the lecture was on the important choice that every young scientist needs to make - "Industry or Academia?" Dr. Franklin suggested that one must make this choice on the basis of the skills that one has and the goals that one wishes to achieve. She also introduced the difference between an Academic CV and Industrial CV as well as the difference between Academic and Industrial interviews and also gave a brief introduction to the STAR Model for competency based inerview questions -

- Situation (setting the context)
- Task (what was required of us?)
- Action (what did we do?)
- Result (what was the outcome?)
- and most importantly what did we learn

Another major aspect of this lecture was the development of a professional network and how networking can allow individuals from the same field can help one another. Dr. Franklin focused on the use of social sites such as LinkedIn and ResearchGate to network with individuals from academia and industry.

ANNEXURE III

Summary of selected five Lectures/Classes attended

Annexure - 3 - Summary of Selected five Lectures/Classes attended

Lecture–1 - A Geophysical Interactive session with the students

The lecture was taken by our mentor for Group-9 of Project-1, Prof. Debasis D. Mohanty and it was an interactive session where we were introduced to the main Aim/objective of the Project-1 i.e. **"Frequency-Magnitude Relations and Hazard Estimation"** and we were provided a brief description of the various techniques and mathematical tools that we would be using in this project. Prof. Mohanty introduced the *Gutenberg-Richter Relation*

$$\log_1 0N = a - bM$$

Where N is the number of events having magnitude $\geq M$ i.e. Cumulative Frequency; M is the Magnitude of the earthquake; a and b aare constants for a given value of N and M. Essentially a is an indicator of the total events that took place and b is the b-value which essentially gives information about how stressed that particular region is as far as seismic activity is concerned.

This relation is also known as the Frequency-Magnitude Relation obtained using Frequency-Magnitude distritbution curve and he informed us about the importance of this relationship in Seismology and how we use the b-value in this relation (i.e. the slope of the semi-log plor of N with M) for Hazard Estimation.

He gave a brief introduction to the Spatio-Temporal variation of b-values and how these variations can be analysed for a given region and the hazard estimation of that region can be carried out. Prof. Mohanty also gave a brief introduction to the following 2 techniques

- The Least Square Fit Method
- The Maximum Likelihood Method

These are two distinct methods used independently for the b-value estimation from the Frequecy-Magnitude ditribution. He mentioned the benefits and drawbacks of each method. The final part of the Lecture focused on the b-values in different parts of the world and also an overview of Seismo-tectonics and b-value study in the Indian context.

Lecture-2 – Various Catalog studies for downloading the seismic data and their use.

This lecture was a Hands on session focused on the introduction to seismic catalogues used all over the world by Seismologists for data analysis and visualisation specifically for Hazard Estimation. The students were introduced to the importance of Seismic Catalogue and how these catalogues are maintained and recorded by institutions all over the world.

We were given a brief inrtroduction to different Magnitude Scales in which earthquake magnitude is measured, such as moment magnitude (M_w), Body wave magnitude ((M_b)), etc. And relative advantages and disadvantages of each of theses scales.

After this we were introduced to the main catalogue of Seismic Catalogue, i.e. **Internationa Seimological Center or ISC catalogue**. We were provided the estimation of Andaman Region as the region for study and we were trained how to download the seismic data for this region from the ISC catalogue and how to prepare and clean this data to be used in Zmap software and MATLAB. We were also shown the disadvanteges of using small datasets.

Lecture-3 – Basics of Gutenberg-Richter Relation and different methods of estimation of b-value

This lecture was centered around the topics discussed on Lecture-1 but going into a more detailed and in-depth understanding of the GR-Law and its importance and the physical meaning of the mathematical constants a and b in the GR relation.

A large emphasis was also paid on the understanding of the Geo-tectonics and Seimo-tectonics of the Andaman region and the Western Himalayas region which were the two regions whose seismic data was downloaded to analyse for Hazard estimation in Project-1. The Seismic history of these regions were also discussed briefly.

Further detailed instructions were given on the two methods of b-value of estimation was also provided.

Lecture-4 – Hands session on softwares such as MATLAB, Zmap, etc.

MATLAB and Zmap are standard pieces of software for analysis of Seismic data for Hazard estimation and in this session, we were introduced to the use of MATLAB and Zmap for analysing the seimic data we downloaded in the previous lectures. We were shown how to download and install Zmap on our computers and how to intialise the Zmap library in MATLAB and how to use the various options available in Zmap to analyse the data properly to get the best estimation for b-value.

We were introduced to concept such as declustering of data to reduce data dependency on minor events such as fore-shocks and after-shocks. We were introduced to concept of using Zmap for data visulaisation and also how to use Sampling options ot divide the data and by extension the region under study into different seismic zones (based on the distribution of data) and how to do b-value and Hazard estimation for these different Seismic zones.

Lecture-5 - Applications of study of Frequency-Magnitude relation in a seismotectonic area/spatial and temporal variations of b-value

The lecture was carried out after me and other students in group 9 of Project 1 of CSIR-SRTP 2020 were asked to download the seismic data and analyse the data using Zmap software themselves. This lecture focused on the inferences that we can draw from the data analysis and visualisation. It focused on concepts such Magnitude of Completion (M_c), b-value variation with depth and magnitude, but most importantly it was focused in the variation of b-values with different hypocenters in the region and with time, i.e. spatio-temporal variation of b-value.

One major aspect of this lecture was to understand how these spatio-temporal variation graphs can be used along with the known seismic history (seismo-tectonic and geo-tectonic history) of the region to do hazard estimation for the different entire region and/or of the different seismic zones in which the region was divided into. The lecture was given by our mentor – Prof. Debasis D. Mohanty who emphasised the importance of using b-value for hazard estimation and gave us a brief overview and explaination of all the graphs obtained from the analysis and visualization of data from the regions of Andaman and Western Himalayas.

ANNEXURE IV

Summary of selected five SRTP videos

Annexure - 4 - Summary of selected 5 SRTP videos

Video 1 – Seismometer

The video gives an introcution to the history and evolution of Seismic instruments used to detect/measure earthquake magnitude/intensity, starting from the oldest ancient chinese seismometers, to the gradually development of analogue seismometers based on the principle of intertia. Today, digital seismometers are extensively used for measurement of earthquake magnitude. The principle of these seismometers is Electromagnetism. In them a heavy mass wrapped with a metallic foil is place in a strong magnetic field which generates an EM wave on ground motion which is amplified and digitised by a digitizer. It also has a GPS Port which is used to get the exact location and time of the earthquake event. The video also gives a brief overview of how to use a digital seismometer.

Video 2 – Strong Motion Accelerograph

The video gives a brief overview of the working of a Strong Motion Acceleograph or SMA which is used to record acceleration of the ground during times of strongs of earthquakes. The SMA has a power cable connected to a 12V battery. It has an internet port which helps in configuring the device using a computer. There is a GPS port which gives information of the location and time of the event (earthquake). It is placed oriented towards north and completely balanced on a flat surface. Whenver a high magnitude earthquake occurs, the SMA measures the acceleration and transfers the data to an external memory card. The SMA has small MEMS (Microelectromechanical systems) chips present which are the sensors for measurement of acceleration

Video 3 - Nuclear Magnetic Resonance Spectrometer

The video gives an overview of the contruction and working principle of the NMR Spectrometer. The source of energy in NMR is radio waves. It works on the principle of Magnetic Resonance. If the external energy source of radio waves has the same energy as the difference in the energy of stable and excited magnetic energy states, then. Absorbing such RF radiation causes nucleas to spin flip and relaxing back to original sate causes Nuclear Magnetic Resonance. The video then gives a step by step approach of sample preparation, loading, information and insertion to study the final NMR spectra for the biological sample.

Video 4 - Demonstration of Fluorescence Spectrometer

The vido goes over the brief introduction of the phenomenon of Fluorescence, which is essentially emmission of light by a substance after absorption. The Fluorescence spectrometer is used to obtain the emission and absorption spectrum of the sample. The video then demonstrates sample loading for a pre-prepared sample for a given source of light. For the sample of carbon dots, the Fluorescence spectrum was obtained which was a Gaussian.

Video 5 - Thermo gravimetric Analysis

Thermal Analysis is a technique to study the properties of materials as they change with temperature. Thermo Gravimetric Anaysis or TGA is a specific type of Thermal Analysis in which sample is heated in a given environment and the change in the weight of the subtrate is recorded as a function of temperature (which increases at a constant rate). The plot of weight vs temperature is called a Thermogram. TGA tells us about the Thermal and oxidative stability of a material, estimated lifetime of a substance as well as the moisture content of a material. The video also gives a demonstration of the working of a TGA to obtain the Thermogram of Calcium Oxalate which decomposes into calcium carbonate and subsequently into calcium oxide.

ANNEXURE V

Survey forms, questionnaires and/or consent form

Annexure - 5 - Survey forms, questionnaires and/or consent form

Process to Download Catalogue Data

- We downloaded the data from the ISC catalog`isc.ac.uk/registration` for the same information about the seismic stations but for those used by the ISC for data cataloguing.
- Now to download the data catalogue from ISC, I went to the link `isc.ac.uk/iscbulletin/search/catalogue` and downloaded the data for the Andaman region with the follwing co-ordinates
  - Group 9 (Andaman) -> Top Lat. = 13.734, Bottom Lat. = 10.275, Left Long. = 91.901, Right Long = 93.593
- Entered the respective co-ordinates as mentioned in the previous point.
- Mentioned the start date as 1st Jan. of 1964, when the cataloguing had started till the present date.
- Took min. depth as 0 and max. depth as 6731 km which is the Radius of the Earth
- Min Magnitude = 0.1 and Max. magnitude as 10 were taken
- Chose Magnitude type as Body wave magnitude i.e. M_b and selected author as "Any".
- Clicked output Event Catalogue and then copied the data and pasted in Excel.
- Chose the Text to Column option in Excel and delimited the data using Tab and comma. After this cleared everything after the Magnitude column. This step is called Data Cleaning.
- Ploted the frequency vs. Magnitude curve after calculating frequency in Excel just to get a feel for the data.
- The actual plotting and analysis process was carried using Zmap in MATLAB. One can use a Data analysis oriented programming language of their choice to visualise the data using Python or R. The data was further cleaned by me to make suitable for Zmap compatibility using the Pandas library of Python

Error for small datasets.

$>$ 2000 good quality earthquakes are required for 98% confidence in the final data results.

N (frequency)	B value
500	0.91-1.12
100	0.86-1.20
50	0.50-1.49
30	0.70-1.74

Objective of data-

The data was collected to analyse the seismic data and obtain the Frequency-Magnitude Distribution curve which was then fitted to the theoretical Gutenberg-Richter relation to obtain the b-value and subsequantly the spatio-temporal variation of b-value. These plots were then analysed and suitable inferences were made in reference to hazard estimation of the Andaman Region

CSIR-SUMMER RESEARCH TRAINING PROGRAM(CSIR-SRTP)2020 ONLINE

ANNEXURE VI
Feedback Form

1. How is the CSIR-SRTP program?

The program was a great initiative to give students a chance to learn new skills during this pandemic.

2. How are you benefited from SRTP?

I learned a lot about the importance of inter- and multi-disciplinary sciences and learned many new skills

3. Rate the SRTP videos and live demonstration in a scale of 0 to 5.

Scale	0	1	2	3	4	5
(Tick "√")					✓	

4. Rate the project related lectures in a scale of 0 to 5.

Scale	0	1	2	3	4	5
(Tick "√")					✓	

5. Will the experience in the SRTP be helpful in your future research career?

Yes, the experience will be extremely helpful in the future.

6. How the multi-disciplinary approach of SRTP was beneficial for you?

The muti-disciplinary approach exposed me to the possibilities of using my skills in unique ways in other related fields

7. What will be your contribution towards creating a knowledge society?

I will try and do my bit by becoming an Atmospheric scientist and contribute through research.

8. How was the insight of the mentor on the project?

Our mentor and hist team of research scholars were very helpful and insightful

9. Suggestions for new course content?

More group projects will be very helpful and will foster team-work

10. Overall comment on the SRTP? Very useful and engaging experience

Name of the Mentee : Aditya Sengupta
Application No : 4855

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ANNEXURE VII

Mentee's Self Evaluation of Project

(Please tick "√")

Project title: Frequency-Magnitude Relations and Hazard estimation

Project no.: 1

Name of the mentor: Dr. Debasis D. Mohanty

Rating	Evaluation Parameter					Remarks
	Originality	Novelty	Statement of purpose	Relevance to Indian science	Mentor's involvement	
Poor						Very engaging project
Good						
Very good						
Excellent	√	√	√	√	√	
Outstanding						

Name of the mentee: Aditya Sengupta

Address: Sec-137. Noida, U.P., India

E-mail: adityasenguptasai99@gmail.com

Application no. 4855

Phone no: 9717335942

ANNEXURE VIII

Evaluation and Recommendation of the Mentee

(Please tick "√")

Project title:

Project no.:

Name of the mentee:

Sl. No.	Rating	Evaluation Parameter				Recommendation
		Mentee's involvement	Sincerity and punctuality	Assignment completion	Originality, novelty and creativity	Grades: • S: Outstanding • A: Excellent • B: Good • C: Poor • F: Fail
1.	Poor					
2.	Good					
3.	Very good					
4.	Excellent					
5.	Outstanding					

Name of the Mentor:

---------- **For office use only** ----------

Recommendation by SRTP team:

Grade (Tick "√")	S	A	B	C	F

Expert 1 **Expert 2** **Project Coordinator**

Final approval:

Director
(CSIR-NEIST)