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Temporal Variation in Fractal Dimension as a Precursory Signal for the 2015 Nepal Mw 7.8 Earthquake

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INTRODUCTION & AIM

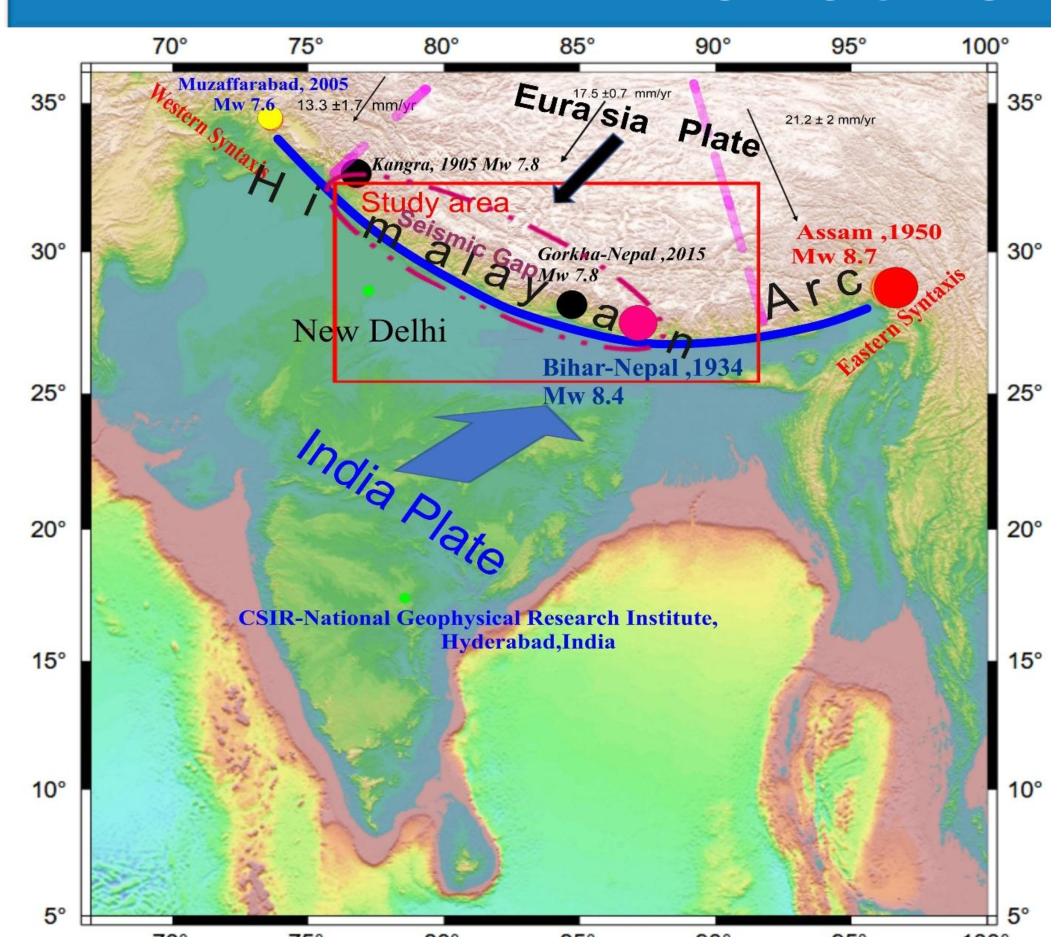


Fig.1.Largest earthquakes in the Himalayan arc since 1900 (marked by colored yellow, black, pink, and red circles). Modified after Bilham, 2020.The study area is marked in red rectangular area. Blue and black thick arrows show the India and Eurasia plate motion direction respectively. Blue line is the Himalayan arc.

- Collision of the India and Eurasia plates causes a complex tectonic environment, resulting in large seismicity.
- Large size earthquakes in the Himalayan region are a real threat to humanity and infrastructure.
- The Nepal Himalaya lies in a **seismic gap**, making it highly prone to **large earthquakes.**
- Studying seismic patterns in this region is important for understanding **earthquake behavior and risks.**

Objectives

- To analyze the **temporal evolution of seismic activity** in the Himalayan region.
- To identify **possible precursory signals** before the **2015 Nepal earthquake of Mw 7.8**.
- To examine the **fractal characteristics (correlation dimension, Dc)** of earthquake occurrences.
- To understand how changes in **fractal behavior relate to stress accumulation** in the Earth's crust
- To improve insights for **seismic hazard assessment and precursory signals of major earthquakes**.

METHOD

Study area with Latitude (25 °N - 32 °N) and Longitude (76°E -92°E)

- Fractal correlation dimension of earthquakes distribution estimated using ISC catalogue 1970-2015 with Mc≥ 3.9
- Completeness magnitude (Mc) and crustal stress estimated by b value of Gutenberg –Richter relation,1944 (1)

$\log_{10}(N) = a - bM$; where N=Number of earthquakes, M=magnitude, b the slope of distribution and a the seismic activity level

- The period of increasing trend has relatively lower crustal stress as estimated by the equation in the above relation.

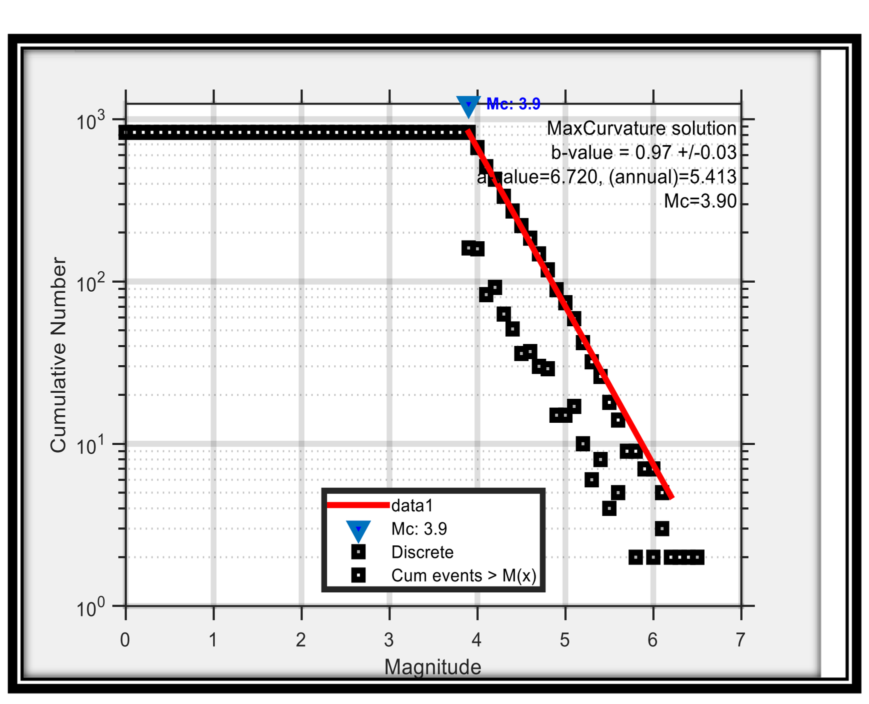


Fig.2. is shown for the Mc estimation for the whole data set using Gutenberg –Richter ,law.

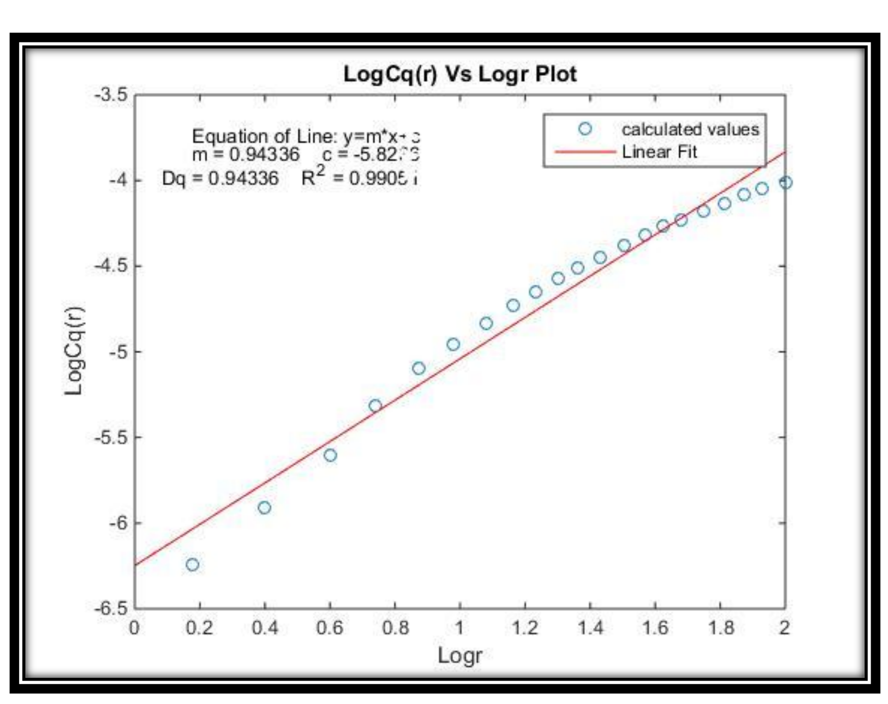


Fig.3. Log Cq(r) vs log (r) for estimation of fractal correlation dimension using the correlation integral approach

Correlation Integral Approach

Correlation Function:

$$C(r)=\frac{2}{N(N-1)}\sum_{j=1}^{N}\sum_{i=j+1}^{N}H\left(r-r_{ij}\right)$$

Generalized Correlation function:

$$\log C_q(r)=D_q\log r(r\to 0)$$

The plot of C(r) versus r in logarithmic coordinates is used to get correlation dimension (Dc).

Adopted from (Grassberger and Procaccia 1983; Roy and Mondal 2012; Mondal and Roy 2025; Roy and Padhi 2007, Roy and Nath, 2007)

RESULTS & DISCUSSION

- The early phase of Dc (fractal correlation dimensions) change exhibits a sinusoidal-like pattern, indicating relatively stable seismic conditions.
- After nine years, Dc values decrease notably, suggesting enhanced spatial clustering of seismic events.
- Increased clustering is indicative of progressive stress accumulation within the Earth's crust.
- The decreasing trend phase corresponds to higher crustal stress compared to the earlier increasing phase, highlighting a critical transition period. (See fig.4)

RESULTS & DISCUSSION (Contd.)

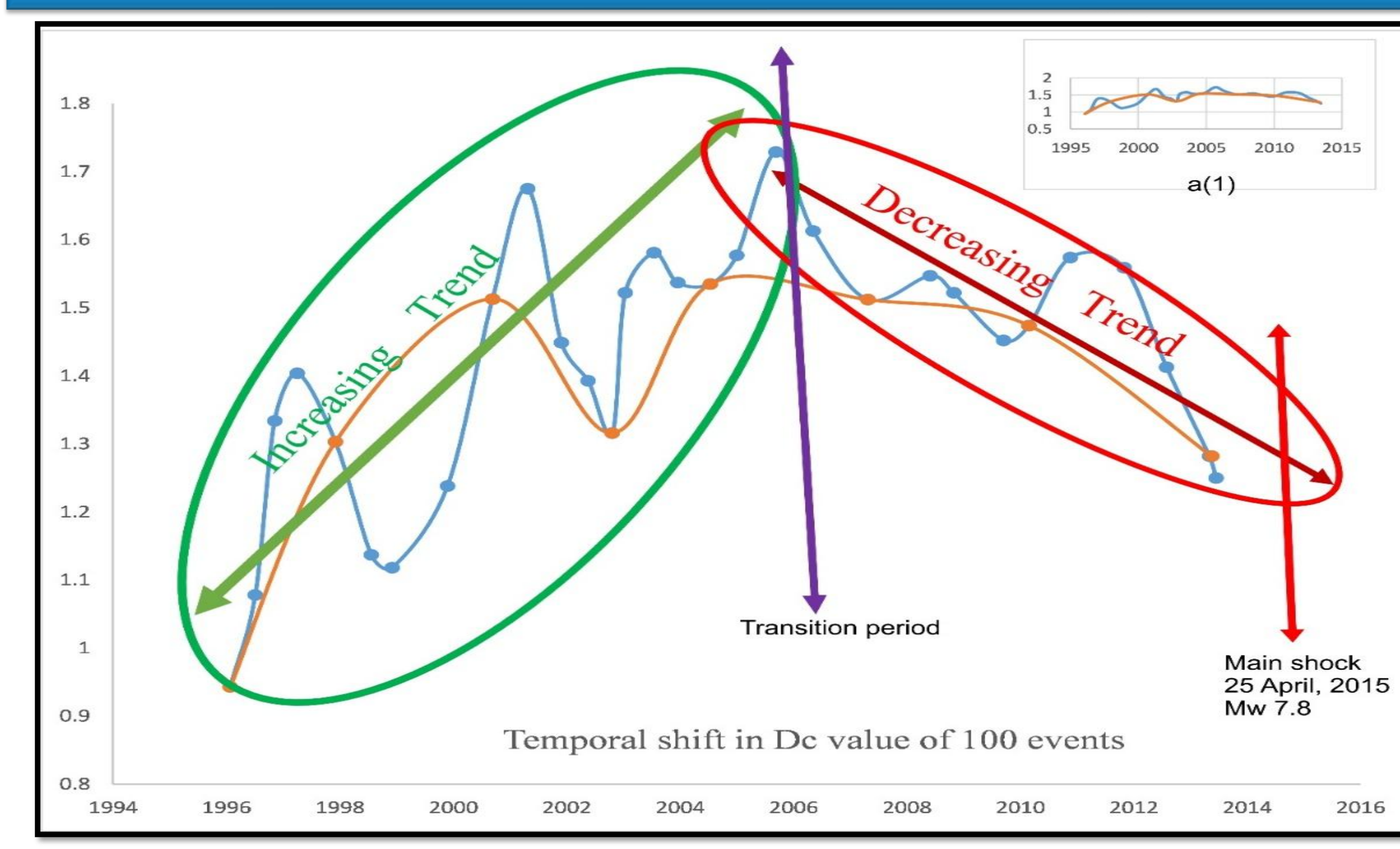
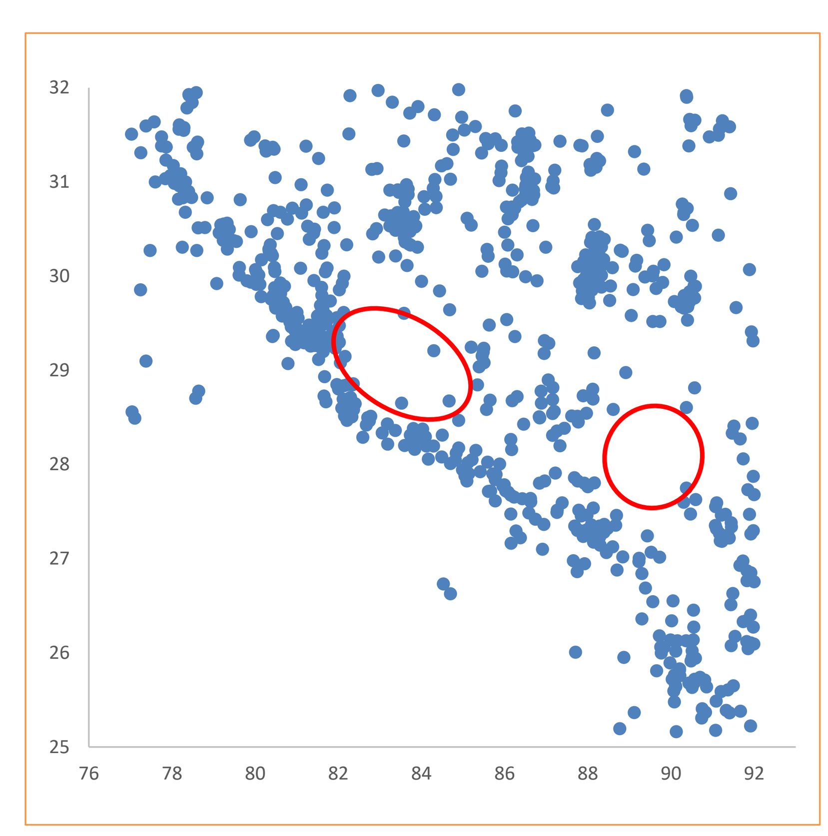
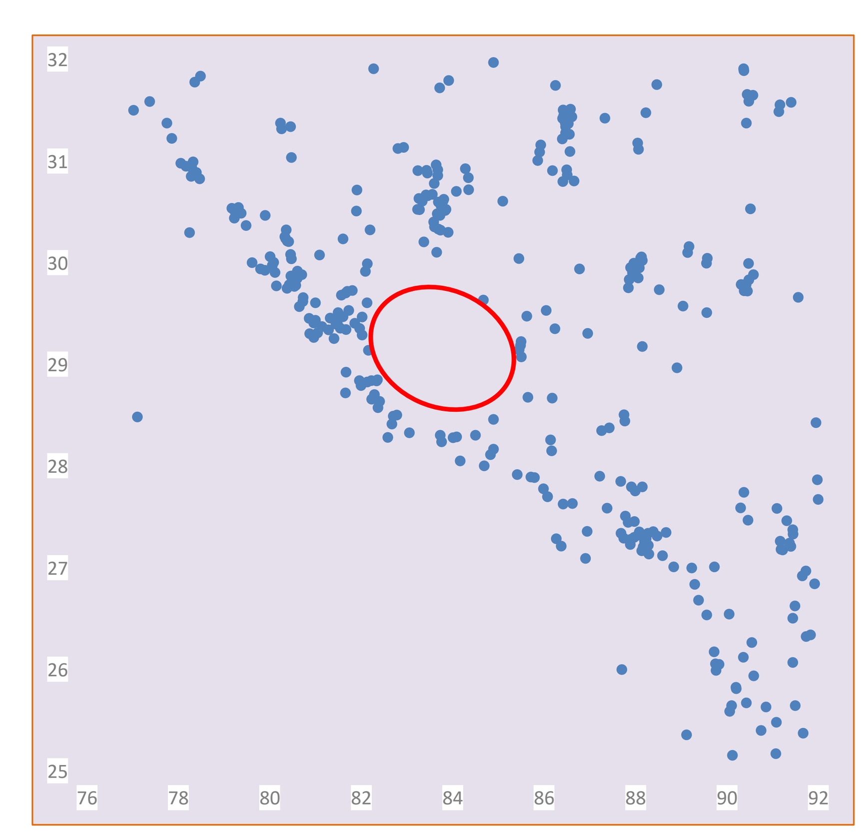


Fig.4.The green ellipse indicates the period of increasing DC value and clearly shows the sinusoidal pattern, as indicated by the blue circles and lines. The transition period is indicated by the purple line. Thereafter, the decreasing trend in the DC value is seen. The red arrow line shows the period when the mainshock occurred. The error bars of Dc values are not shown here for the clarity in figure and the ranges are in between +/- 0.01 to 0.08.



Seismicity distribution based on the Gutenberg–Richter, law. Magnitude of completeness (Mc) is identified from deviation from linearity, with the linear portion fitted as shown in Fig.2. Mc ≥ 3.9 is adopted; only events with M ≥ 3.9 are used. Two red-marked areas are low-seismic-activity regions along the arc.



Distribution of seismicity (blue circles) and seismic quiescence (red elliptical area) during the period when fractal correlation dimensions are in a decreasing trend and crustal stress is high.

CONCLUSION

- Changes in the fractal characteristics of seismicity provide critical insights into long-term stress accumulation.
- A clear transition period from increasing to decreasing fractal correlation dimension (Dc) with time is observed possibly indicating a potential precursor to major seismic events.
- The decreasing trend reflects enhanced clustering of earthquakes, suggesting intensified crustal stress buildup prior to large earthquake.
- These findings emphasize the significance of fractal analysis in improving seismic hazard assessment in terms of statistical analysis.
- Continuous monitoring of such patterns can enhance the understanding and forecasting of major earthquakes, particularly in seismic gap regions.

FUTURE WORK / REFERENCES

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#Roy PNS, Mondal SK (2012) Multifractal analysis of earthquakes in Kumaun Himalaya and its surrounding region. J Earth Syst Sci 121:1033–1047. https://doi.org/10.1007/s12040-012-0208-4

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