భారతీయ సాంకేతిక విజ్ఞాన సంస్థ హైదరాబాద్
भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

CE6670

Term Project:Spatial and Elevation Variation of Daily Time Series Rainfall Data in India

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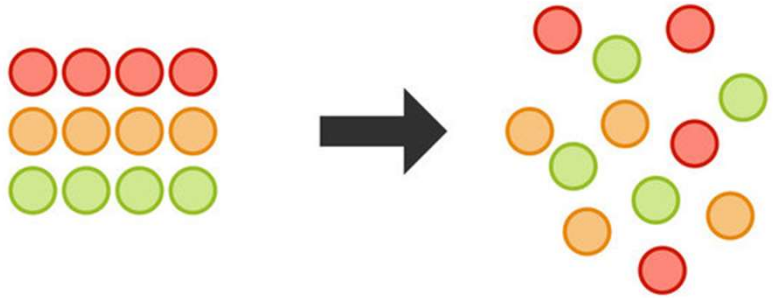
Introduction

What is Entropy?

Entropy is a concept that describes the measure of disorder or randomness in a system



Introduction

What is Sample Entropy

Sample entropy is a concept used in signal processing and biomedical engineering to quantify the regularity or predictability of a time series data. It is derived from the concept of entropy and provides a measure of complexity in a time series

$$SampEn = -\ln \frac{A}{B}$$

Where

A = number of template vector pairs having $d[X_{m+1}(i), X_{m+1}(j)] < r$

B = number of template vector pairs having $d[X_m(i), X_m(j)] < r$

$$SampEn(m, r, N)$$

m = embedded Dimension
R is the tolerance interval,
N length of data

Objective of the study

As there is complexity in the time series data available in hydrological modelling, it shows entropy which can be made into meaningful information for analysing the behavior of the data and region. By correlating with spatial information we can therefore make conclusions and discussions about how entropy changes with spatial variation. The Main Objective was to calculate the sample entropies and see their relation with elevation(m) and their spatial variation in all around India.

Literature Review

Paper 1:Spatial variability and possible cause analysis of regional precipitation complexity based on optimized sample entropy

Authors:Liangliang Zhang, Tianxiao Lia, Dong Liu, Qiang Fua, Mo Lia, Muhammad Abrar Faiza, Shoaib Alia, Muhammad Imran Khan.

Journal : Royal Meteorological Society

Year of Publishing:2020

The study focused on monthly precipitation (MP) and extreme daily precipitation (EDP) complexities in Heilongjiang Province, China., showing unsteady fluctuation characteristics.Sample entropy was optimized using the distinction degree theory to study spatial differences in precipitation complexity.

Paper 2

Paper 2: Spatial Patterns of Sample Entropy Based on Daily Precipitation Time Series in China and their Implications for Land Surface Hydrological Interactions

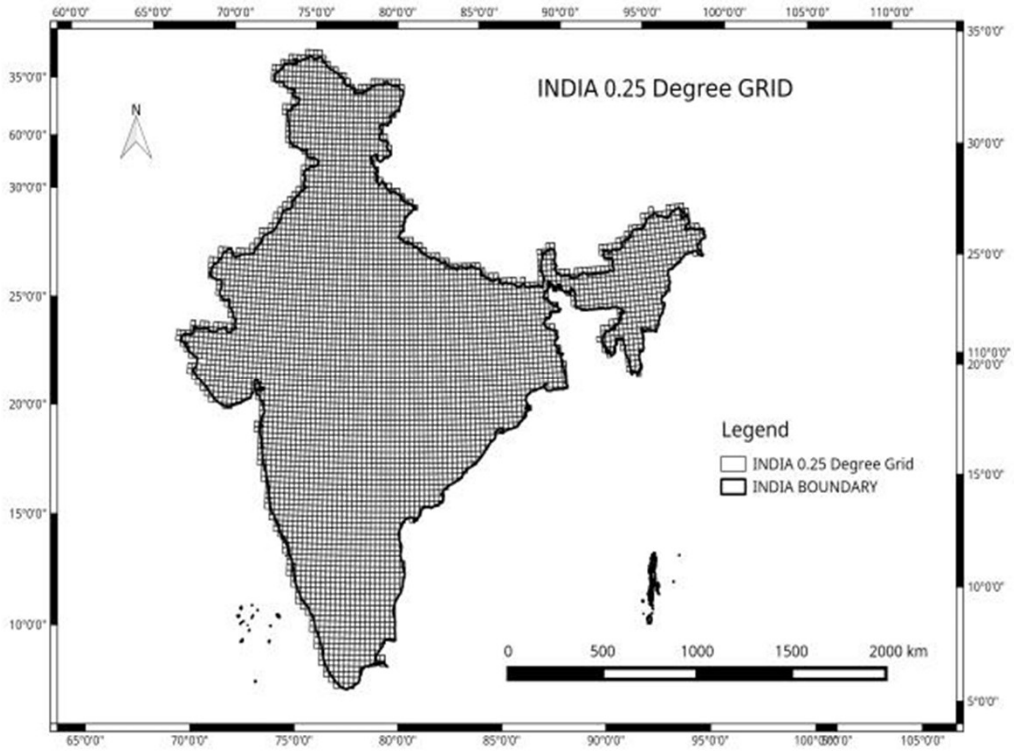
Authors:Xiangyang Zhou,Wenjuan Lei
Journal : Royal Meteorological Society

Year of Publishing:2020

The paper discusses the use of entropy as a measure of variability in assessing potential water resource availability (PWRA) at different scales, such as global, national, regional, and watershed scales

Study Area

Whole India has been taken into the study area and the Analysis is done from 1901 to 2021.



Methodology

Downloading of Data, Both rainfall and Elevation.

Using R Cleaning of Data into readable form and Splitting of Data

Calculation of Entropy using SampEn function and Visualizing it.

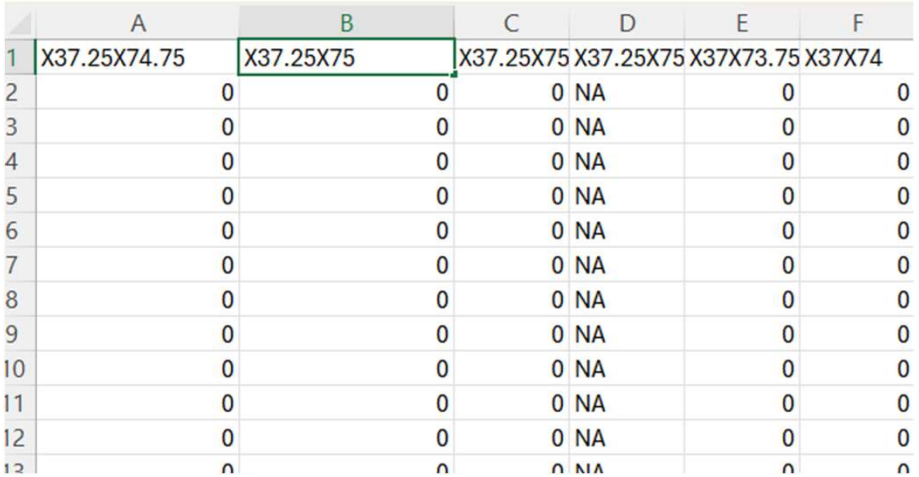
Data

Data was from IMD which was in the form of 0.25x0.25 gridded form(1 Degree grid = 111km)

Needed to be cleaned by removing columns with NA values.

Extraction of each lat long respective file done by running code in R.

Also for the seasonal Analysis, Date Column was added and Divided to 4 seasons Pre Monsoon,Post,Monsoon and Winter

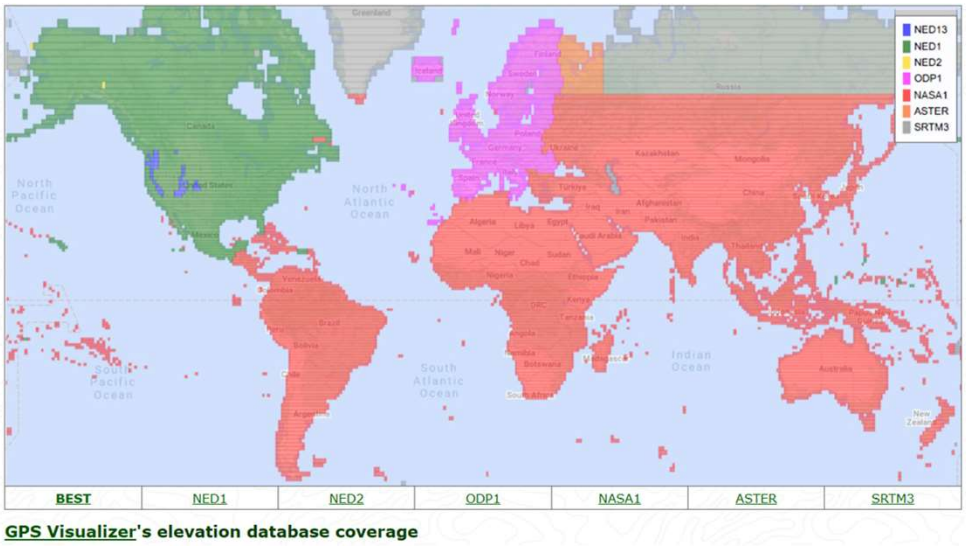


	A	B	C	D	E	F
1	X37.25X74.75	X37.25X75	X37.25X75	X37.25X75	X37X73.75	X37X74
2	0	0	0	NA	0	0
3	0	0	0	NA	0	0
4	0	0	0	NA	0	0
5	0	0	0	NA	0	0
6	0	0	0	NA	0	0
7	0	0	0	NA	0	0
8	0	0	0	NA	0	0
9	0	0	0	NA	0	0
10	0	0	0	NA	0	0
11	0	0	0	NA	0	0
12	0	0	0	NA	0	0

Data Time Period was from 1901 to 2021

Data

DEM Data was downloaded from from gpsvisualiser.com, after feeding to with lat and long of gridded points. The elevation procured was in meters(Aster Satellite).



	lat	lon	Add DEM Data (m)
2	37.25	74.75	4670
3	37.25	75	4939
4	37.25	75.25	5106
5	37	73.75	3667
6	37	74	5158
7	37	74.25	5073
8	37	74.5	5017
9	37	74.75	4935
10	37	75	5116
11	37	75.25	4788
12	37	75.5	4343
13	36.75	73.25	5009
14	36.75	73.5	4435

Calculation of Sample Entropy

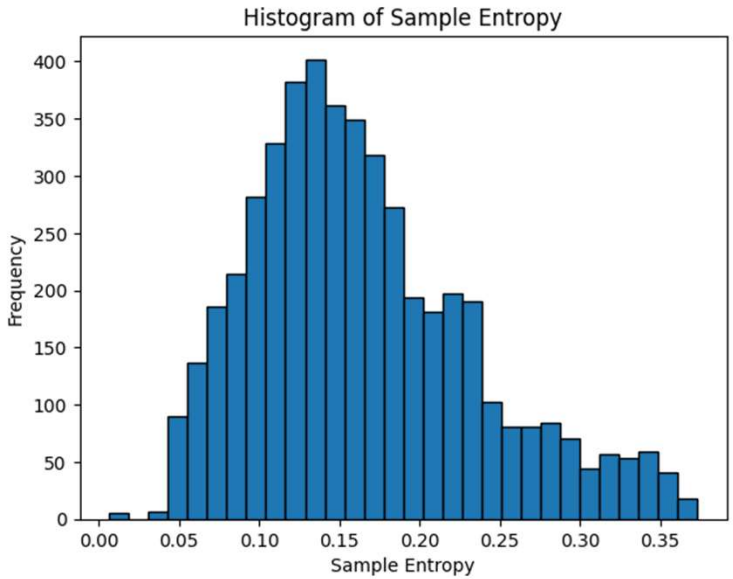
- All the files were then run into a function of MATLAB, where we have to give the signal(rainfall values),m=2 (Embedded Dimension),r =0.2(Tolerance level)
- Now for every Seasonal Files, same code was used .
- A total of 23,945 files were processed,which took over 7 days to process(including debugging)

```
csvFiles = dir('C:\Users\ROG\Desktop\StatsTermP\Stats\*.csv');
numFiles = numel(csvFiles);
results = cell(numFiles, 2);
for i = 1:numFiles

    filename = fullfile(csvFiles(i).folder, csvFiles(i).name);
    data = readtable(filename);

    % Extract location name from filename or data
    [~, baseFileName, ~] = fileparts(filename);
    locationName = baseFileName;
     coordinates = data{:, 2};
     coordinates = coordinates(:);

    sampleEntropy = sampen(coordinates,2,0.2);

    % Store results
    results{i, 1} = locationName;
    results{i, 2} = sampleEntropy;
```

Results after Calculation

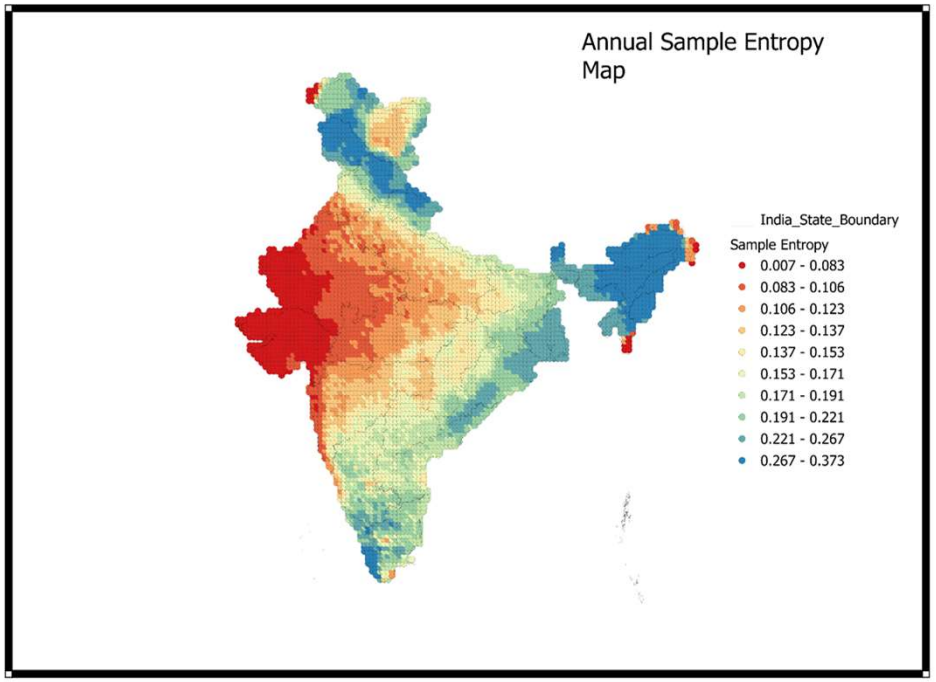
After Running the code it gave an array of Sample Entropy, Which was repeated for 5 times.

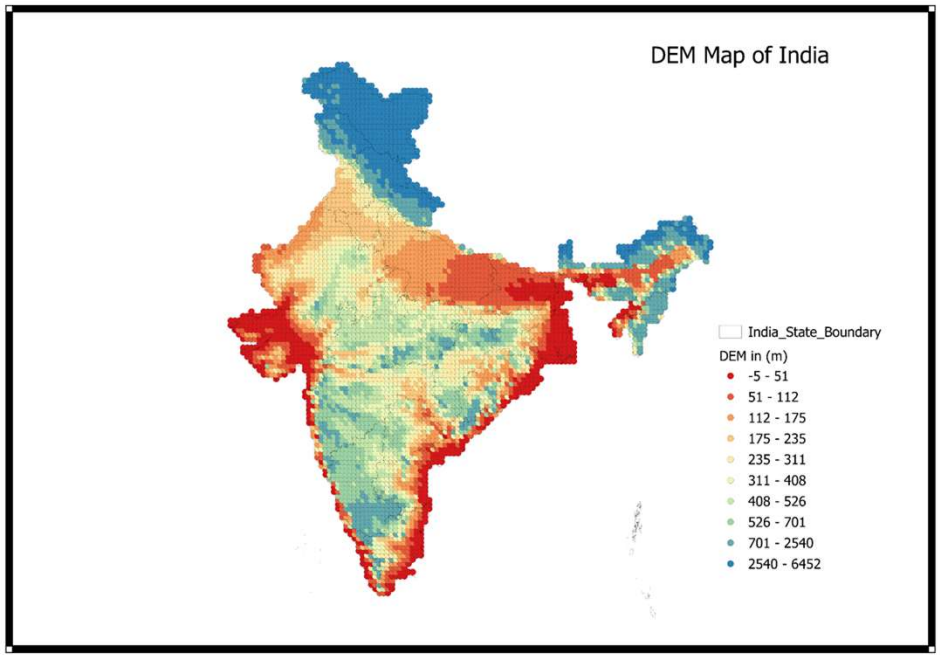
Lat	Long	SampleEntropy
8.25	77.25	0.233802
8.25	77.5	0.133574
8.25	77.75	0.172892
8.5	77.25	0.308817
8.5	77.5	0.162274
8.5	77.75	0.146528
8.5	77	0.319453
8.5	78	0.11859
8.75	76.75	0.330875



4789 no of Rows were produced.

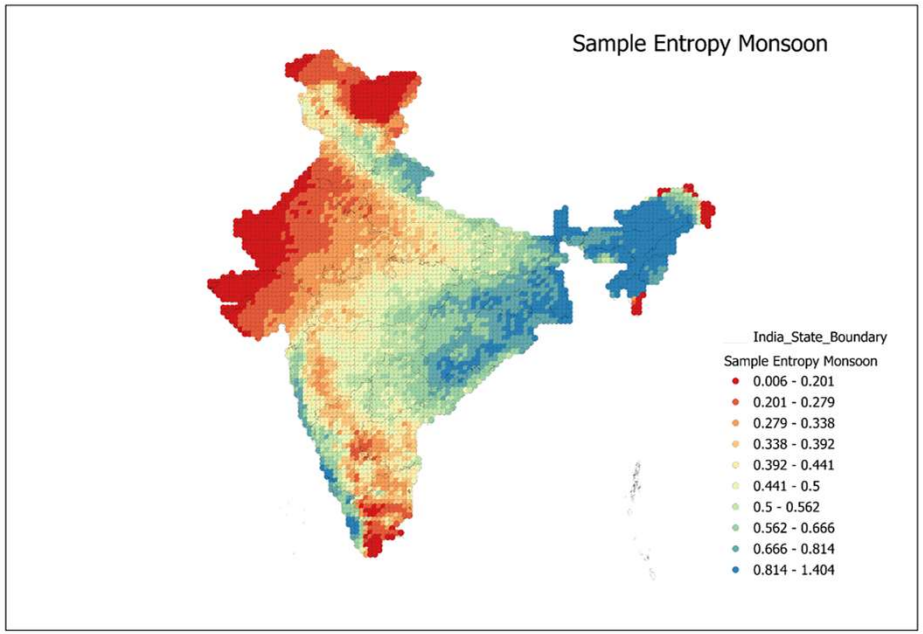
Results Sample Entropy

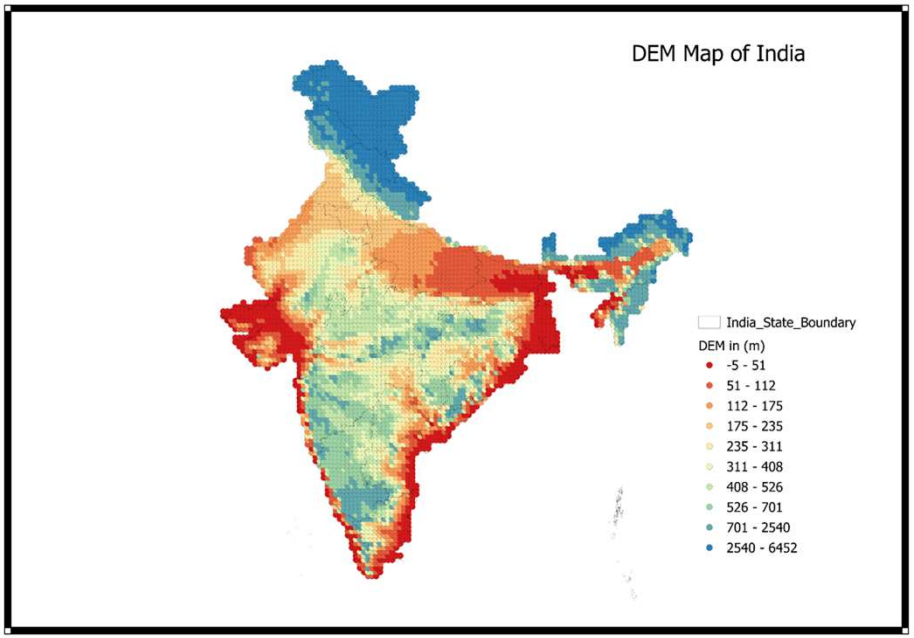




Pearson Correlation Coefficient: 0.33607796436521137

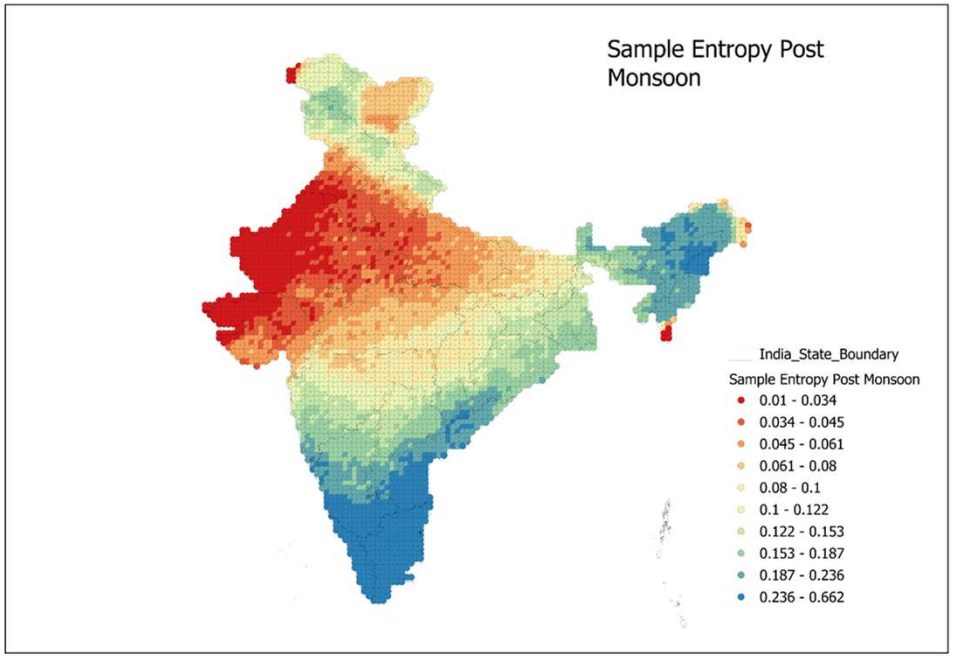
Results Monsoon

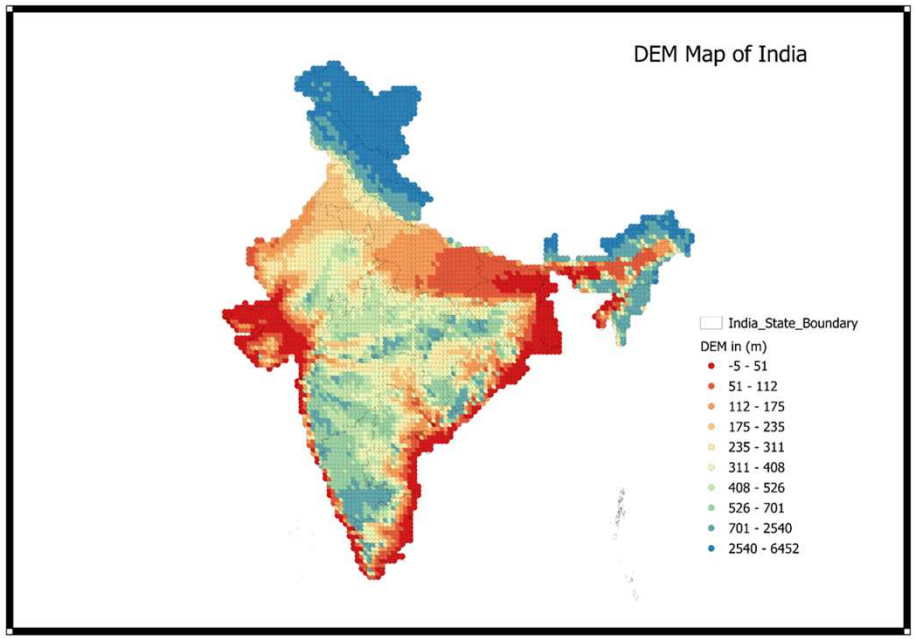




Pearson Correlation Coefficient: -0.1401375121323287 2

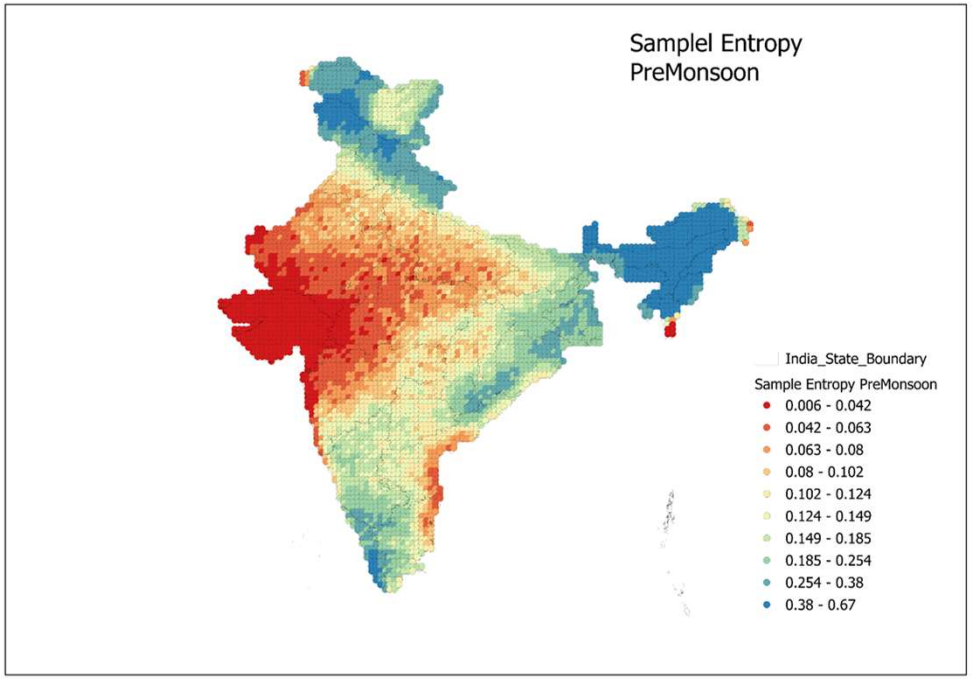
Results Post Monsoon

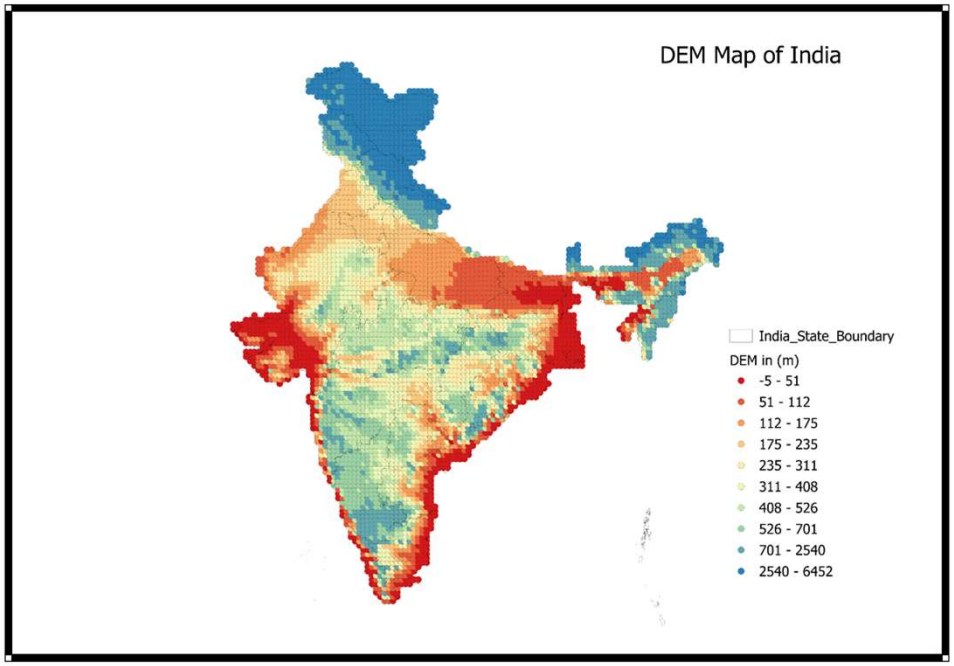




Pearson Correlation Coefficient: 0.4013348882656683

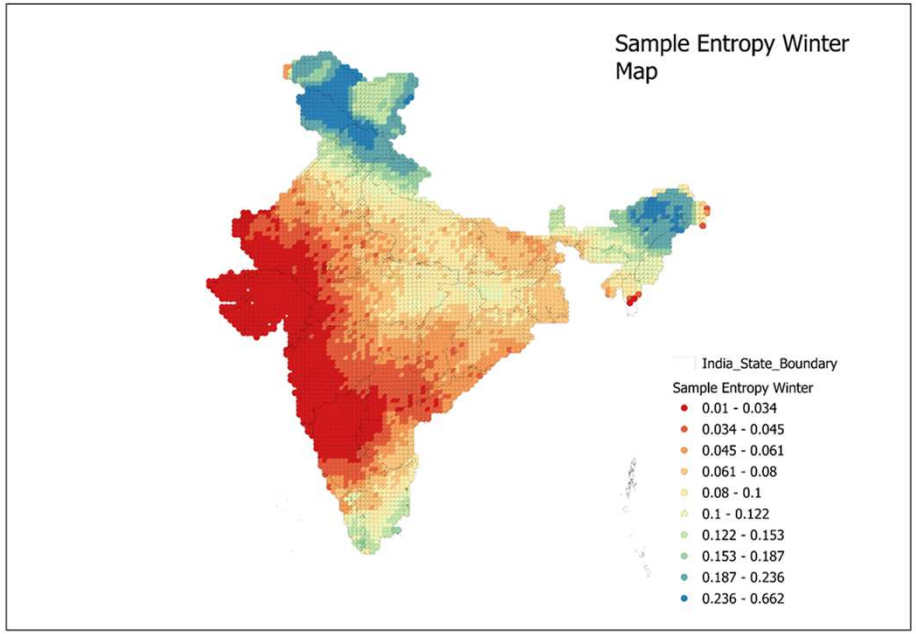
Results Pre Monsoon

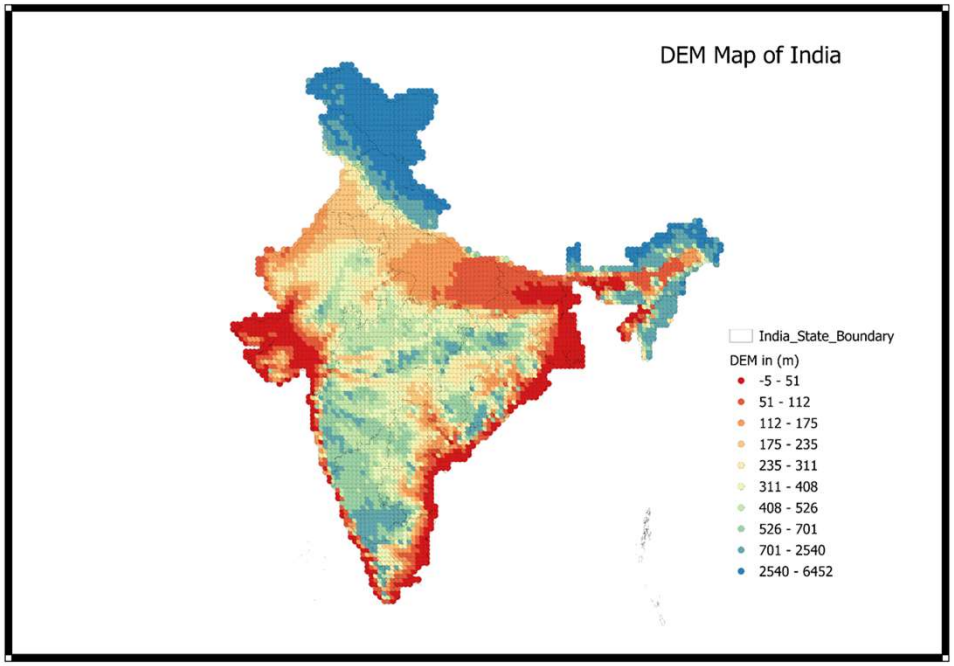




Pearson Correlation Coefficient: 0.40133488826566 83

Results Winter





Pearson Correlation Coefficient: 0.4838882656683

Statistics For each seasons

The range of Monsoon is having the highest whereas Pre and Post shows a drastic change.Also it is showing Winter having the lowest of the entropy indicating less variation.

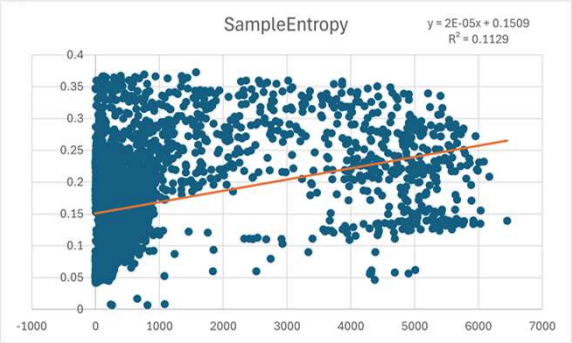
```
Basic Statistics for Sample Entropy:
count    4788.000000
mean        0.481237
std         0.238317
min         0.005571
25%         0.308333
50%         0.441432
75%         0.610079
max         1.404248
Name: SampleEntropy, dtype: float64
Minimum Sample Entropy: 0.005571288
Maximum Sample Entropy: 1.404247793
```

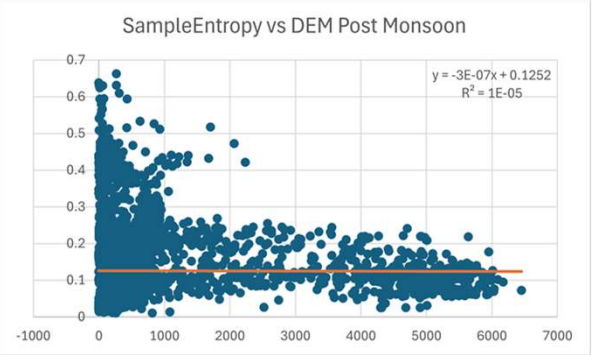
```
Basic Statistics for Sample Entropy:
count    4788.000000
mean        0.165602
std         0.133468
min         0.005611
25%         0.072620
50%         0.124224
75%         0.220477
max         0.670180
Name: SampleEntropy, dtype: float64
Minimum Sample Entropy: 0.005610671
Maximum Sample Entropy: 0.670180142
```

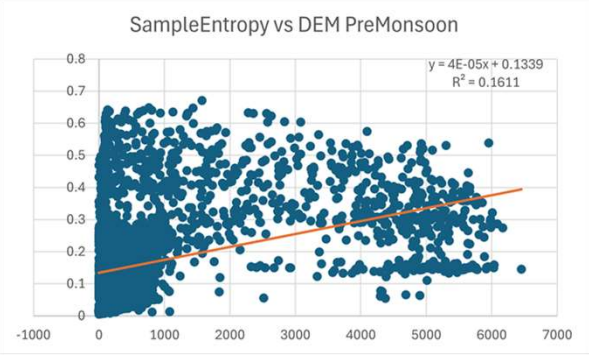
```
Basic Statistics for Sample Entropy:
count    4788.000000
mean        0.164838
std         0.070052
min         0.006532
25%         0.114721
50%         0.153069
75%         0.205671
max         0.372915
Name: SampleEntropy, dtype: float64
Minimum Sample Entropy: 0.006531578
Maximum Sample Entropy: 0.372915189
```

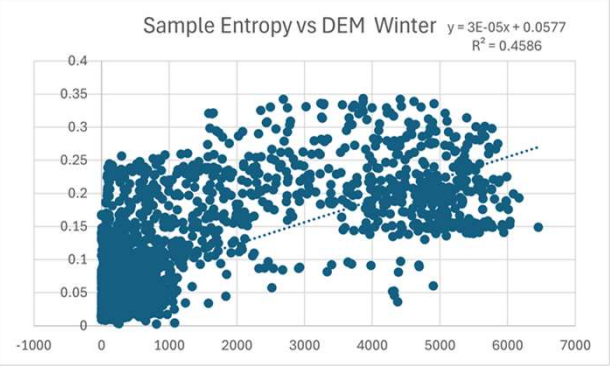
```
Basic Statistics for Sample Entropy:
count    4788.000000
mean        0.083611
std         0.064517
min         0.002762
25%         0.039209
50%         0.067710
75%         0.096694
max         0.343269
Name: SampleEntropy, dtype: float64
Minimum Sample Entropy: 0.002762494
Maximum Sample Entropy: 0.343269491
```

Scatter Plots of Every Season with respect to DEM





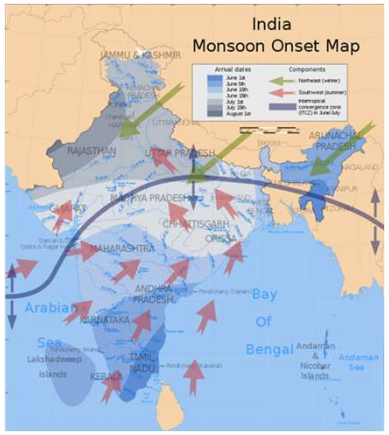




Conclusions

- It has a negative correlation between Latitude and positive relationship with Longitude.
- The variation is highest in the NE part of India in almost all the Seasons.
- The Southern part of India Results in high entropy during the post monsoon season.
- The highest Range of Entropy was seen during Monsoon Season.

```
Pearson Correlation Coefficient:
                    lat      long  SampleEntropy
lat            1.000000  0.054839      -0.131861
long           0.054839  1.000000       0.774418
SampleEntropy -0.131861  0.774418       1.000000

Spearman Correlation Coefficient:
                    lat      long  SampleEntropy
lat            1.00000 -0.000310      -0.222960
long          -0.00031  1.000000       0.745233
SampleEntropy -0.22296  0.745233       1.000000
```



References

- Spatial Patterns of Sample Entropy Based on Daily Precipitation Time Series in China and their Implications for Land Surface Hydrological Interactions,Xiangyang Zhou,Wenjuan Lei.
- Spatial variability and possible cause analysis of regional precipitation complexity based on optimized sample entropy,Liangliang Zhang,et.al.
- gpsvisualiser.com
- https://www.mathworks.com/matlabcentral/fileexchange