An AI/ML-based study on North Indian Ocean Cyclonic Disturbances and City-specific rainfall: Climatological Analysis and Future Prediction

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ABSTRACT

Extreme weather events including the cyclonic disturbancs (CDs) can cause significant damage to livelihood. Hence, a precise prediction may have great positive impacts on the life and economy. This study is an attempt to use AI/ML-based frameworks for performing city-specific rainfall analysis, and studying North Indian Ocean (NIO) CD activity, and their landfalling over the Indian coasts (both eastern and western coasts) along with the rim countries. The NIO CD-related analysis involves both seasonal and annual variations along with categorization. Also, an effort is made for forecasting as well. NIO CD-related studies are carried out using the ARIMA model, whereas rainfall-related analysis is carried out using techniques like Long Short Term Memory (LSTM) networks, Gated Recurrent Unit (GRU) and Bidirectional LSTM (BiLSTM). The ARIMA model prediction shows a decreasing trend over the North Indian Ocean. An increasing trend is quite visible over the AS, whereas over the BOB, a decreasing trend is seen. On the east coast of India, an increase in landfal is predicted by the ARIMA model over Tamil Nadu, whereas on the west coast, Konkan and Goa is going to experience an increase. In case of the RIM countries, an increasing trend is seen in Bangladesh and IAA (Iran, Arabian Peninsula and Africa). The rainfall-related analysis is carried out over 45 smart cities using 121 years of IMD gridded data by computing monthly averages for the years 1901 to 2021. The model was trained using actual grid point value along with 8 neighbourhood grid points data based on region wise and city wise performance of the three deep learning (DL) models (i.e., LSTM, GRU, and BiLSTM) in terms of two performance indicators i.e. Root Means Squrae Error (RMSE) and Mean Absolute Error (MAE). BiLSTM model found to perform relatively better for all cities and GRU could predict better in places of large range of rainfall variation. Therefore, a combination of BiLSTM and GRU may be considered. In case of univariate rainfall prediction, the RMSE values range from 1.476 (Davangere) to 5.34 (Shillong), and MAE values range from 0.8232 (Jaipur) to 3.72 (Shillong). And, for multivariate forecasting, LSTM model performed better than others for all cities considered where RMSE values range from 1.376 (Tumukara) to 4.951 (Shillong) and MAE values range from 0.821 (Udaipur) to 3.057 (Shillong).

Keywords: NIO, rainfall, ARIMA, LSTM, BiLSTM,

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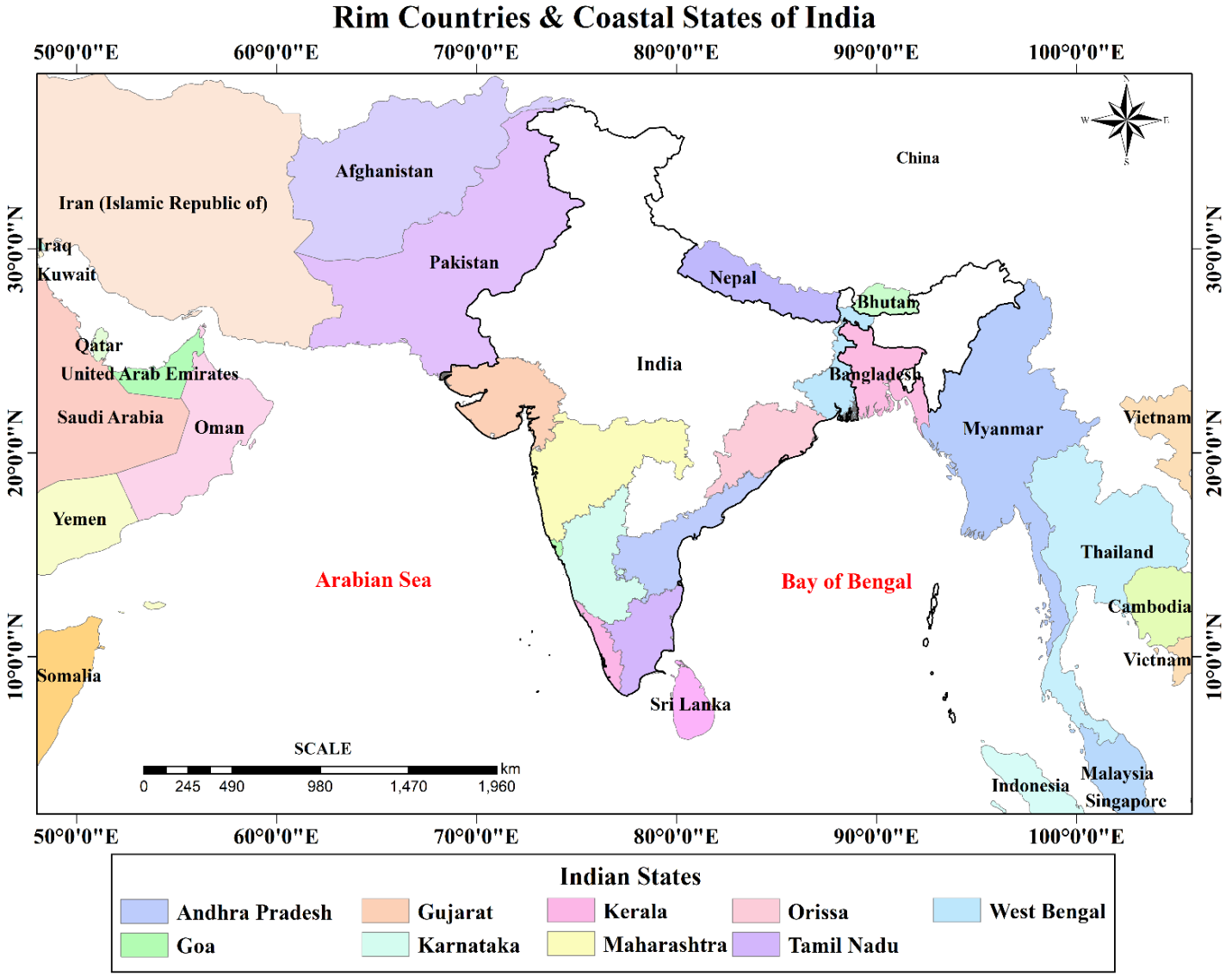
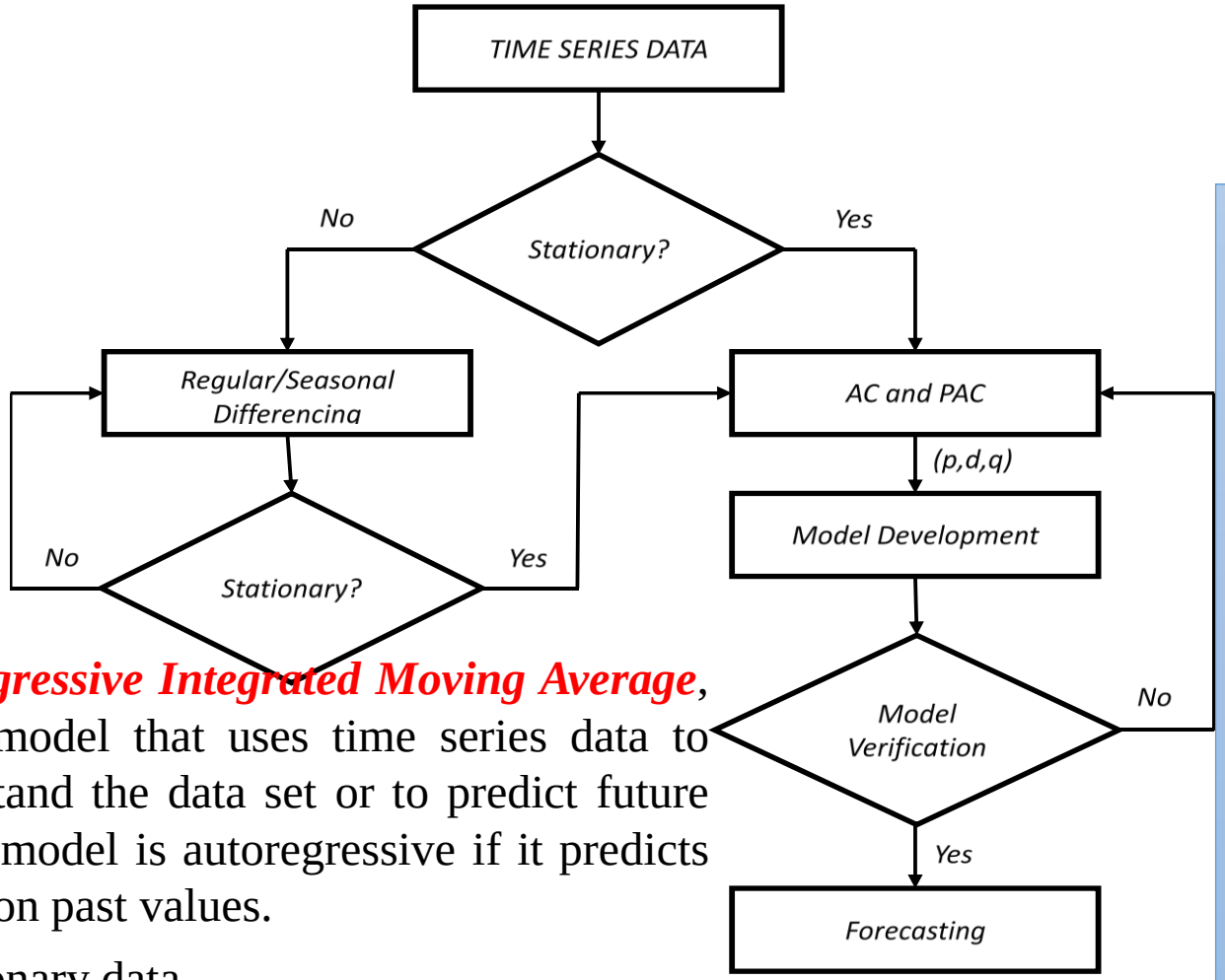
AI/ML Application in the Study of NIO Cyclonic Disturbances



- Climatological analysis of North Indian Ocean (NIO) cyclonic disturbances (CDs) for their occurrence and landfalling activity
- Analysis and prediction of NIO CD activity using ARIMA model
- Analysis and prediction of landfalling activity of NIO CDs over Indian coastal states and rim countries of NIO using ARIMA model

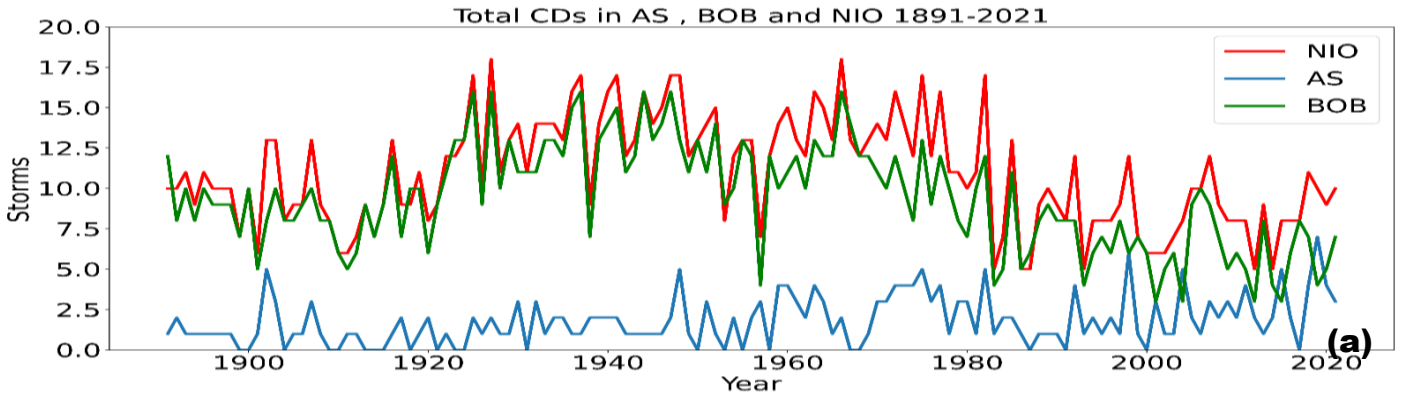
DATA & METHODOLOGY



AR-I-MA : ***Autoregressive Integrated Moving Average***, statistical analysis model that uses time series data to either better understand the data set or to predict future trends. A statistical model is autoregressive if it predicts future values based on past values.

- Model uses stationary data.
- To make data stationary differencing method is required. 'Dickey-Fuller test' is employed-a unit root test that examines the null hypothesis
- Model has three components p, d and q i.e. p is for Autoregressive d is for differencing and q is for moving average

- IMD TC best track data was considered for the period 1891-2021
- For the analysis and future forecast ARIMA model is used.
- For model training and testing, 101 and 30 years of data was respectively considered.
- Forecasting was done till 2050 for both CD occurrence and landfalling activity.



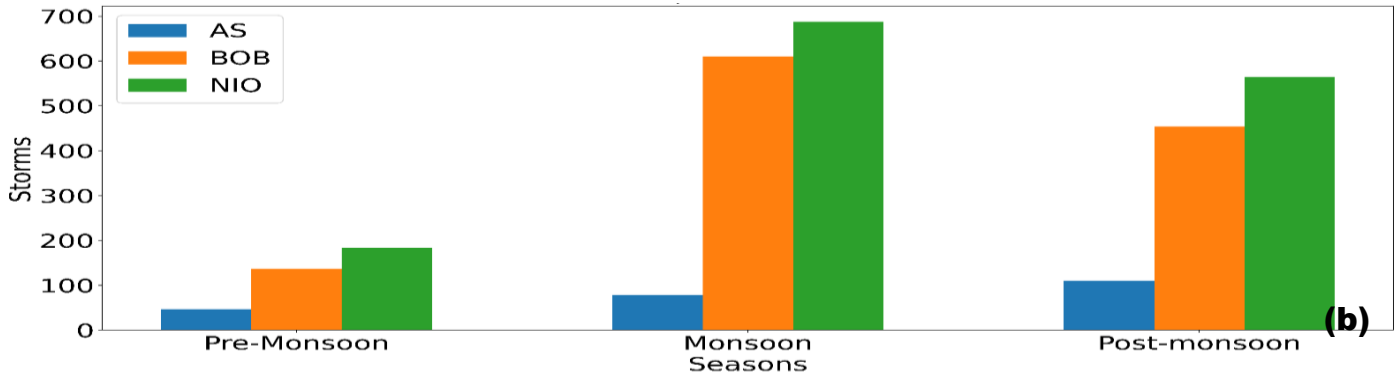
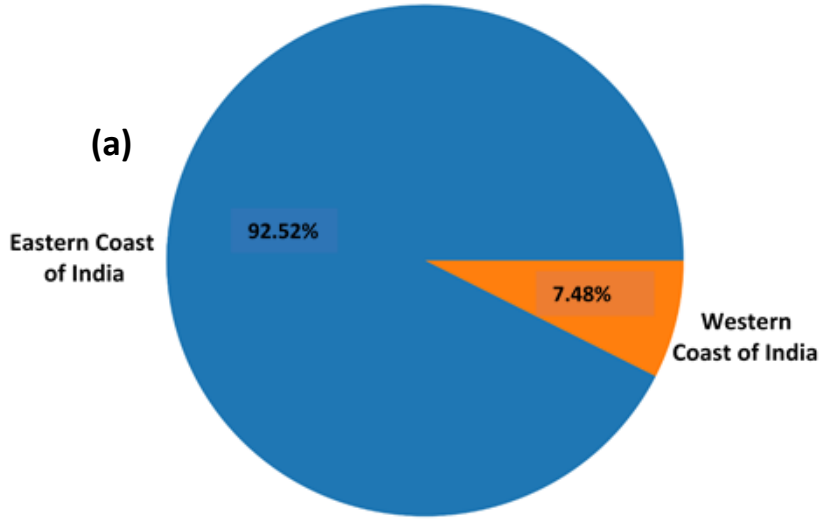


Figure: (a) Frequency of annual CDs over NIO (red line), BOB (green line), AS (blue line), and (b) seasonal distribution of CD occurrence over NIO (green bar), BOB (orange bar) and AS (blue bar).



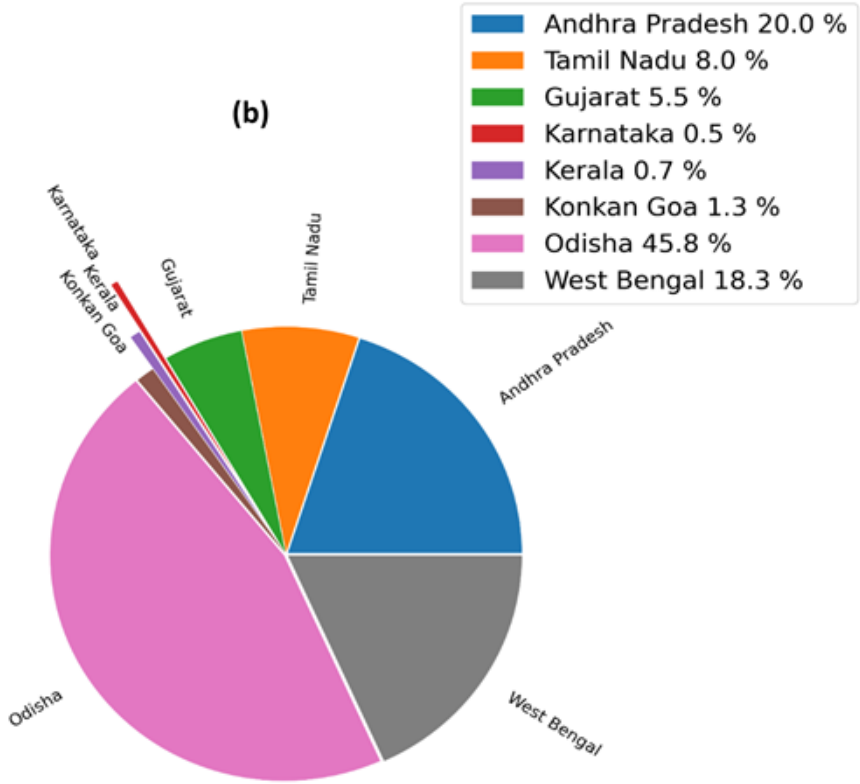
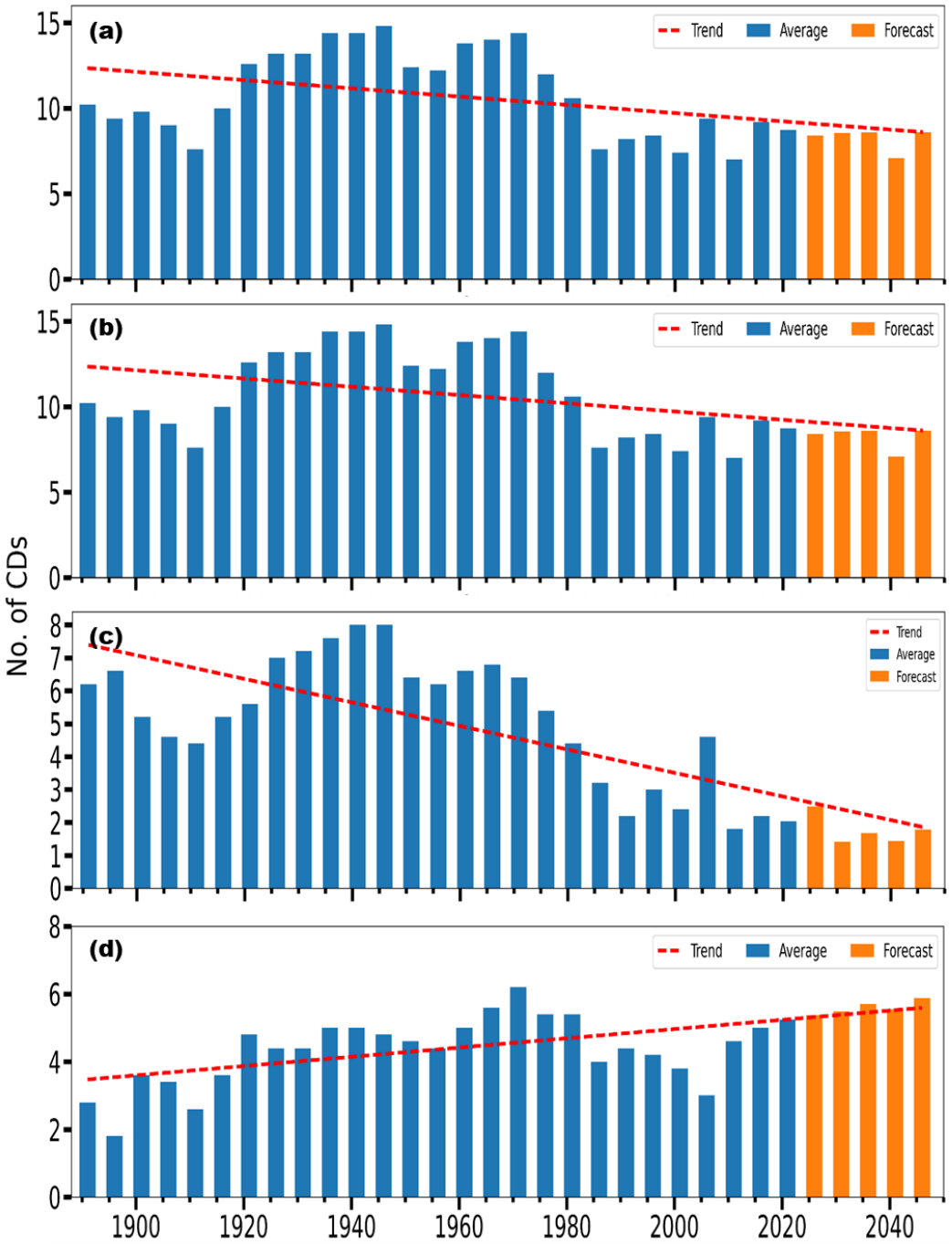


Figure: (a) land falling of CDs over Eastern and western coasts, (b) percentage of landfalling CDs over various coastal states of India



Annual

Pre-monsoon

Monsoon

Post-monsoon

Figure:

(a) Annual variability and prediction (pentad) of CD frequency over **NIO**.

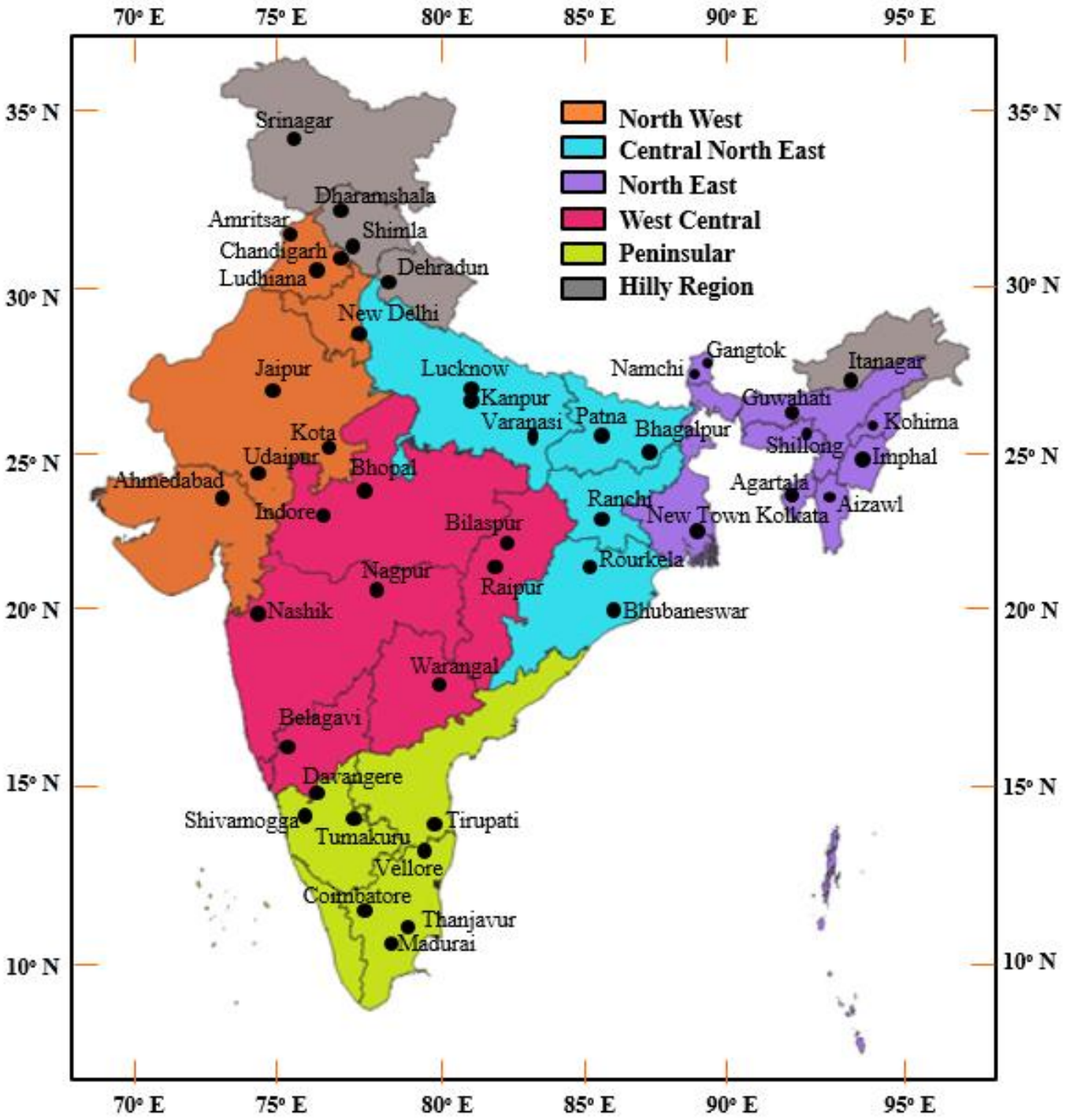
Prediction (pentad) of CD frequency (based on seasons) over NIO, i.e., for (b) pre-monsoon, (c) monsoon, and (d) post-monsoon period.

The period 2022-2050 (orange bars) is the predicted period.

Season	**RMSE**
Pre-monsoon	1.12
Monsoon	1.90
Post-monsoon	1.85

Points to be highlighted further……..

- ✓ ARIMA model, with univariate approach shows a realistic variation of NIO CD activity and predicts them reasonably till 2050
- ✓ A multivariate approach using SST as a dependable variable is employed to predict the CD annual frequency over NIO, where three variants of the model was employed as ‘three new models’.
- ✓ The multivariate approach indicated, the total count of CDs would never be less than 8 and it can reach up to 11 TCs per year in the upcoming decade.
- ✓ The multi-variate approach also suggested 4-6 CDs and at least 3 CDs to be formed annually in the years till 2050.



AI/ML applications in city-based rainfall analysis and forecasting

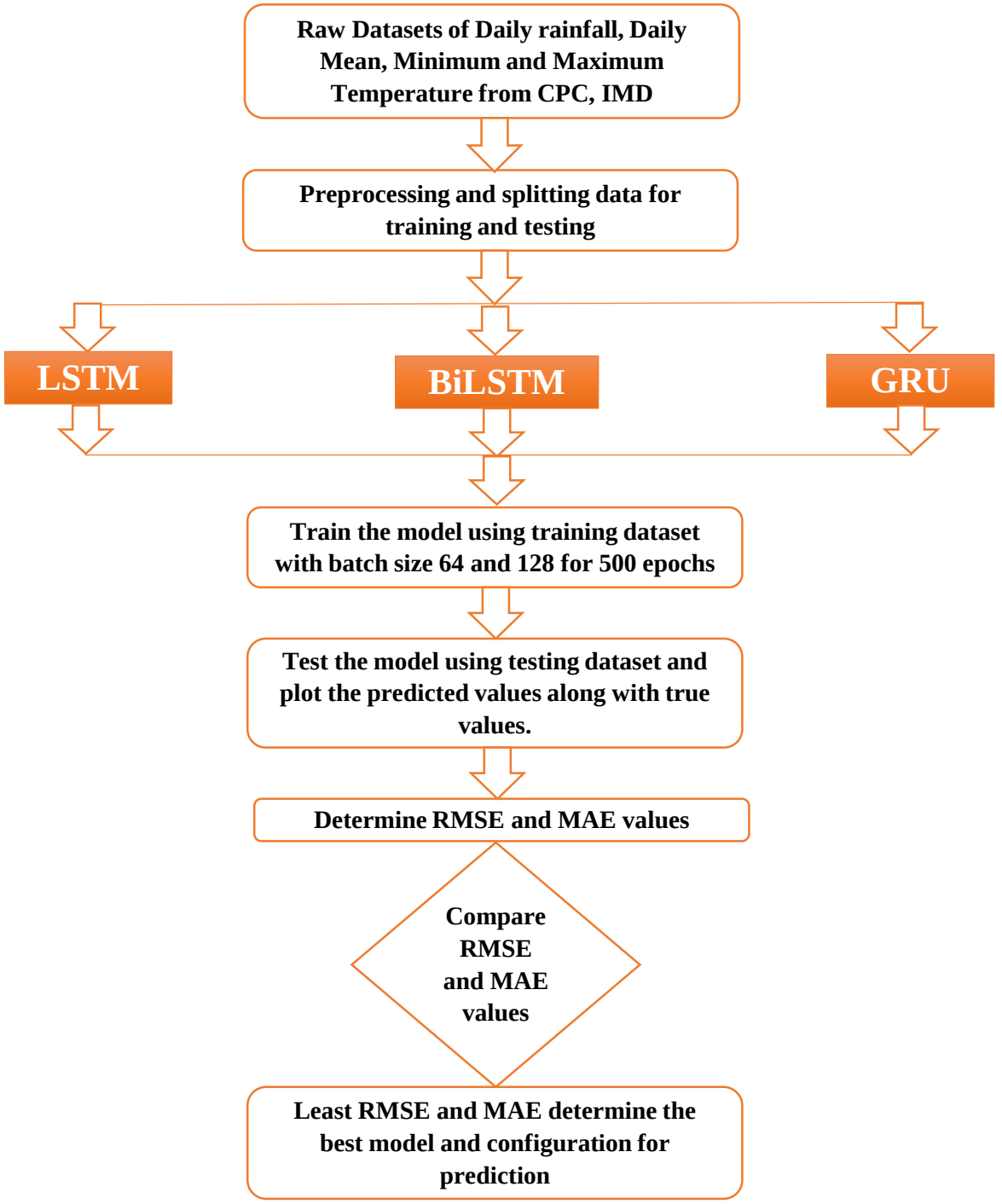
45 selected Smart cities

Source:

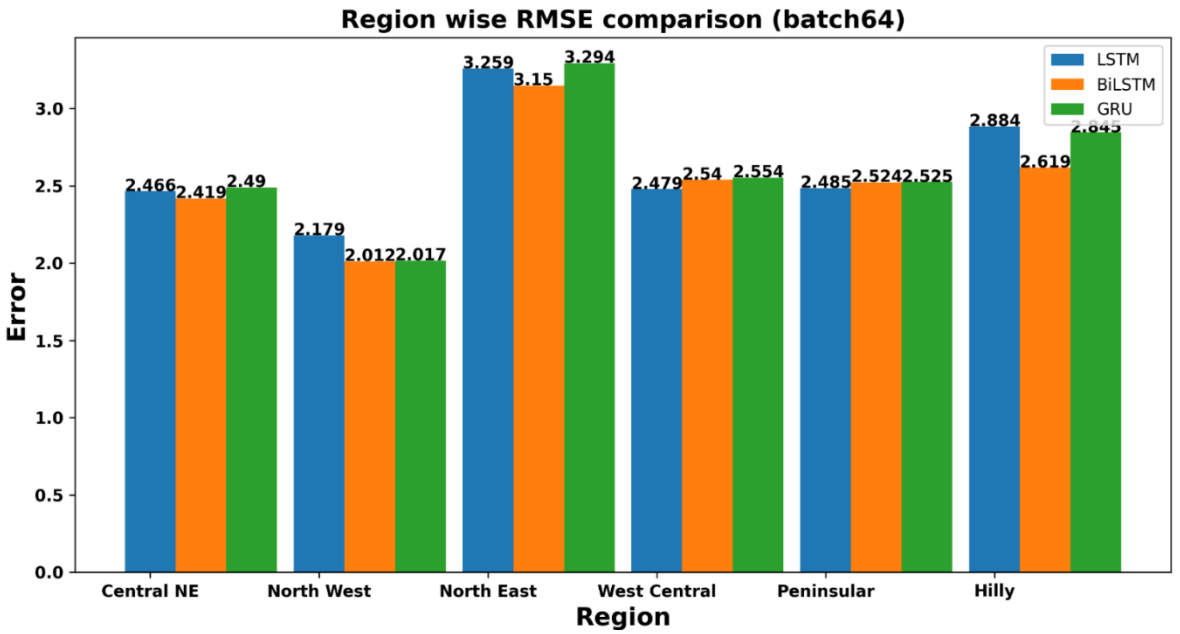
Smart Cities Mission,
Ministry of Housing and
Urban Affairs

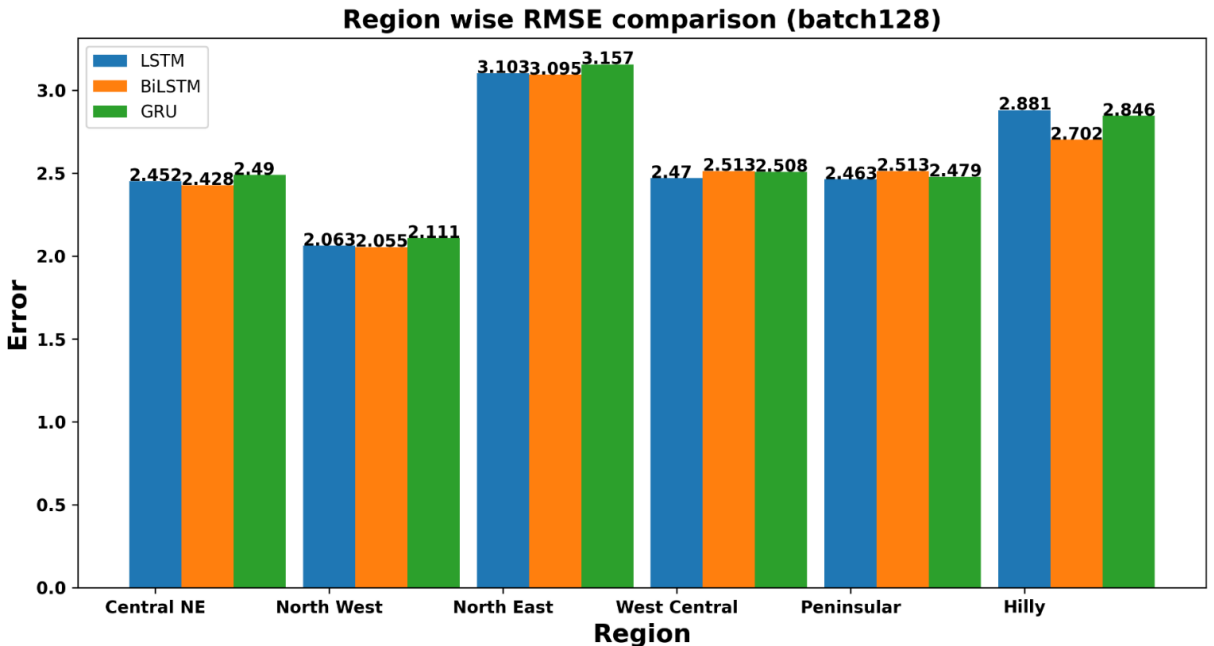
Methodology

Deep Learning Models Adopted

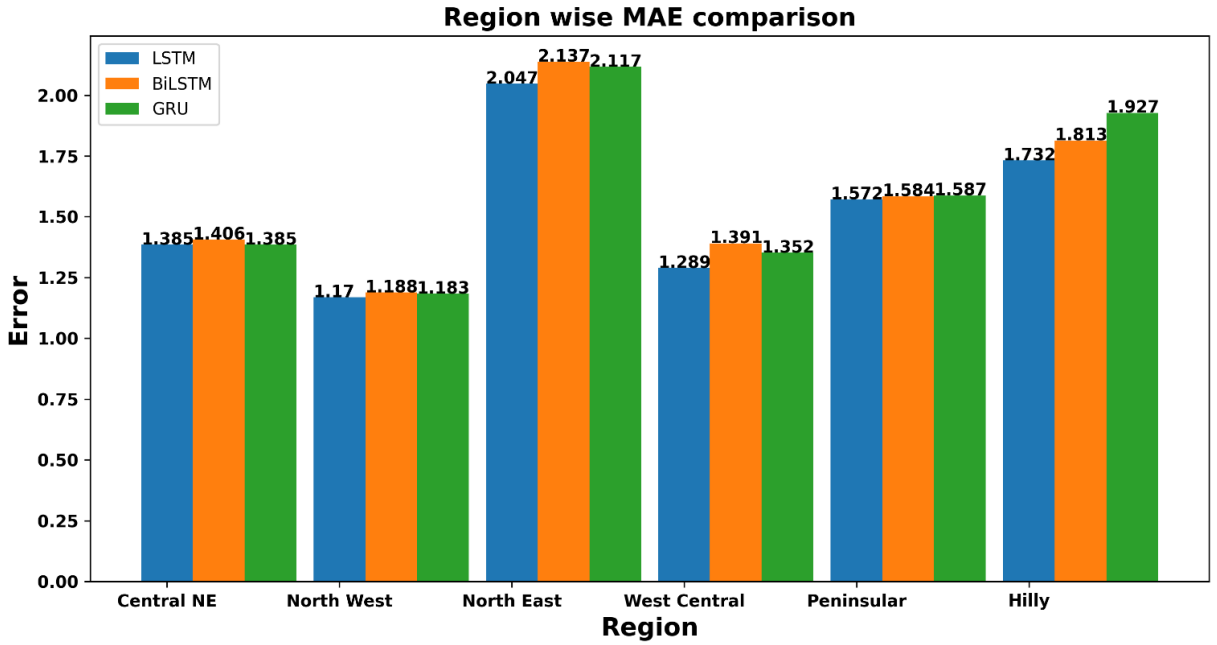


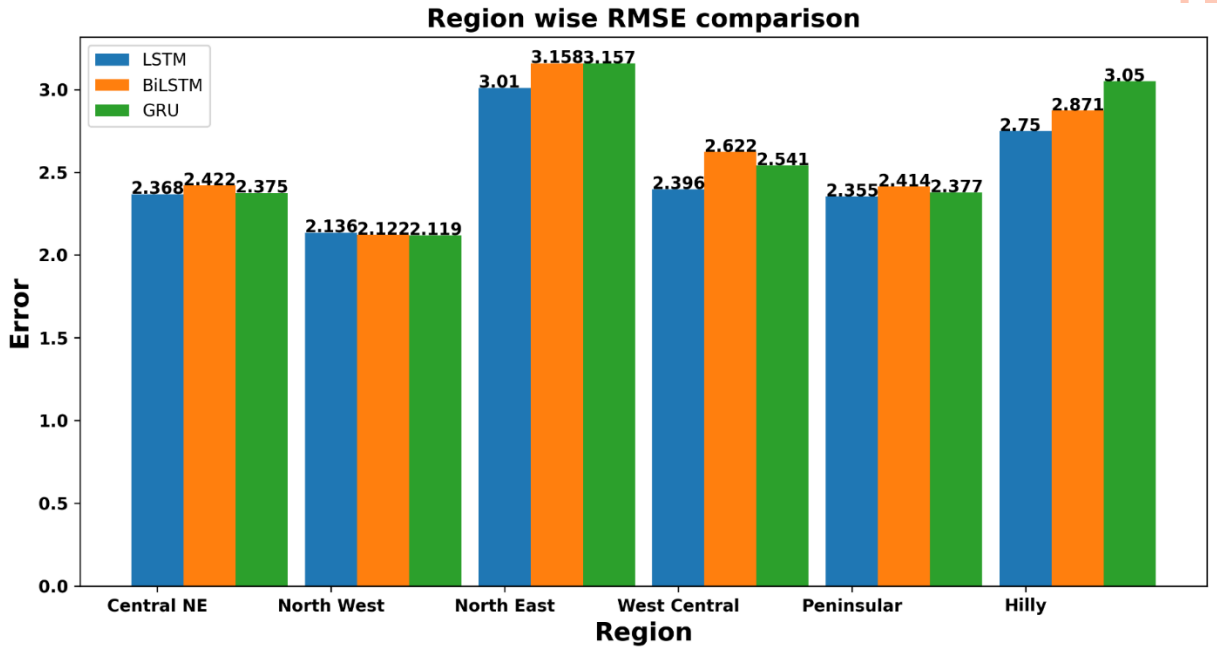
REGION WISE COMPARISON (UNIVARIATE)





REGION WISE COMPARISON (MULTIVARIATE)





Summary From Rainfall Study

- Comparing all the results, it can be said that for univariate forecasting BiLSTM model has performed better than others on an average for all cities considered. GRU has been able to predict better for places of large range of rainfall variation. Hence, a combination of BiLSTM and GRU can be tried.

- The RMSE values range from 1.476 (Davangere) to 5.34 (Shillong).

- The MAE values range from 0.8232 (Jaipur) to 3.72 (Shillong).

- For multivariate forecasting, LSTM model has performed better than others on an average for all cities considered. RMSE values range from 1.376 (Tumukara) to 4.951 (Shillong). MAE values range from 0.821 (Udaipur) to 3.057 (Shillong).

- Deep learning models have nothing to do with actual dynamics of the rainfall. But it depends on the correlation of the input parameters. In fact, its prediction is based on the sequence of the input parameters. The model learns the variation of the rainfall with respect to variation of the input parameters from the training set and it predict the rainfall on the basis of training. So, in this work, these techniques are explored.

- AI/ML framework may provide some additional understanding to what we can get with the usual way of analysing the available data sets. For instance, such a framework can always be helpful in the data based future prediction…..

- In order to identify the primary issues encountered and to develop an effective ML model, researchers need to have a decent understanding of the primary objective concerning climate studies besides the relevant AI/ML framework.

- AI/ML applications in weather and climate science will keep on growing rapidly in the coming years as more and more sophisticated ML architectures are becoming available with easy deployment processes.

- AI/ML may be used within many components of NWP workflow which would make the complicated flow easier.

Thank You.