Nonlinear variability of the Indian Summer Monsoon Rainfall

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- Linear Principal Component Analysis (LPCA) technique has been applied by many researchers in the past to study the important modes of variability of rainfall .

- Shukla (*Monthly Weather Review*, 115 (1987) 695–703) used data of 31 Indian meteorological subdivisions, covering entire India and identified the homogeneous regions of seasonal monsoon rainfall variability over India by considering PCA as one of the methods.

- Singh (*Atmospheric Research*, 79 (2006), 317-326) used the PCA for determining the dominant rainfall patterns from rainfall records (1940-1990) over India and estimated the nature of the rainfall distribution and percentage variance

- Non-Linear Principal Component Analysis (NLPCA) technique using Auto-Associative Neural Network has not been applied so far for the study of rainfall variability over India.

Auto-associative neural networks for NLPCA

- PCA is a composite map of the form
  - ✓ $f[s(\boldsymbol{u})]$ such that $(M>P)$
    - $s: R^M \longrightarrow R^P$
    - $f: R^P \longrightarrow R^M$
- Thus a five-layer neural network is sufficient to model this relation
- The desired output of the network is the same as the input
- Applied to the All India summer monsoon rainfall to study non-linear variability

Example of the NLPCA: Lorenz system

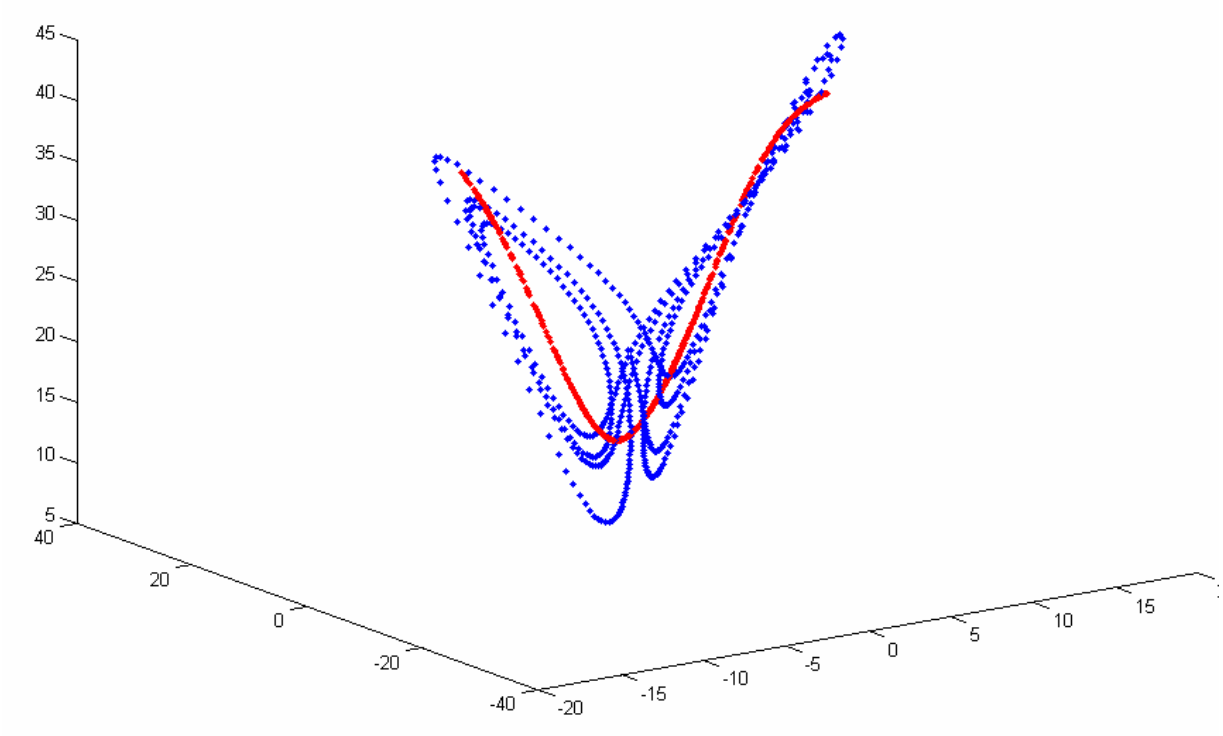
The Lorenz model (Lorenz, 1963) is governed by the equations:

$$\frac{dx}{dt} = \sigma(y - x)$$

$$\frac{dy}{dt} = rx - y - xz$$

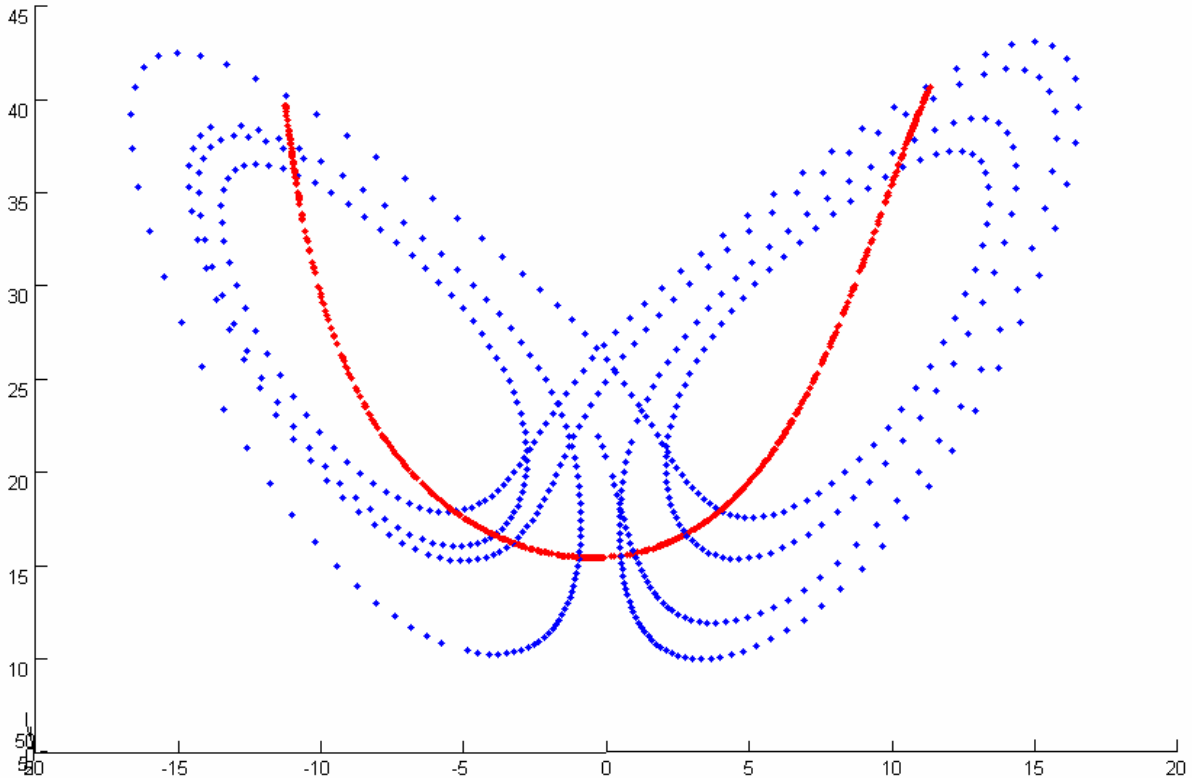
$$\frac{dz}{dt} = xy - bz$$

where $\sigma = 10, b = {}^{8}/_{3}, r = 28$

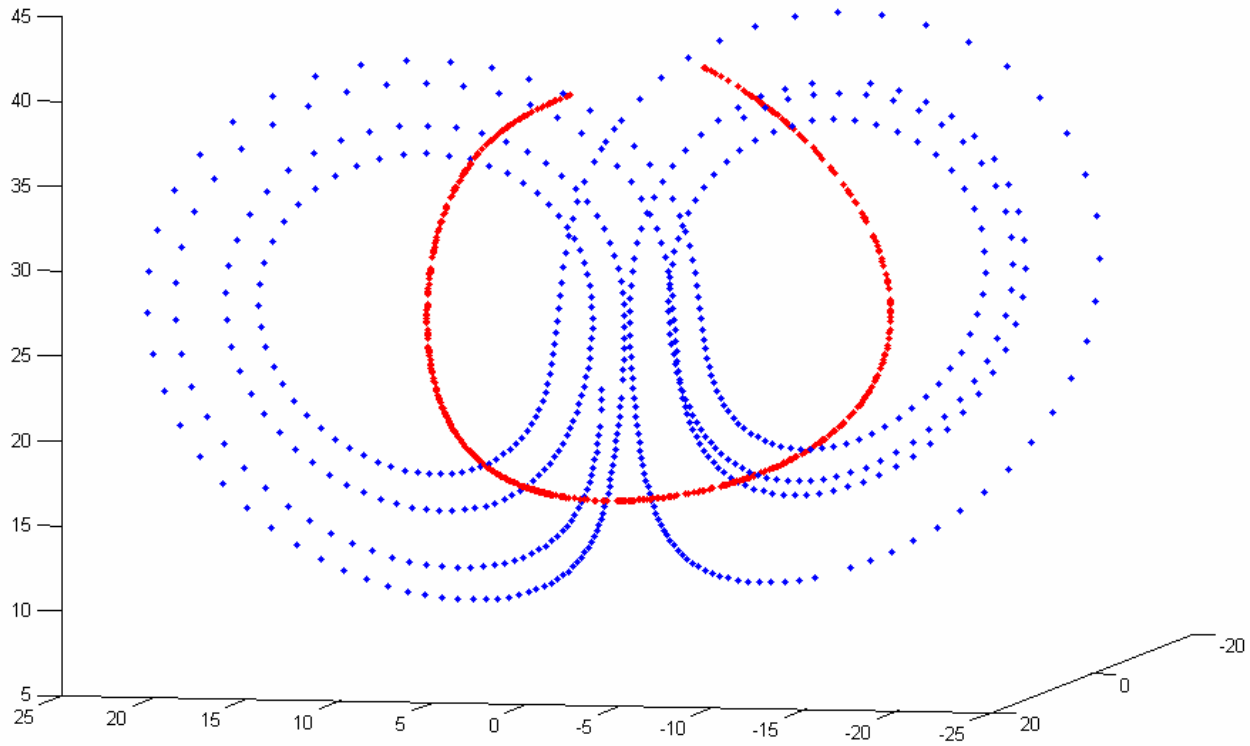


NLPCA of the Lorenz system using auto-associative ANN

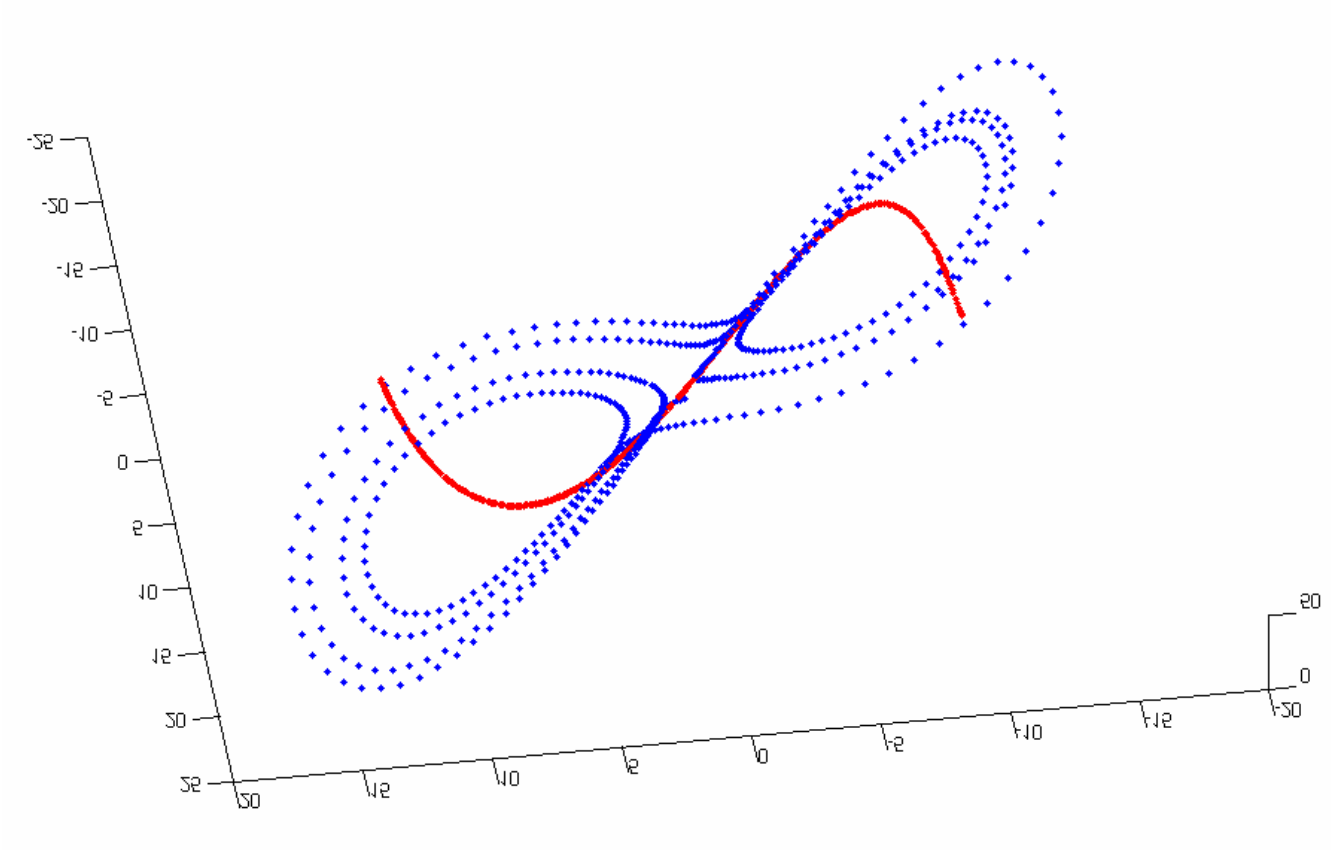
(Blue: Actual data points of Lorenz system; Red: Non-linear PC1)



1st orientation of 2-dimensional view of NLPC of the Lorenz system using auto-associative ANN (Blue: Actual data points of Lorenz system; Red: Non-linear PC1)



2nd orientation of 2-dimensional view of NLPC of the Lorenz system using auto-associative ANN (Blue: Actual data points of Lorenz system; Red: Non-linear PC1)



3rd orientation of 2-dimensional view of NLPC of the Lorenz system using auto-associative ANN (Blue: Actual data points of Lorenz system; Red: Non-linear PC1)

Data

- Gridded rainfall data from 1803 rain guage stations by the IMD for the period 1951-2003

- Geographical area covered in the data is 6.5^0 N-37.5^0 N and 65.5^0 E-101.5^0 E

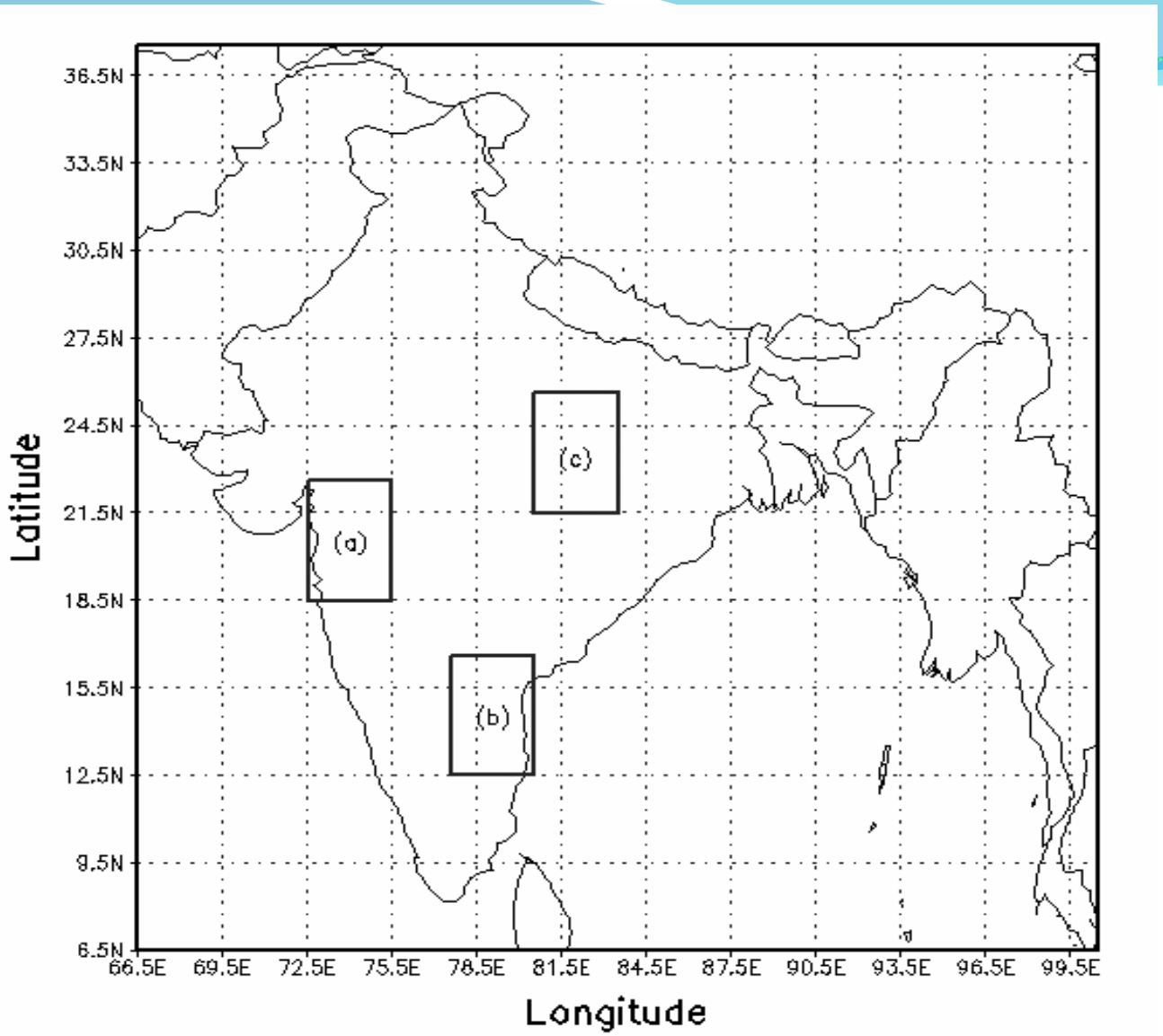
Region of analysis

- Three spatially separated regions of India have been taken to observe the non-linear modes of the rainfall patterns

  - ✓ South-west region (72.5 °E – 75.5 °E and 18.5 °N – 22.5 °N) of high variability

  - ✓ South-east region (77.5 °E – 80.5 °E and 12.5 °N – 16.5 °N) of low variability

  - ✓ Central region (80.5 °E – 83.5 °E and 21.5 °N – 25.5 °N) of moderate variability



Geographical regions of which the NLPCA has been done. The regions are (a) south - west (18.5° – 22.5°N, 72.5° – 75.5°E), (b) south - east (12.5° – 16.5°N, 77.5° – 80.5°E) and (c) central (21.5° – 25.5°N, 80.5° – 83.5°E)

ANN Architecture

- 5 layer MLP
- Error Back-propagation with Delta learning rule
- Sigmoid activation function
- Since all the three regions have 20 grid points, the input layers of the corresponding ANN models have 20 neurons
- Bottle-neck layer has 1 neuron in all the three cases
- The number of neurons in the encoding and decoding layers are 30 for southwest, 30 for southeast and 35 for central region.

Linear PCA and NLPCA comparison

PCA

- The 1st PC corresponding to 1st EOF of the
  - ✓ SW explains 31.2 % of the total variance
  - ✓ Central explains 31.5 % of the total variance
  - ✓ SE explains 24.7 % of the total variance

NLPCA

- The 1st non-linear principal component accounts for
  - ✓ 38 % of total variance in SW
  - ✓ 39.3 % of total variance in central India
  - ✓ 28.7 % of the total variance of SE region

Conclusion

- NLPCA is capable of extracting lower-dimensional features in the patterns which is reflected in the percent of variance of explained which is significantly higher in the case of NLPCA than the traditional PCA