

Fog Prediction in North India using AI

Aug 30, 2021



Motivation

- Major fog in North Indian IGP during peak winter months (Nov-Feb)
- Impacts flight operations, road accidents, agriculture.

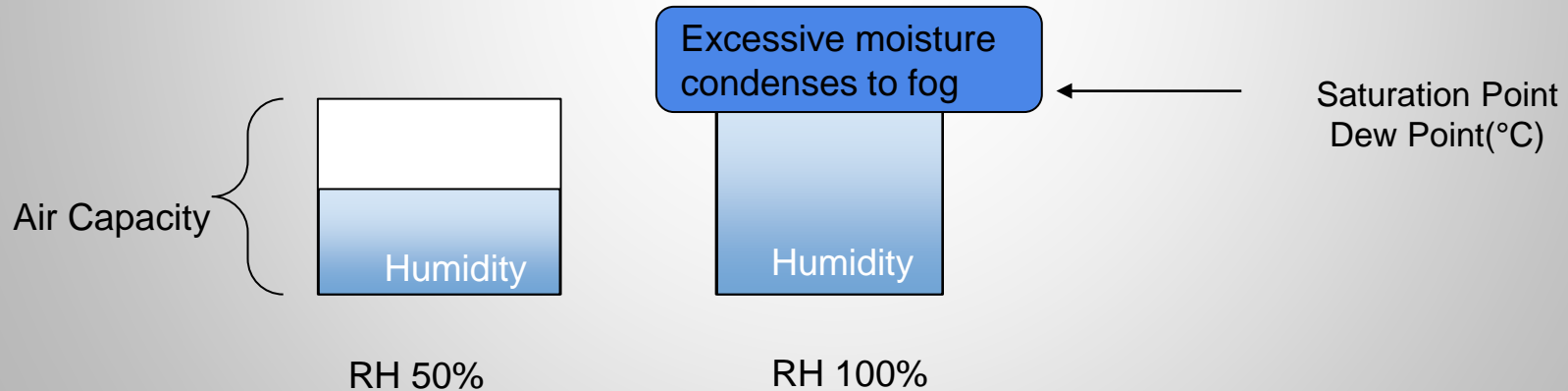


Fog: Definition

Fog is caused by tiny water droplets suspended in the air, reducing visibility at the Earth's surface

Fog is measured w.r.t. visibility. *Visibility* is the measure of distance upto which an object can be perceived.

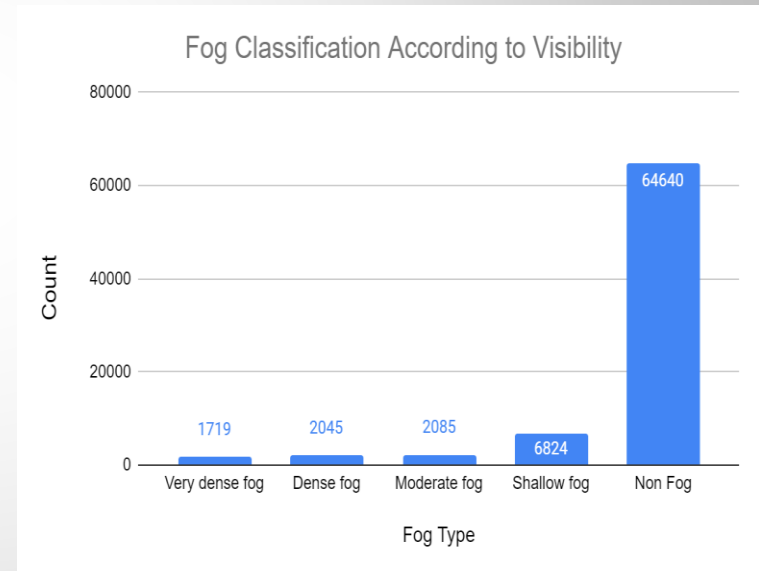
If observed visibility at a location is below 1 km, then it is considered foggy. Otherwise, mist! (WMO 2003)



Fog Classification

- Temperature falls to low values, making water molecules condense.

Fog Based On Visibility	Visibility Range (m)
Very dense fog	<50
Dense fog	51 - 200
Moderate fog	201 - 500
Shallow fog	501 - 1000



Fog Types On Indian Landmass

Types of fog:

- **Radiation Fog**
- Advection Fog
- Precipitation Fog
- Evaporation Fog
- Upslope Fog
- Valley Fog
- Freezing Fog
- Ice Fog

Radiation fog

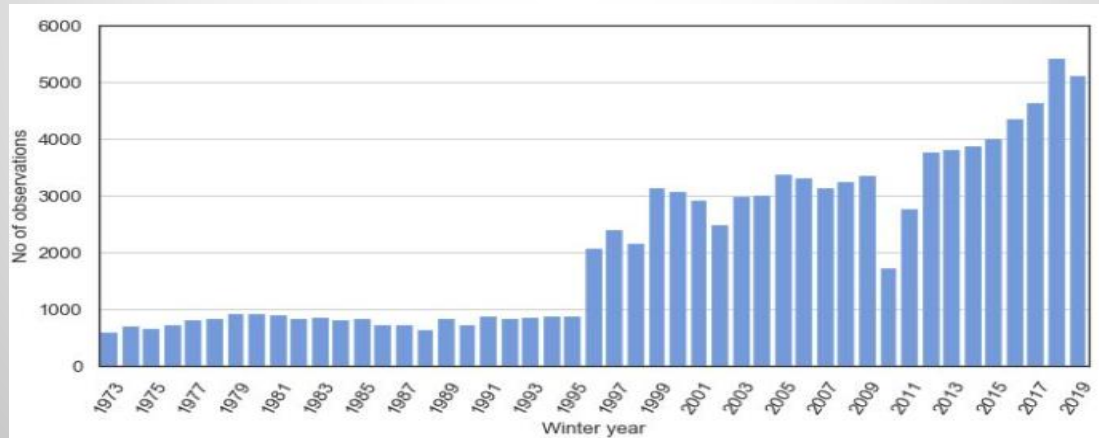
- Requires Radiative Cooling
- Clear Skies
- High Humidity value



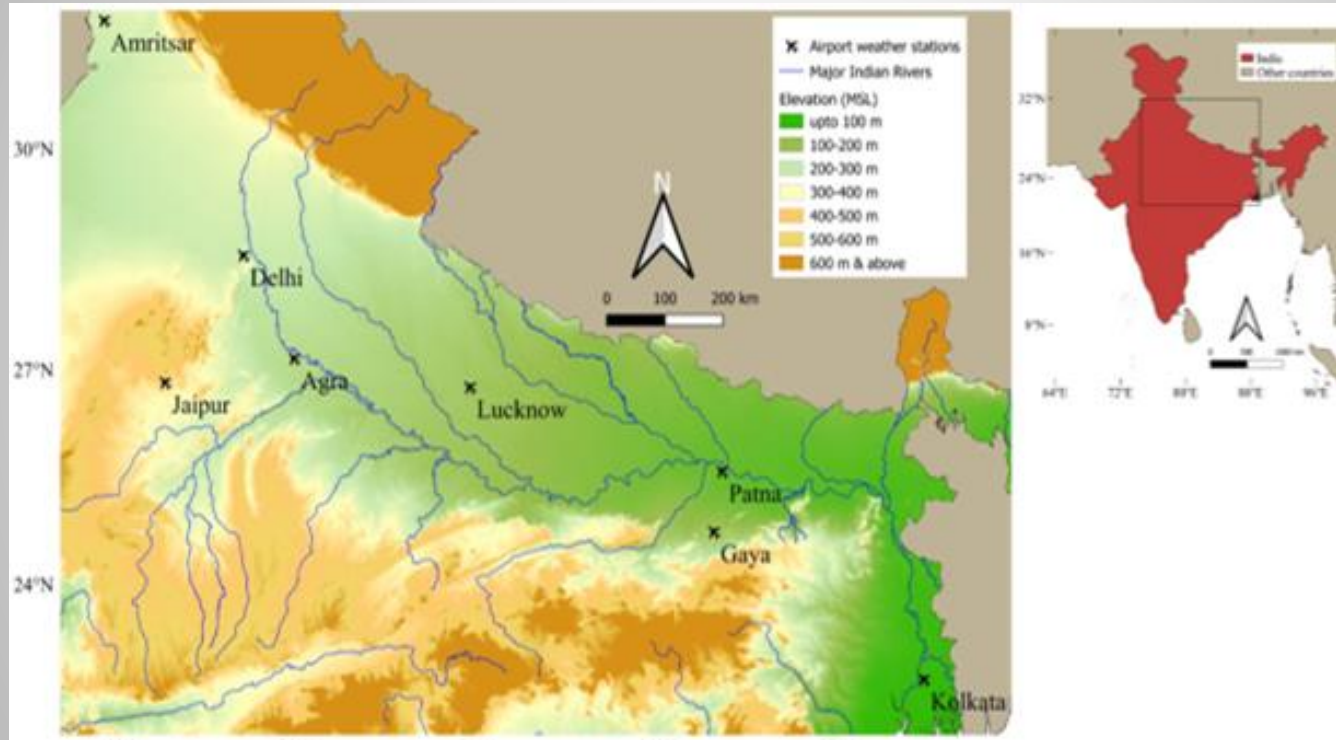
Author (year)	Study area (# stations)	Frequency	Objective
Salman et al. (2020)	Hang Nadim Batam Indonesia Airport (1)	1 day	Visibility forecasting with ARIMA using temperature, dewpoint, humidity.
Pithani et al. (2020)	IGIA, Delhi, India (1)	1 h	Capture variability of fog onset, understand fog formation and limitation of current NWP models
Srivastava et al. (2017)	Ghaziabad, Delhi NCR (1)	1 day	Observation-based climatology and ARIMA forecasts. Predicting number of foggy days, onset, dissipation, duration, intensity
Bednar et al. (2010)	UAE (10)	1 h	Fog spreading as well as fog formation models
Ferrari et al. (2015)	Canberra International Report, Brazil (1)	1 h	Fog classification (binary) using multilayer perceptron
Dewi et al. (2019)	Wamena Airport, Indonesia (1)	1,2,3 h	Fog classification using tree based (Stacked Ensemble of Models)
Wang et al. (2017)	Urumqi International Airport (1)	1 h	Multilayer perceptron model for Fog regression

Objectives

- Detect fog events using ground observations of visibility
- Short-range forecasts of visibility at daily & seasonal scale
- Identify onset/departure of fog
- Historical data of last 20-40 years used for the analysis



Study Area



Data

(In-situ)

→ *Half-hourly* METAR (METeorological Aviation Reports) visibility reports from IEM

→ 1974-2020 (Nov-Feb)

→ Lucknow Airport (VILK)

→ **Attributes**

◆ Visibility (km)

◆ Air Temperature (°C)

◆ Dew Point Temperature (°C)

◆ Relative Humidity (%)

◆ Wind Speed (kmph)

◆ Wind Direction (degree)

◆ Pressure altimeter (inch)

→ Normalization

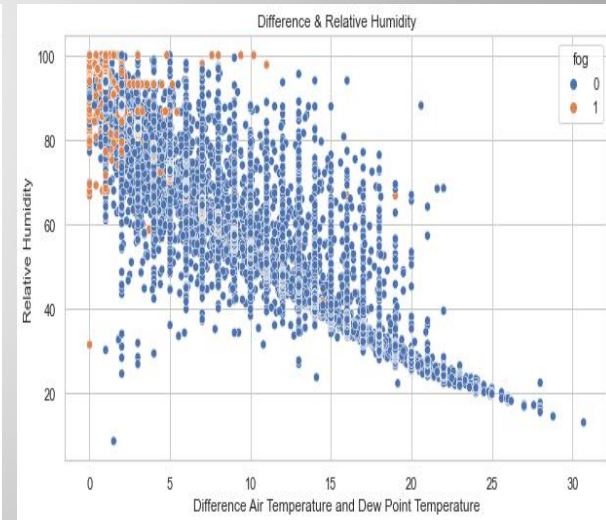
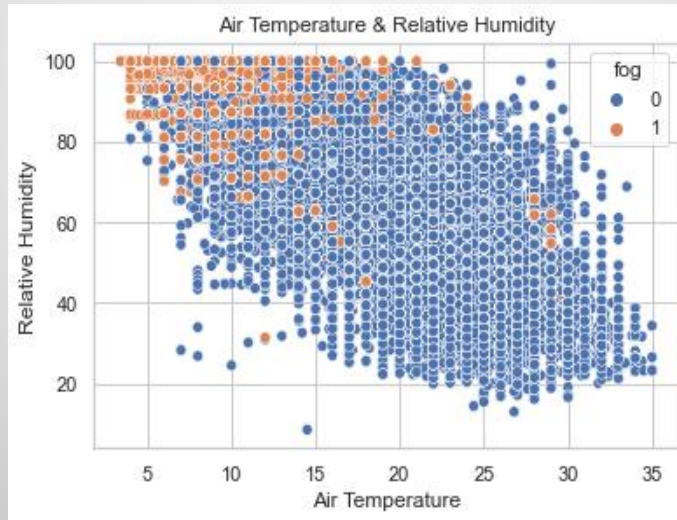
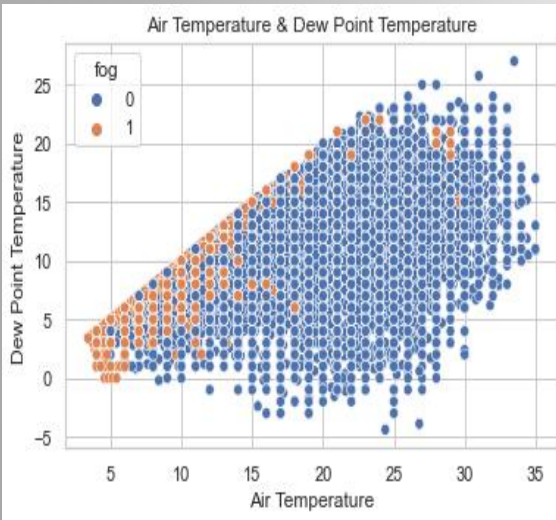
→ Transformation (missing values, units, thresholding etc.)

Modeling Fog

- Machine Learning
 - Regression
 - Classification
- Time Series
- Deep Learning

Data Analysis - Correlation Plots

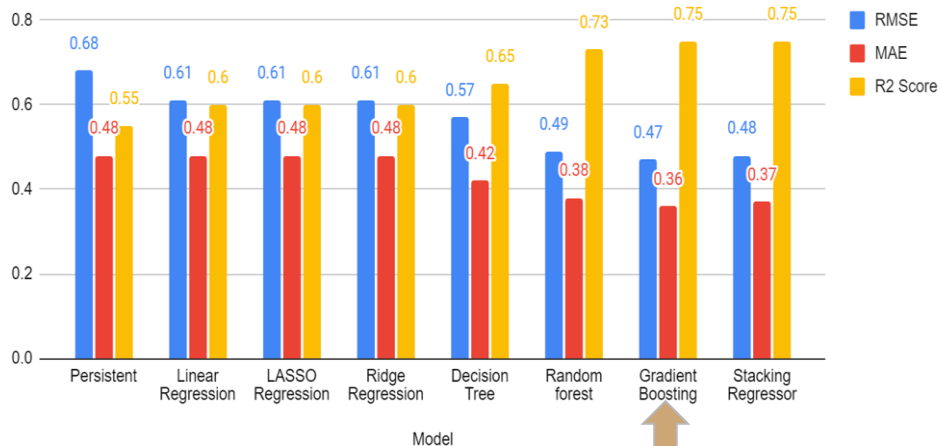
- Dew Point Temperature (T_d)
- Air Temperature (T)
- Relative Humidity Percentage (RH)
- Difference in Air Temp & Dew Point < 2.5 °C
- Calculate Dew point: $T_d = T - ((100 - RH) / 5)$



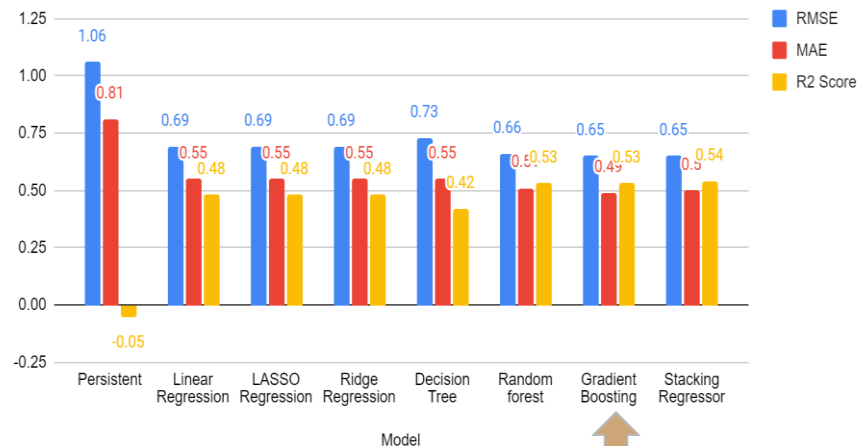
Regression Results

- Lucknow Airport METAR data
- Train Dataset : (2000 - 2015), Test Dataset: (2016 - 2020)

3 HOUR FOG PREDICTION

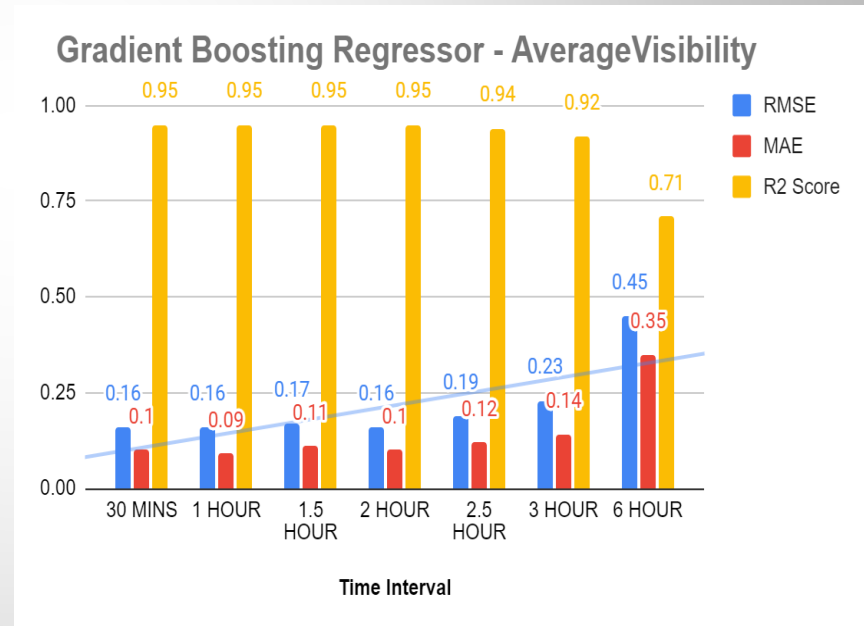
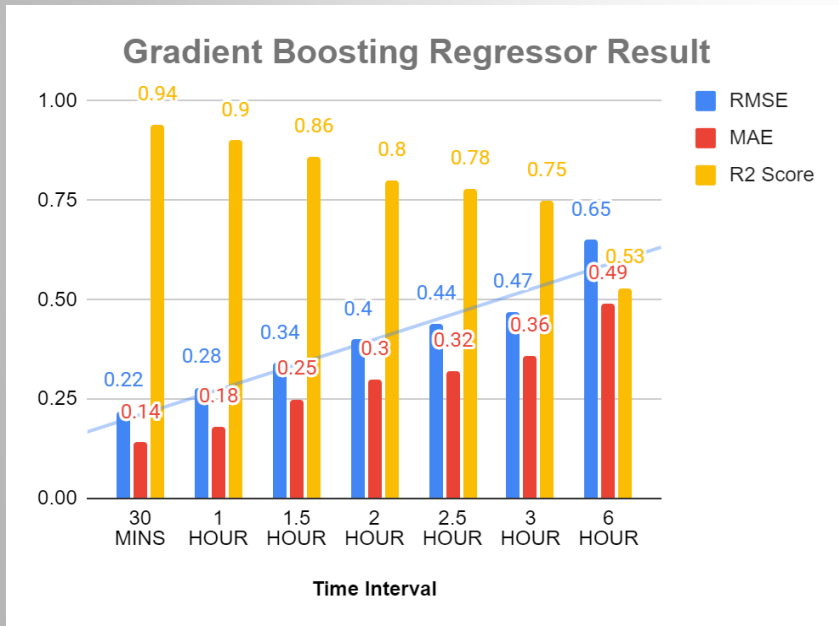


6 HOUR FOG PREDICTION



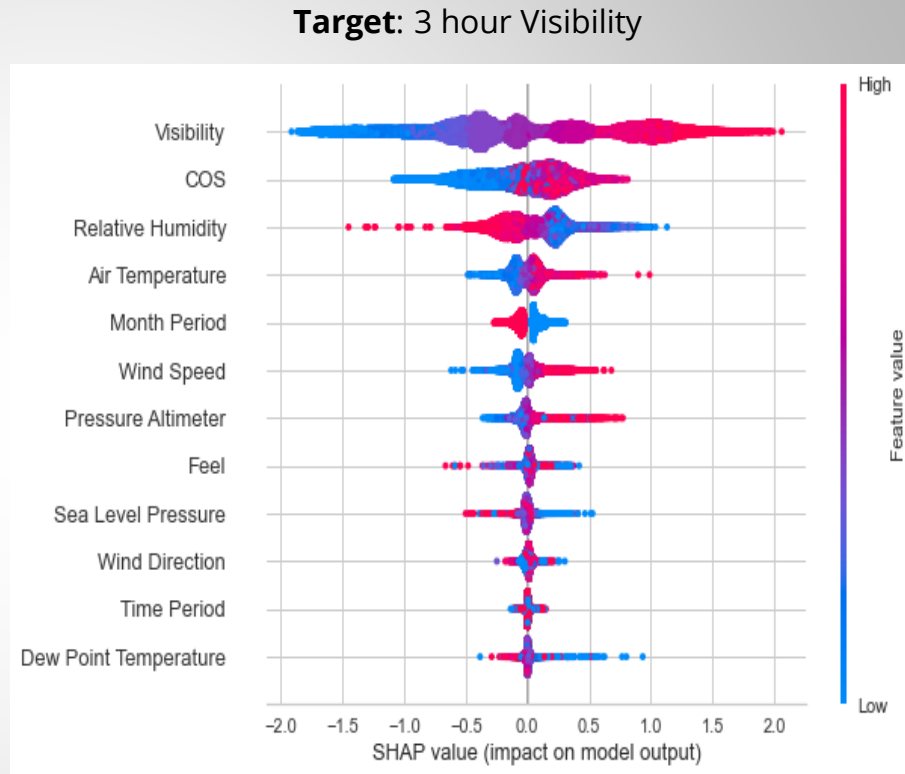
Regression Results (contd.)

- Increase in RMSE with increase in Lead time.
- With addition of variable "Average Visibility", there is reduction in RMSE.



SHAP Values

- *SHAP (SHapley Additive exPlanations)* is a method to explain individual predictions.
- The goal of SHAP is to explain the prediction of an instance x by computing the contribution of each feature to the prediction.
- **Variable**
 - (a) COS: Related to time.
 - (b) Month Period: Dec & Jan.
 - (c) Time Period: Day (6am to 6pm)
Night (6pm to 6am)



Statistical Models

Models that estimate parameters like mean, variance, class probabilities to gather information about data.

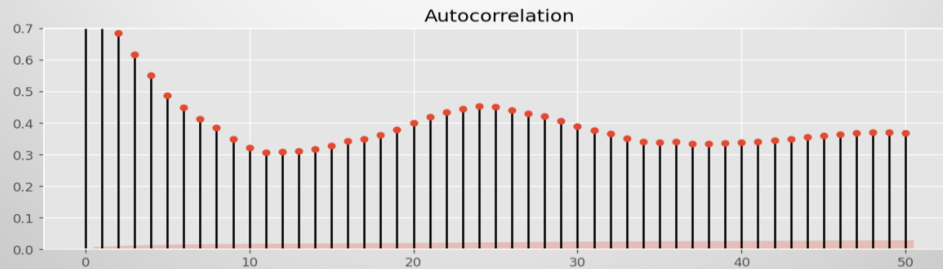
- ❑ Time series is stationary : No upward/downward trend or seasonal effects.
 - ❑ Constant mean
 - ❑ Constant variance
 - ❑ Autocovariance constant over time [homoscedasticity]
- ❑ Time series is stochastic. Each event is random
- ❑ Time series can be cyclic

ARIMA

- ADF test/MK test
- First-order differencing
- Estimation of coefficients - MLE/Grid Search

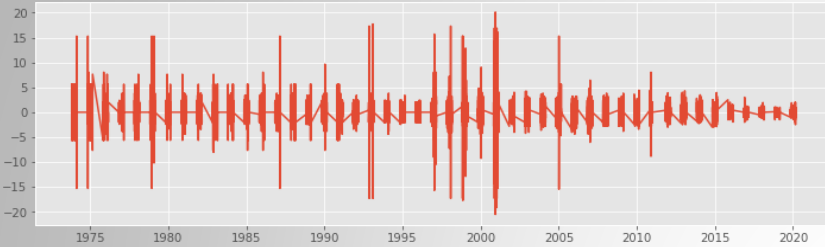
ARDL

- Include lags for exogenous and dependent variables
- Upto 2 lags for visibility, temp, dewpoint, wind speed
- Upto 1 lag for wind direction, altitude

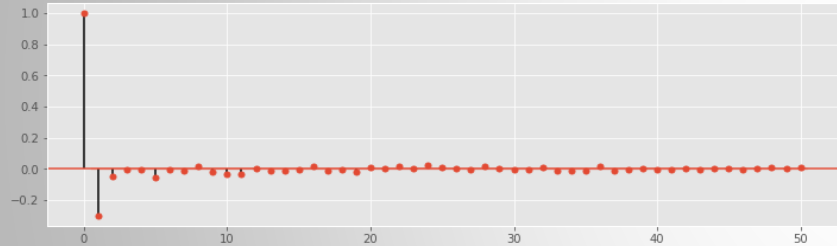


Results

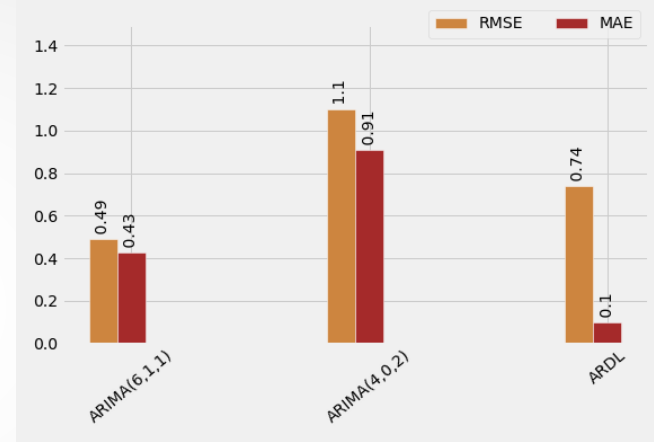
1st Order Differencing



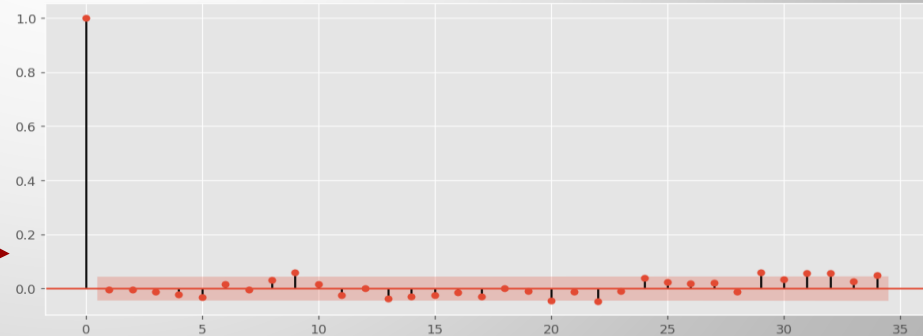
Autocorrelation



Time-Series Models



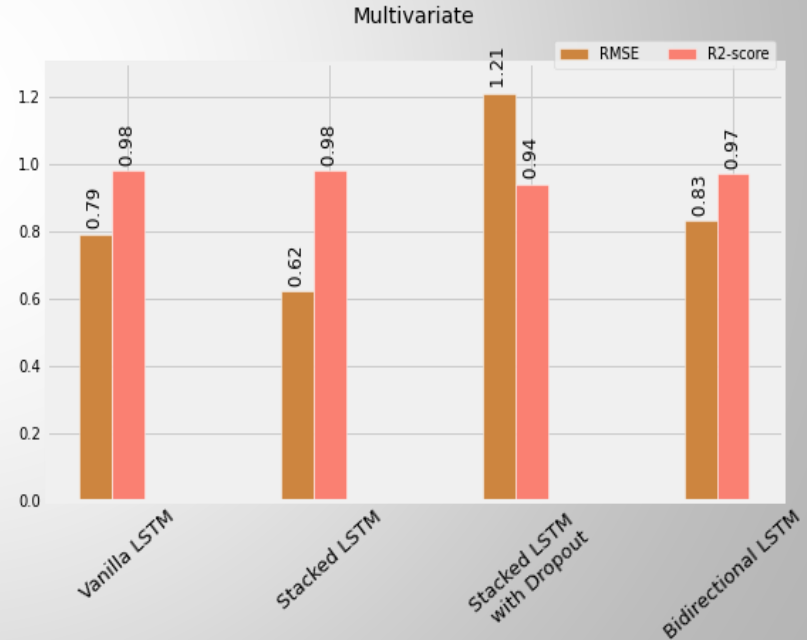
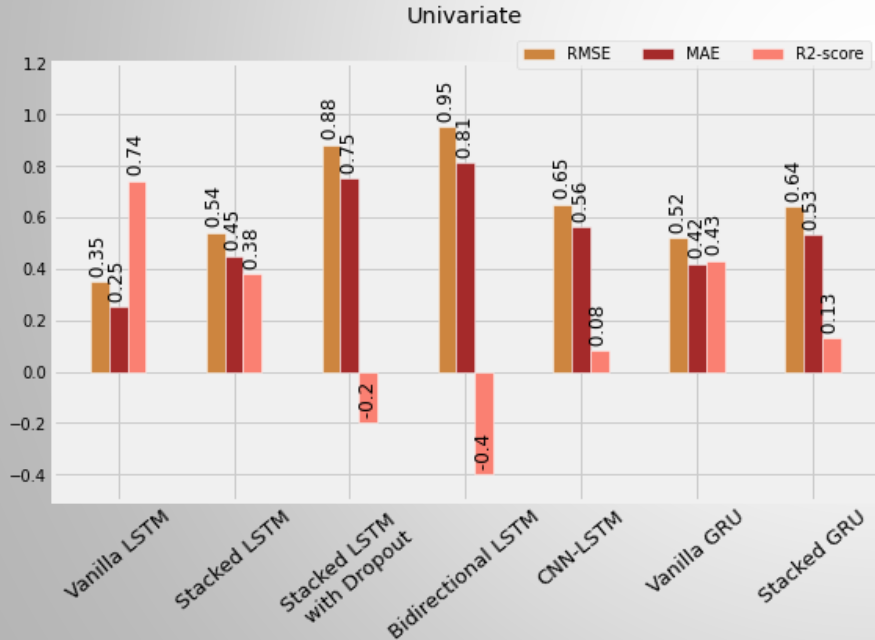
Autocorrelation



ACF of Residuals
(ARIMA(6,1,1))

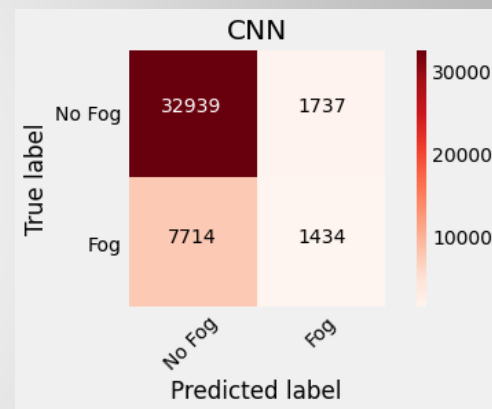
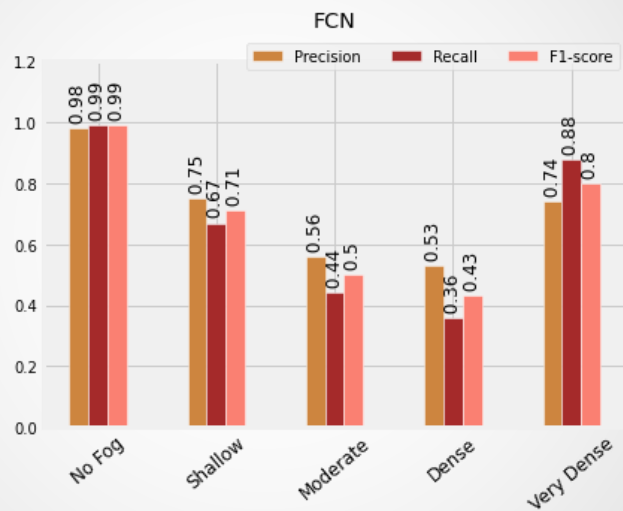
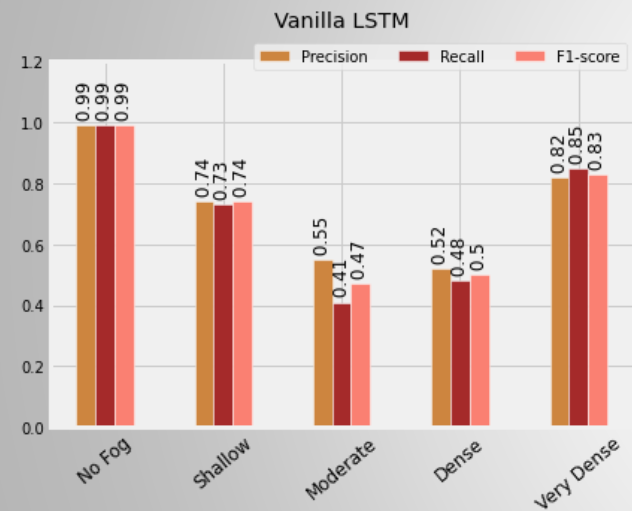
Deep Learning

- Learning dependencies through neural networks and gating mechanism!
- Use of feedback connections



Classification

Binarize the visibility values : Visibility < 1 km → Fog; Else → No Fog



- ❑ Result heavily influenced by class imbalance!

Summary

- ❑ Evaluation during winter months (Nov-Feb) over parts of North India using ground-based observations of visibility
- ❑ Significant class imbalance!
- ❑ Simpler models tend to provide accurate results than the sophisticated ones
- ❑ Most common fog type is radiation fog during early morning hours in North India

Work Ahead...

- ❑ Use of satellite (INSAT-3D) data to predict real-time fog
- ❑ Medium & long-range forecasts
- ❑ Adding additional variables for predicting fog : Soil moisture ,Rainfall
- ❑ Visibility reduction due to aerosols - *Fog or Smog?*

Result dissemination : <https://fog.iitk.ac.in/>

Fog Prediction

IIT Kanpur

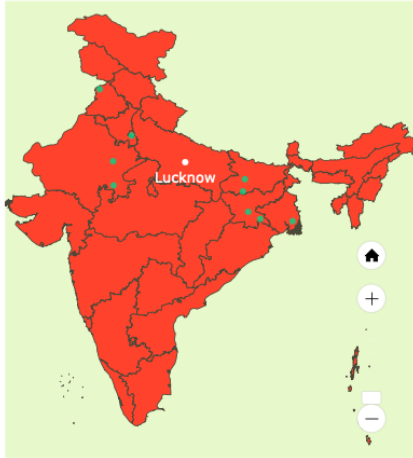
Lucknow

GO

PAST PREDICTIONS

COMPARE RESULTS

ABOUT



Location: Lucknow

Observations at 11/08/2021,
05:30 PM

Visibility: 4.01 km

Temperature: 31°C

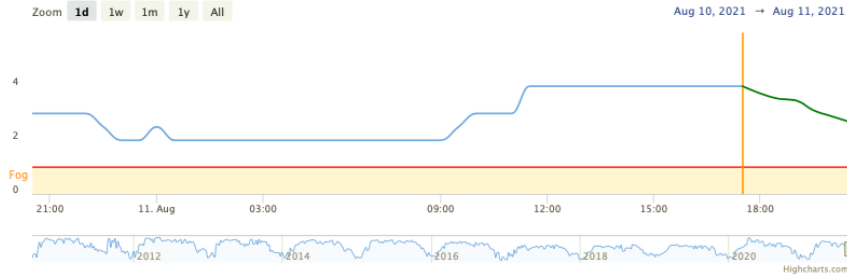
Relative Humidity: 89.13%

Wind: 7.41 km/h

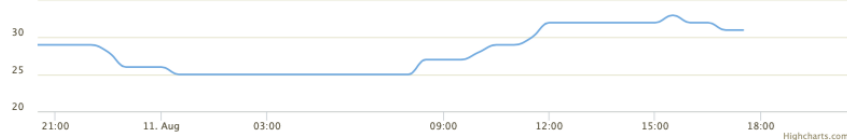
Wind direction: 180° ↑

Visibility below 1 km indicates presence of fog.

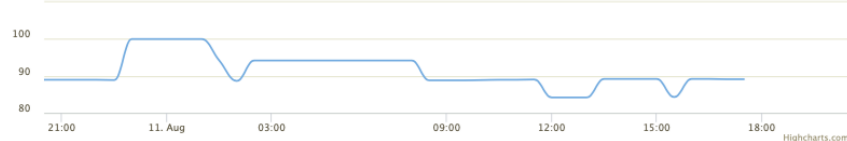
Visibility (km)



Temperature (°C)



Humidity (%)



Fog Prediction Team



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THANK YOU!