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MCL732 ASSGNMENT-4 REPORT

Performance of WRF/Chem over Bihar, Jharkhand, and West Bengal

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1. Introduction

This report evaluates the performance of the Weather Research and Forecasting model coupled with Chemistry (WRF/Chem) over the regions of Bihar, Jharkhand, and West Bengal. The primary objective is to compare simulated gas-phase pollutants and particulate matter (PM10 and PM2.5) concentrations with real-world data from Central Pollution Control Board (CPCB) stations.

2. Background

2.1. WRF/Chem Model Overview

WRF/Chem is a regional atmospheric model that incorporates chemical transport, emission, deposition, and photochemical reactions. It allows for the simulation of air quality, providing insights into pollutant dispersion and chemical transformation.

2.2. Importance of Model Evaluation

Model validation using observational data is crucial for ensuring its reliability. By comparing simulations with CPCB data, this study assesses the model's accuracy in capturing pollutant concentrations.

3. Methodology

3.1. Study Region

The study focuses on **Bihar, Jharkhand, and West Bengal**, which experience frequent air pollution episodes due to industrial activities, vehicular emissions, and biomass burning.

3.2. Pollutants Considered

- Gas-Phase Pollutants: NO, NO2, O3, SO2, CO, NH3
- Particulate Matter: PM10 and PM2.5

3.3. Grid Resolution

The simulations were conducted at a horizontal grid resolution of 50 km x 50 km, ensuring computational efficiency while capturing regional pollution dynamics.

3.4. Temporal Resolution

Hourly data were extracted for comparison with CPCB stations.

4. Model Setup and Configuration

4.1. Domain Configuration

- Domain: Bihar, Jharkhand, and West Bengal
- Resolution: 20 km x 20 km
- Vertical Levels: 45

- Time Step: 60 seconds

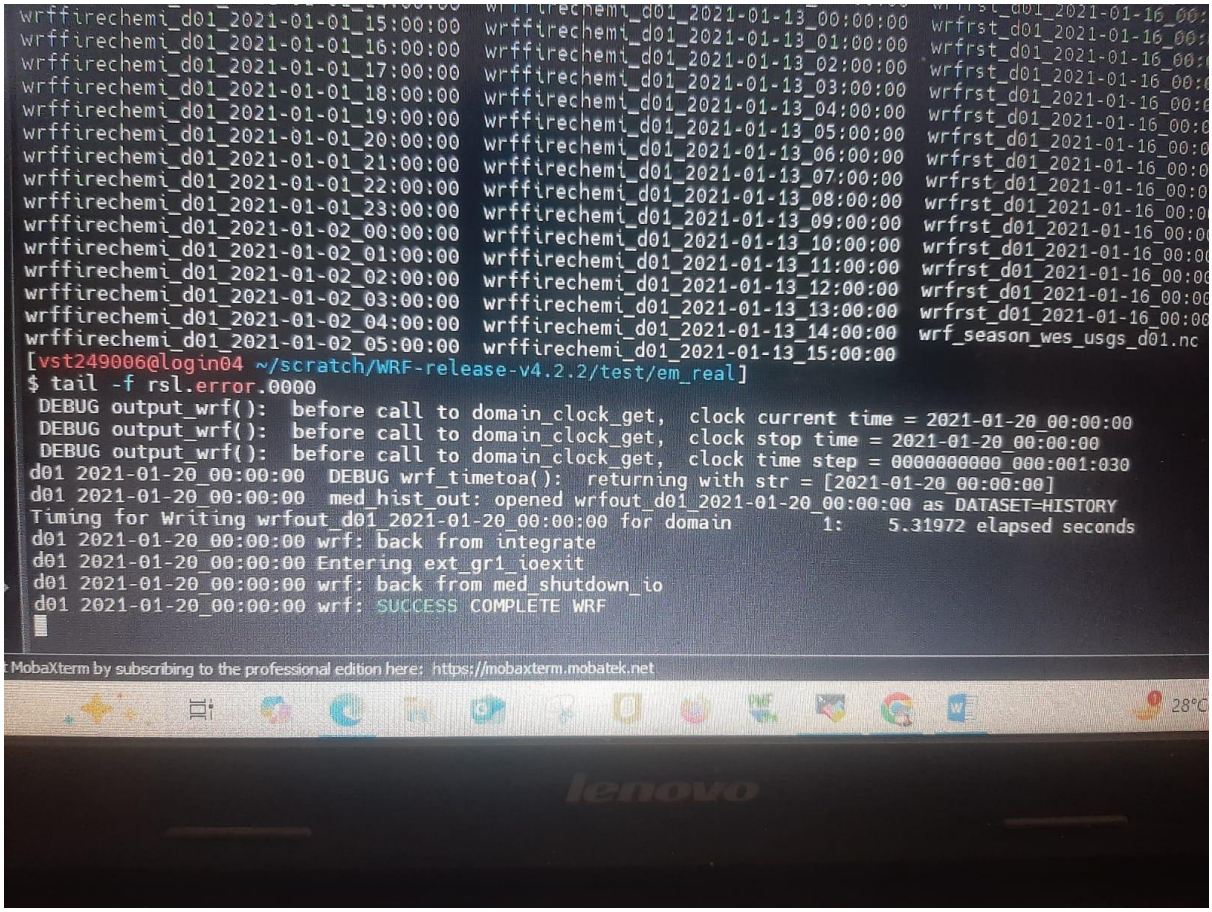


Fig.WRF Built Result

4.2. Chemical Mechanism

The CBMZ (Carbon Bond Mechanism Z) was applied for gas-phase chemistry, while the MOSAIC (Model for Simulating Aerosol Interactions and Chemistry) scheme was used for aerosol representation.

PYTHON CODE:

```
import xarray as xr

import numpy as np

import pandas as pd

import os



# Directory containing the files
```

```
data_dir = "/home/visitor/student/vst249006/scratch/WRF-release-v4.2.2/test/em_real/Ayaanres/"


# Get all .nc files (sorted by date)

file_names = sorted([f for f in os.listdir(data_dir) if f.startswith("wrfout_d01_2021-01") and f.endswith(".nc")])


# Define pollutants

pollutants = ["PM2_5_DRY", "PM10", "o3", "no", "no2", "so2", "co", "nh3"]


# Conversion factors (ppb → µg/m³ at 25°C, 1 atm)

conversion_factors = {"o3": 1.96, "no": 1.23, "no2": 1.88, "so2": 2.62, "co": 1.15, "nh3": 0.77}


# Target location

target_lat = 25.6059

target_lon = 85.1097


# Store extracted data

data_list = []


# Loop through each file

for file in file_names:

    file_path = os.path.join(data_dir, file)

    date_str = file.split("_")[-1].split(".nc")[0]  # Extract date

    date = pd.to_datetime(date_str)
```

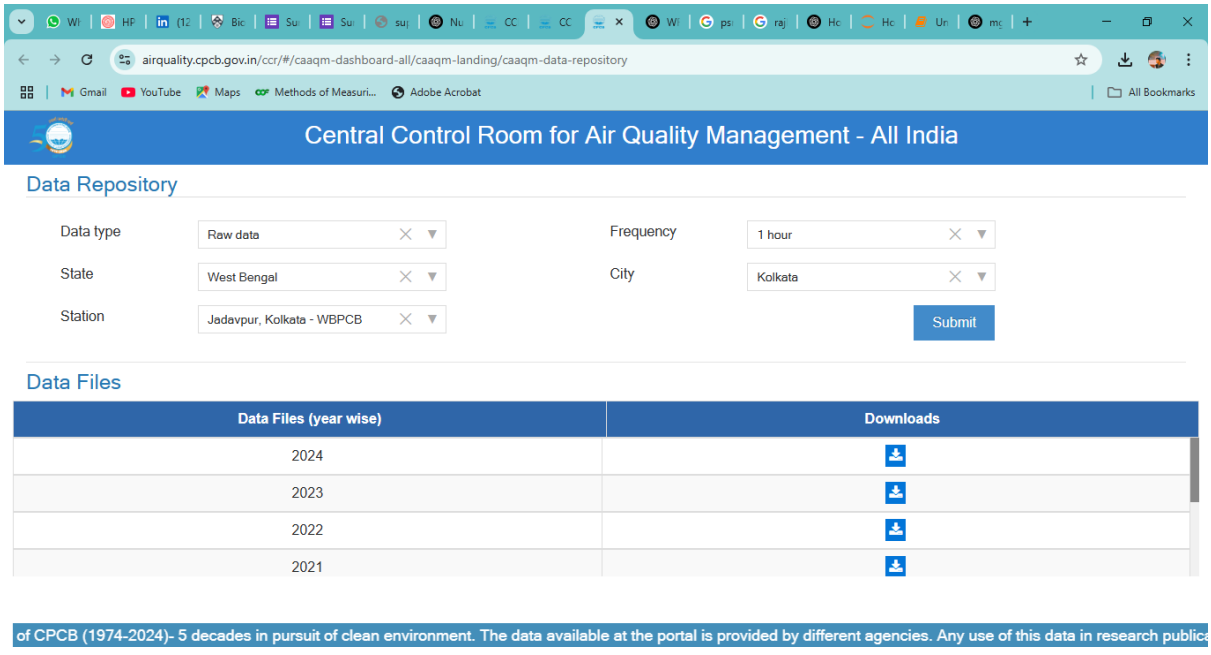
```
    # Include up to Jan 20th at 00:00:00
    if date > pd.to_datetime("2021-01-20 00:00:00"):
        break

    # Load dataset
    ds = xr.open_dataset(file_path)

    # Find nearest grid point to target lat/lon
    latitudes = ds["XLAT"].isel(Time=0).values
    longitudes = ds["XLONG"].isel(Time=0).values

    lat_idx, lon_idx = np.unravel_index(((latitudes - target_lat)**2 + (longitudes - target_lon)**2).argmin(), latitudes.shape)

    # Extract hourly data
    for t in range(ds.dims['Time']):
        time_bytes = ds['Times'].isel(Time=t).values.tobytes().decode('utf-8')
        time_str = pd.to_datetime(time_bytes, format='%Y-%m-%d_%H:%M:%S')
        values = {"DateTime": time_str}

        for pollutant in pollutants:
            if pollutant in ds.variables:
                conc = ds[pollutant].isel(Time=t, bottom_top=0, south_north=lat_idx, west_east=lon_idx).values
                if pollutant in conversion_factors:
                    conc *= conversion_factors[pollutant]  # Convert to µg/m³
```

```
            values[pollutant] = conc

        data_list.append(values)

    ds.close()

# Convert to DataFrame
df = pd.DataFrame(data_list)
df.to_csv("hourly_pollutant_concentration.csv", index=False)
print("Data saved to hourly_pollutant_concentration.csv")
```

5. Data Collection and Processing

5.1. CPCB Data

Hourly and daily concentration data from CPCB monitoring stations were obtained for comparison.



5.2. Data Extraction from WRF Output

NetCDF files were processed using Python to extract pollutant concentrations at the corresponding CPCB station locations.

5.3. Spatial Averaging

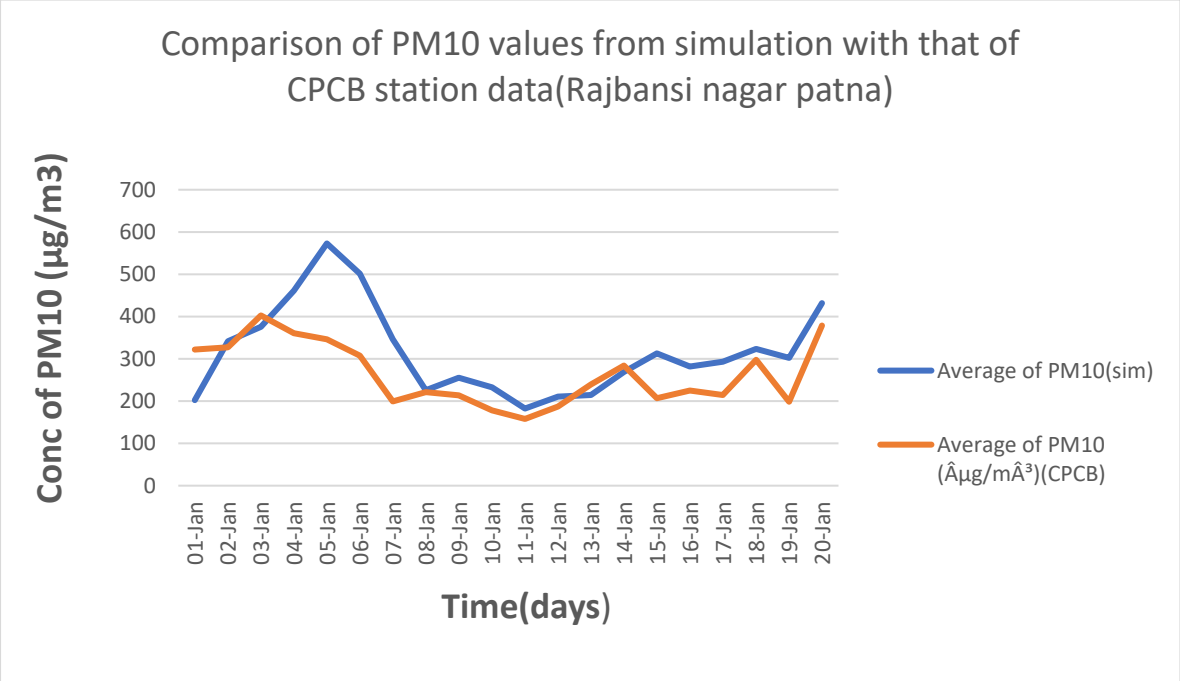
- If one CPCB station fell within a grid, its data were used.
- If multiple stations were within a single grid, the values were averaged.

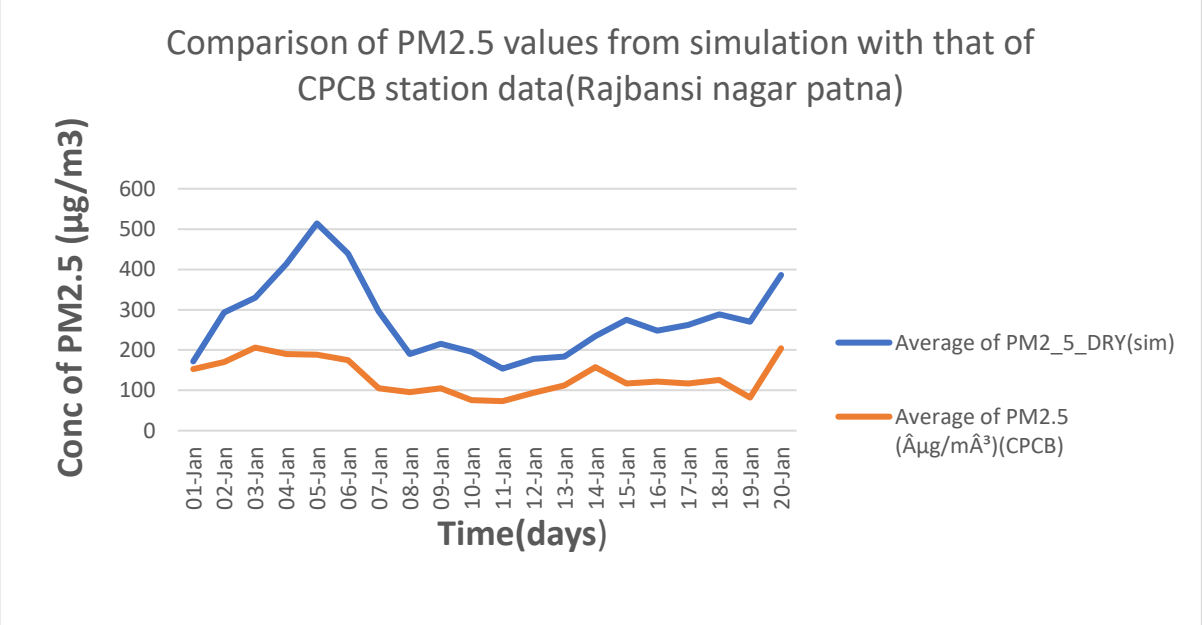
6.Results

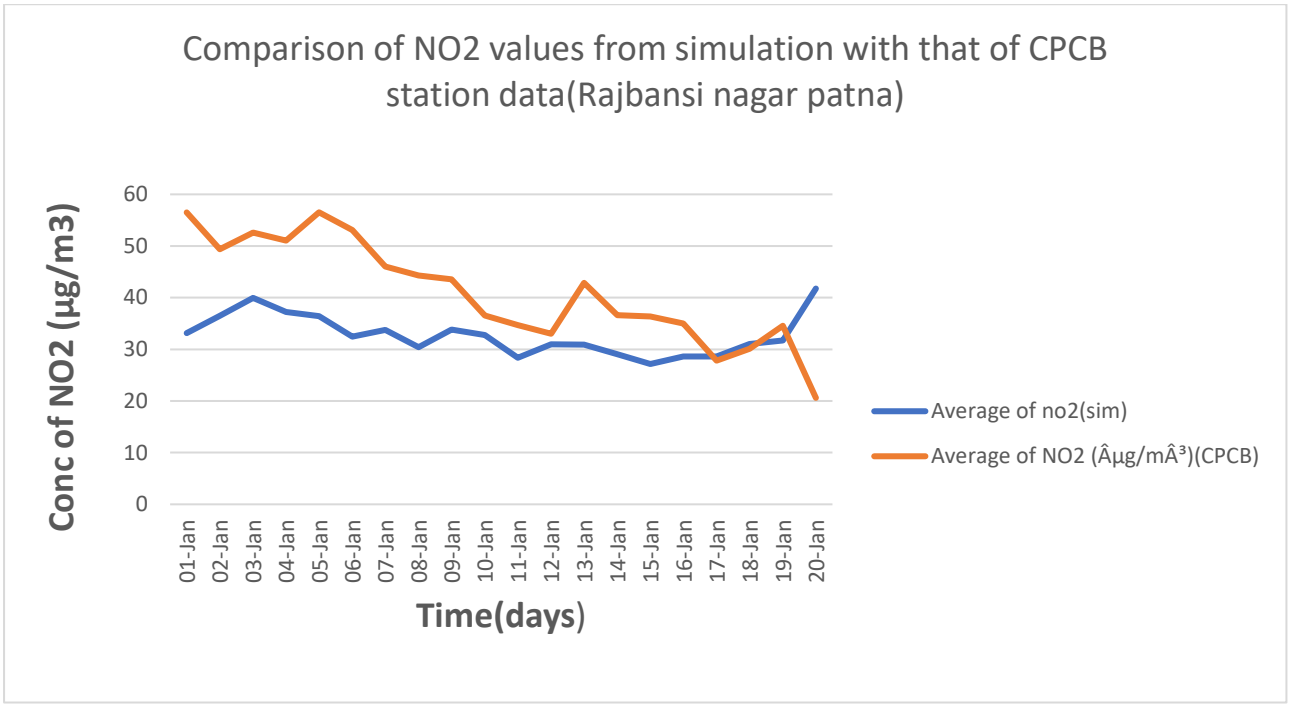
DAILY VARIATION TIME SERIES:

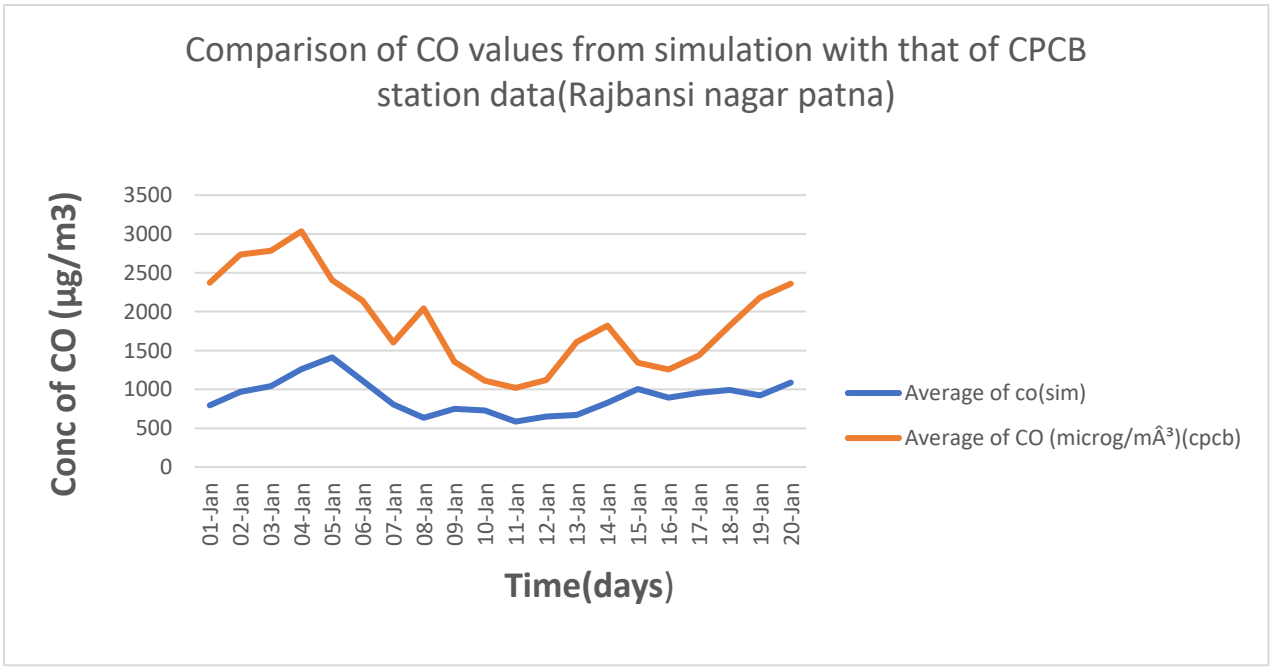
a)State:BIHAR

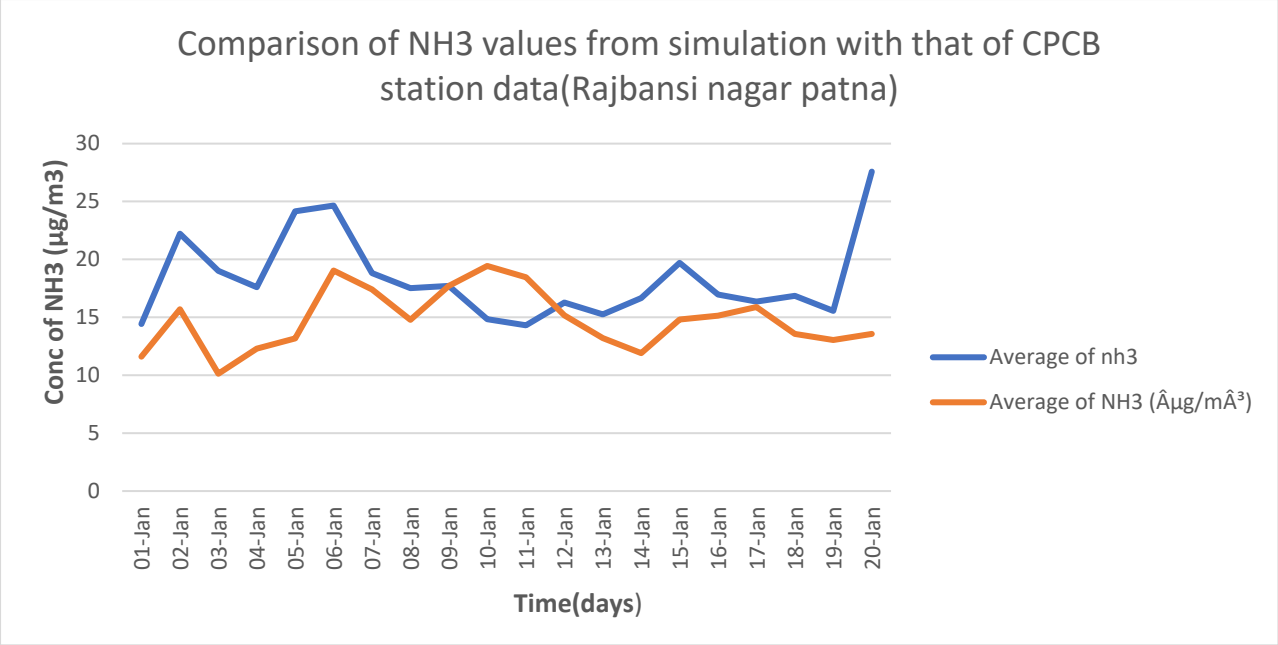
Monitoring Station:RAJBANSI NAGAR PATNA STATION



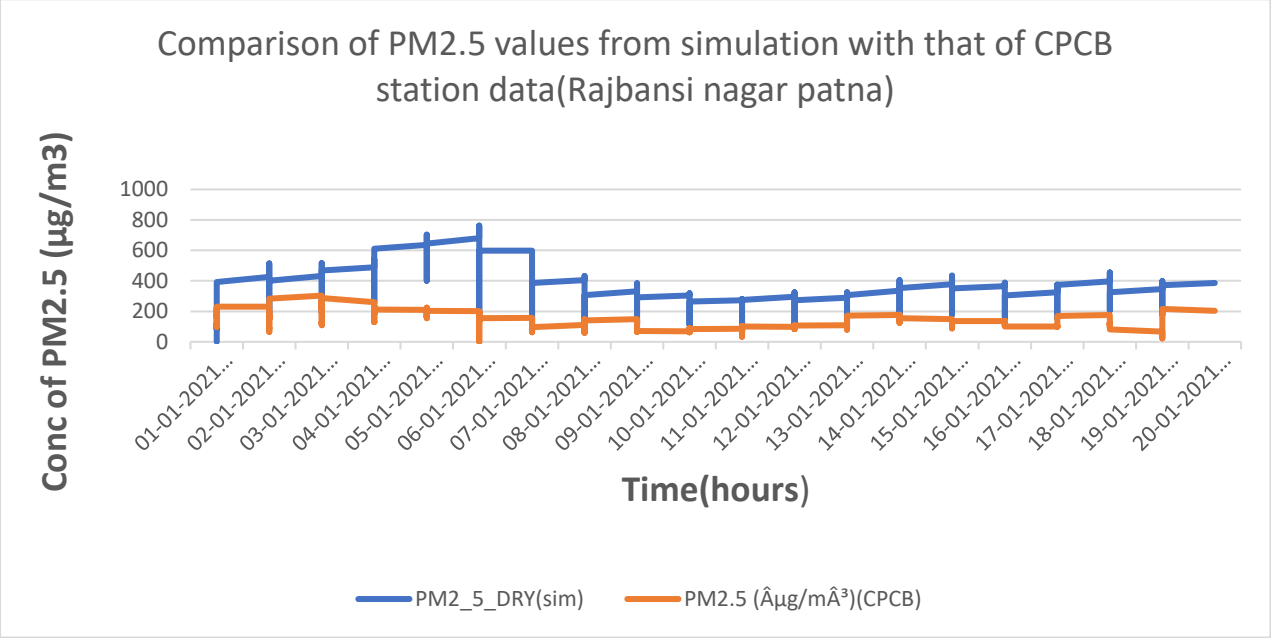


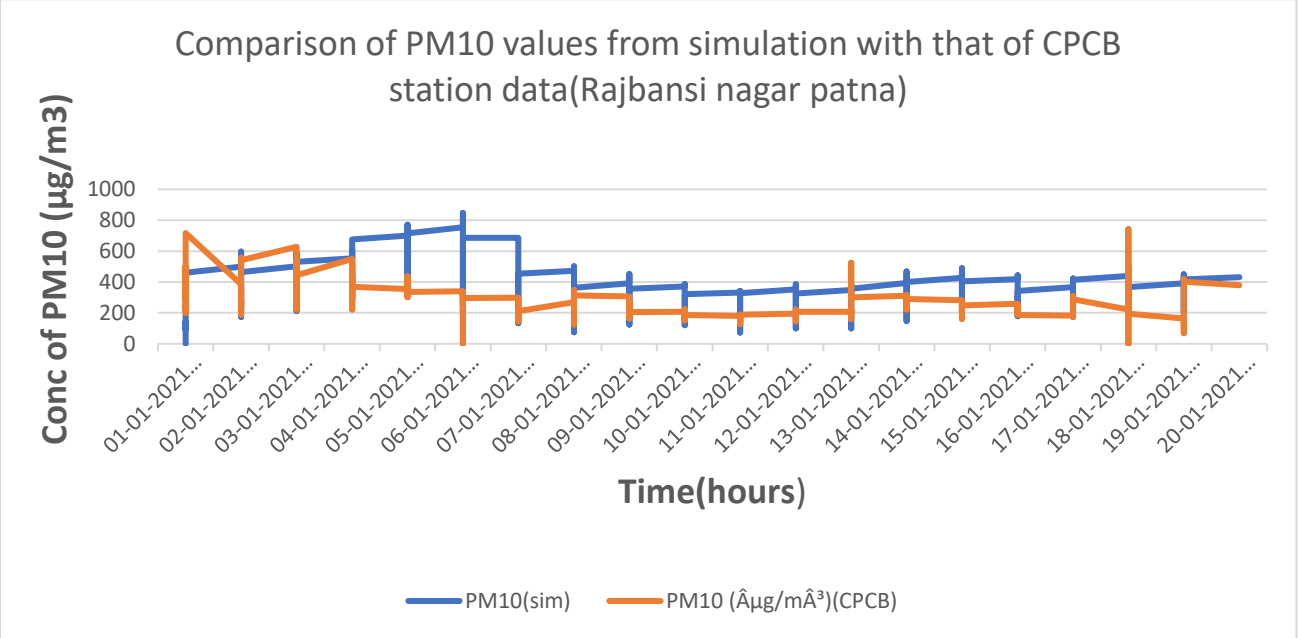

Comparison of NO2 values from simulation with that of CPCB station data(Rajbansi nagar patna)
Conc of NO2 (µg/m3)
60
50
40
30
20
10
0
01-Jan
02-Jan
03-Jan
04-Jan
05-Jan
06-Jan
07-Jan
08-Jan
09-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
20-Jan
Time(days)
Average of no2(sim)
Average of NO2 (Âµg/mÂ³)(CPCB)

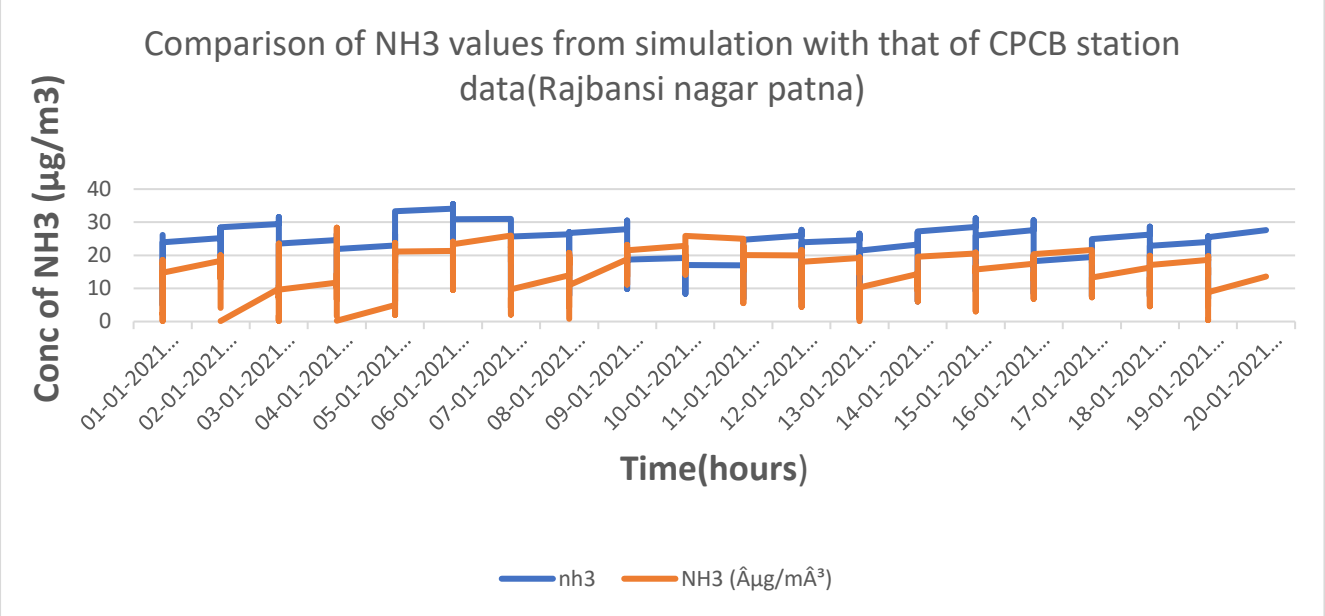

Comparison of CO values from simulation with that of CPCB station data(Rajbansi nagar patna)
Conc of CO (µg/m3)
3500
3000
2500
2000
1500
1000
500
0
01-Jan
02-Jan
03-Jan
04-Jan
05-Jan
06-Jan
07-Jan
08-Jan
09-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
20-Jan
Time(days)
Average of co(sim)
Average of CO (microg/mÂ³)(cpcb)

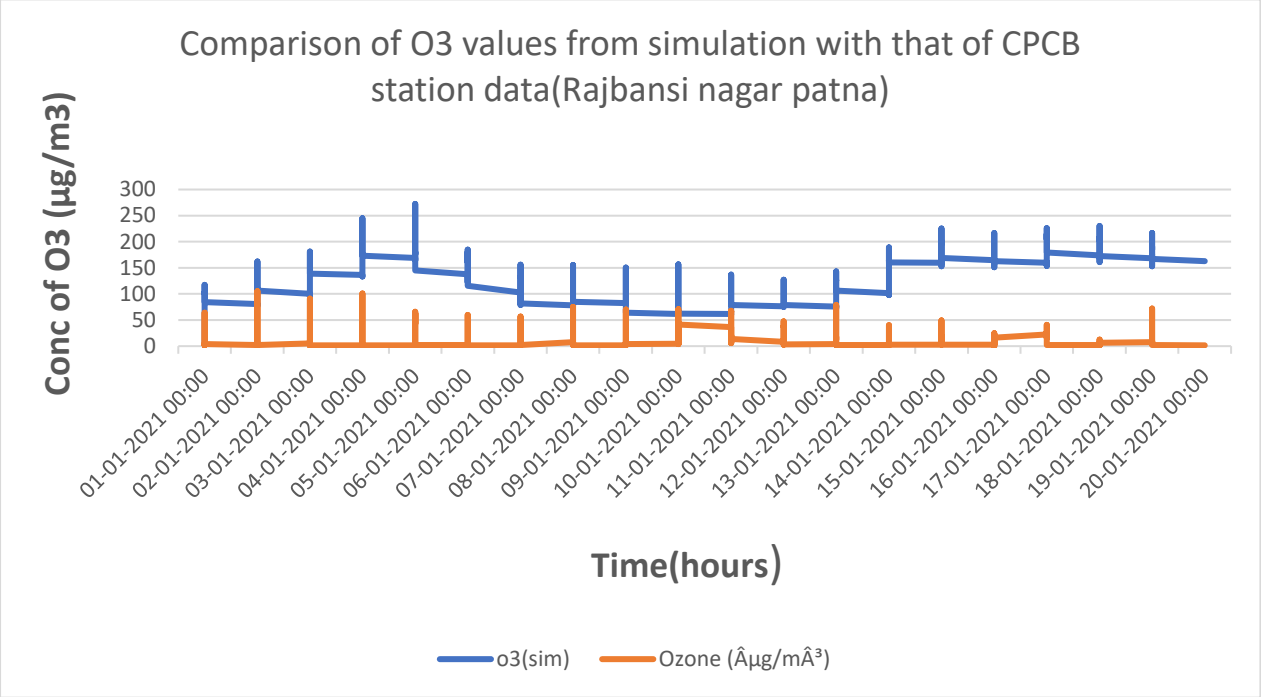


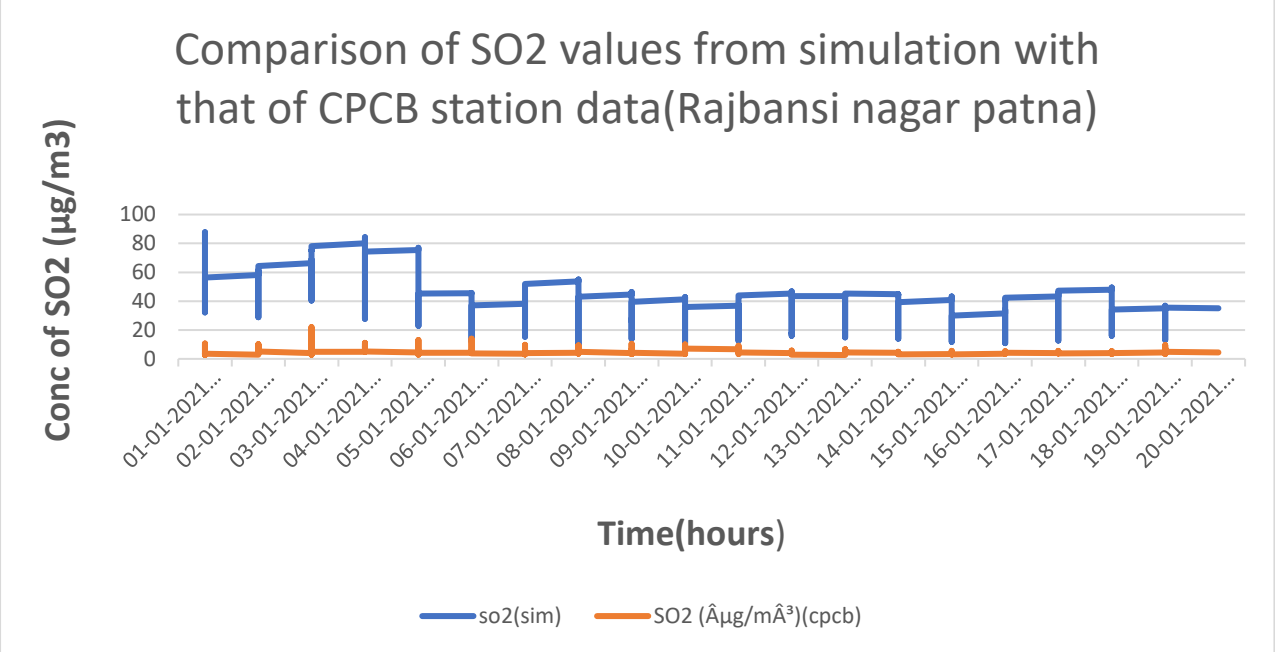
DIURNAL VARIATION TIME SERIES:




Comparison of PM10 values from simulation with that of CPCB station data(Rajbansi nagar patna)
Conc of PM10 (µg/m3)
1000
800
600
400
200
0
01-01-2021...
02-01-2021...
03-01-2021...
04-01-2021...
05-01-2021...
06-01-2021...
07-01-2021...
08-01-2021...
09-01-2021...
10-01-2021...
11-01-2021...
12-01-2021...
13-01-2021...
14-01-2021...
15-01-2021...
16-01-2021...
17-01-2021...
18-01-2021...
19-01-2021...
20-01-2021...
Time(hours)
PM10(sim)
PM10 (Âµg/mÂ³)(CPCB)


Comparison of NH3 values from simulation with that of CPCB station data(Rajbansi nagar patna)
Conc of NH3 (µg/m3)
40
30
20
10
0
01-01-2021...
02-01-2021...
03-01-2021...
04-01-2021...
05-01-2021...
06-01-2021...
07-01-2021...
08-01-2021...
09-01-2021...
10-01-2021...
11-01-2021...
12-01-2021...
13-01-2021...
14-01-2021...
15-01-2021...
16-01-2021...
17-01-2021...
18-01-2021...
19-01-2021...
20-01-2021...
Time(hours)
nh3
NH3 (Âµg/mÂ³)

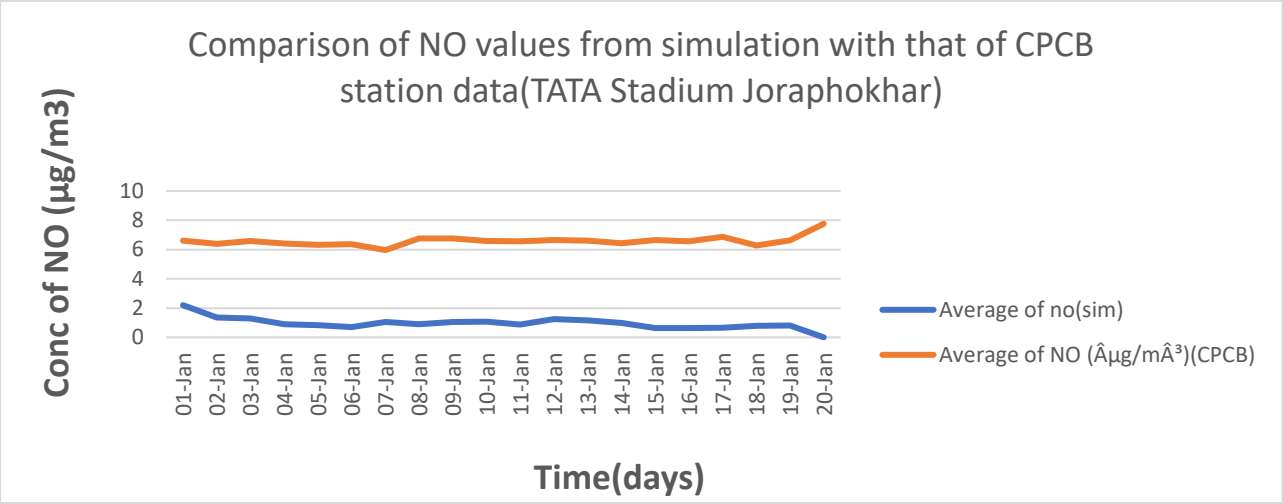

Comparison of O3 values from simulation with that of CPCB station data(Rajbansi nagar patna)
Conc of O3 (µg/m3)
300
250
200
150
100
50
0
01-01-2021 00:00
02-01-2021 00:00
03-01-2021 00:00
04-01-2021 00:00
05-01-2021 00:00
06-01-2021 00:00
07-01-2021 00:00
08-01-2021 00:00
09-01-2021 00:00
10-01-2021 00:00
11-01-2021 00:00
12-01-2021 00:00
13-01-2021 00:00
14-01-2021 00:00
15-01-2021 00:00
16-01-2021 00:00
17-01-2021 00:00
18-01-2021 00:00
19-01-2021 00:00
20-01-2021 00:00
Time(hours)
o3(sim)
Ozone (Âµg/mÂ³)

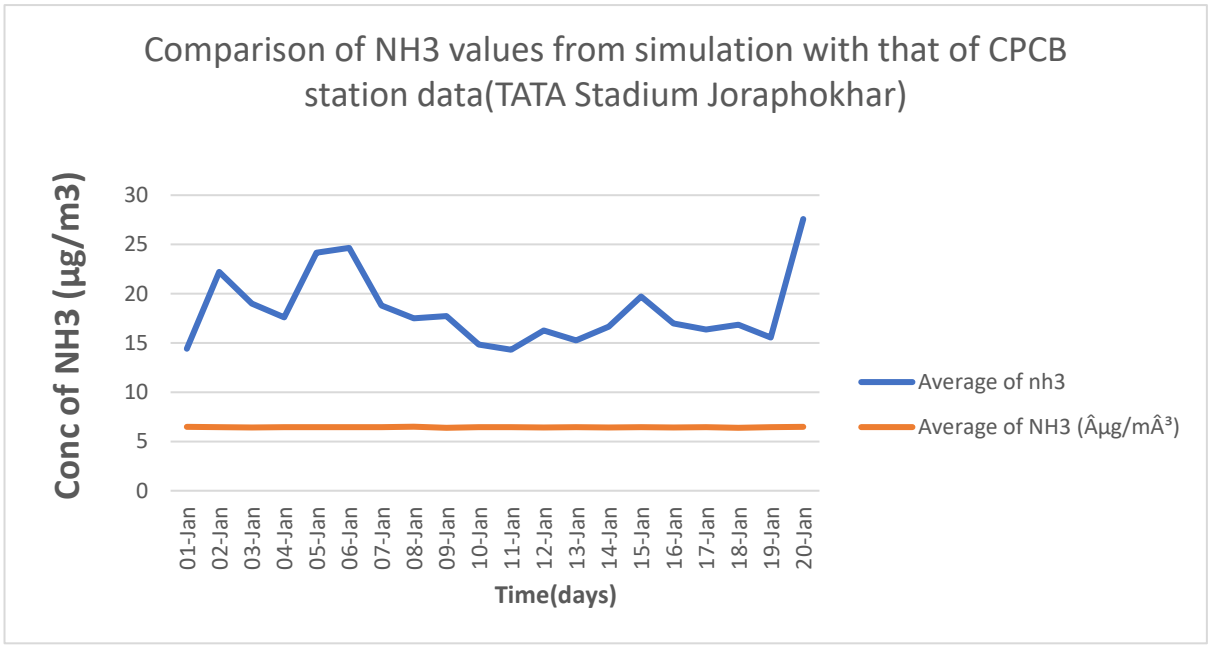

Comparison of SO2 values from simulation with that of CPCB station data(Rajbansi nagar patna)
Conc of SO2 (µg/m3)
100
80
60
40
20
0
01-01-2021...
02-01-2021...
03-01-2021...
04-01-2021...
05-01-2021...
06-01-2021...
07-01-2021...
08-01-2021...
09-01-2021...
10-01-2021...
11-01-2021...
12-01-2021...
13-01-2021...
14-01-2021...
15-01-2021...
16-01-2021...
17-01-2021...
18-01-2021...
19-01-2021...
20-01-2021...
Time(hours)
so2(sim)
SO2 (Âµg/mÂ³)(cpcb)

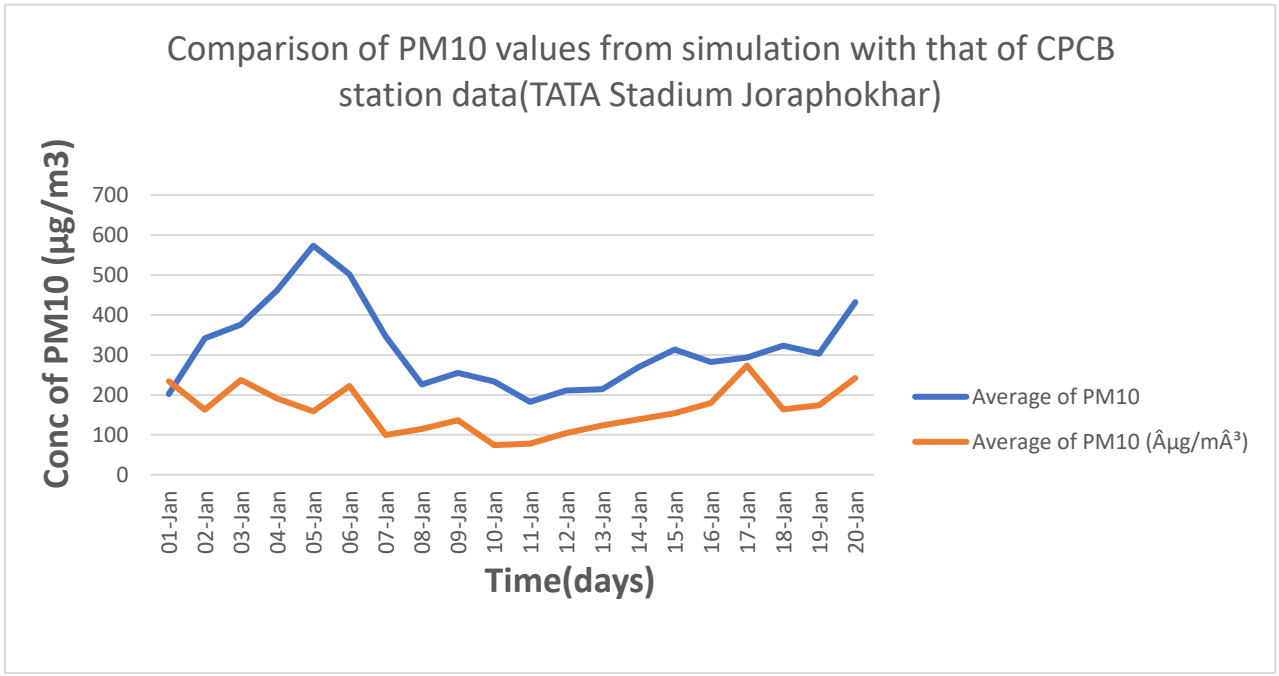
DAILY VARIATION TIME SERIES:

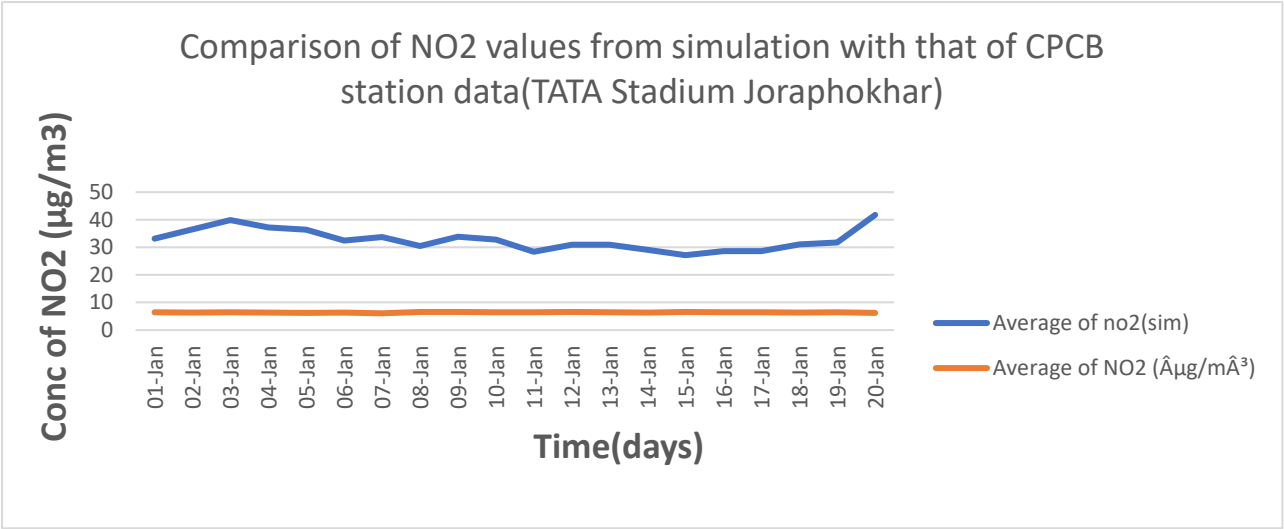
b)State:Jharkhand

Monitoring station:TATA STADIUM JORAPHOKHAR

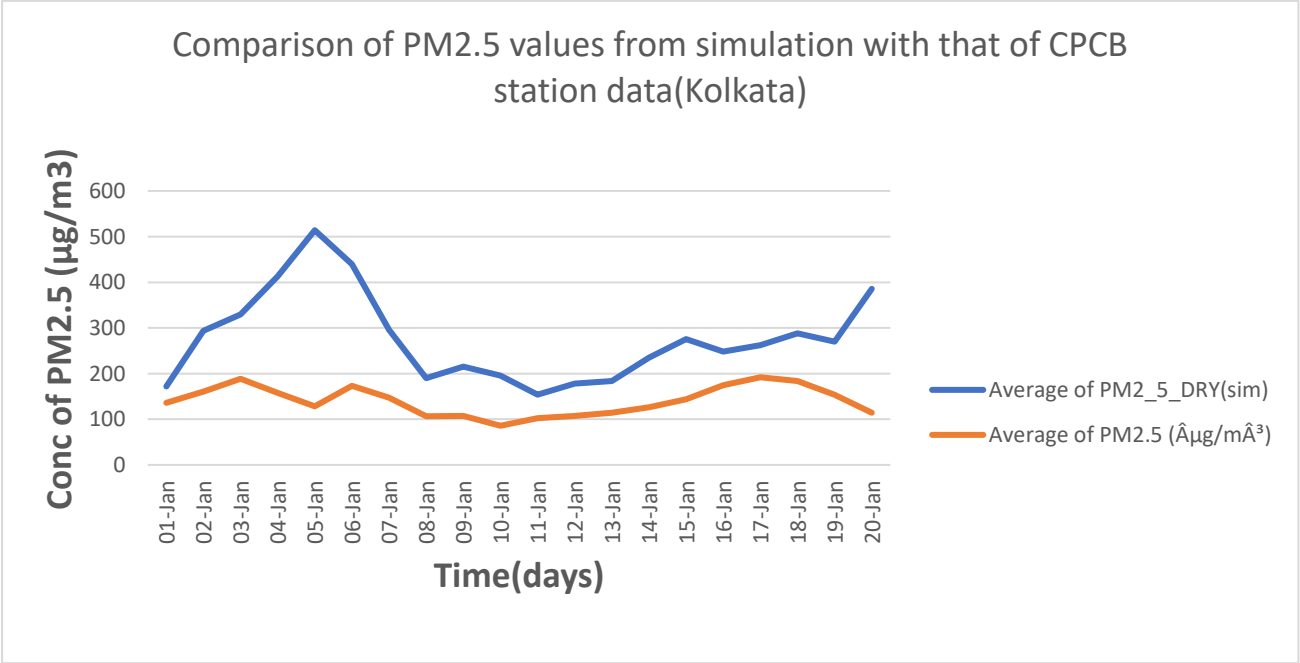


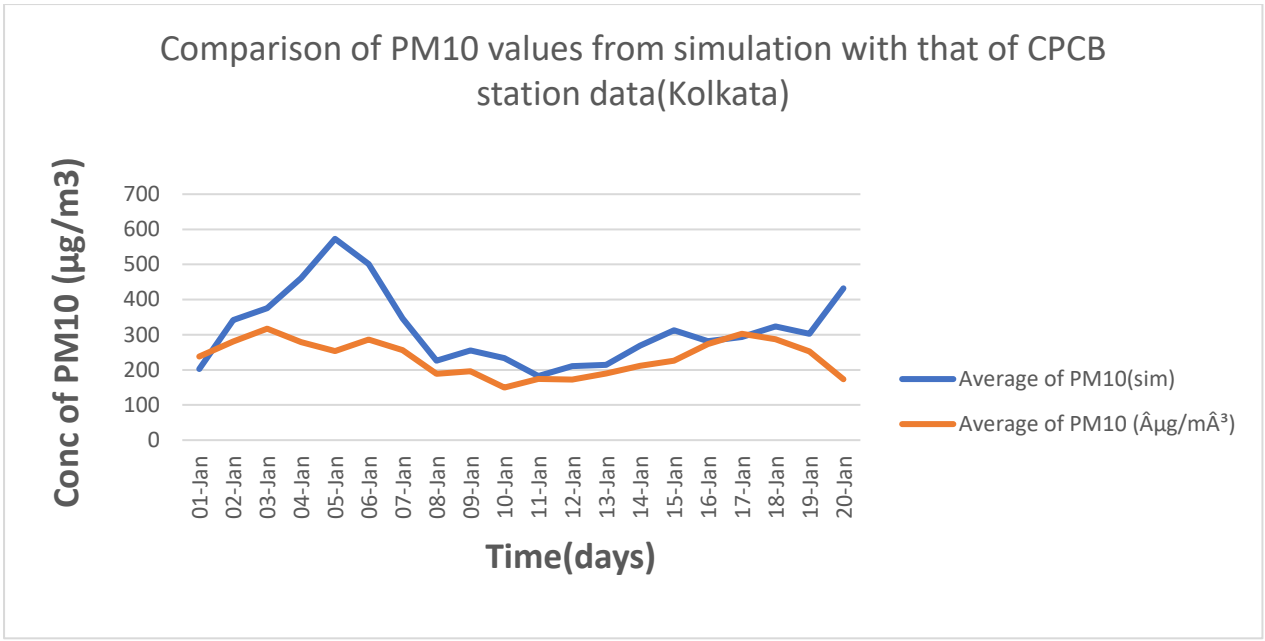

Comparison of NH3 values from simulation with that of CPCB station data(TATA Stadium Joraphokhar)
Conc of NH3 (µg/m3)
30
25
20
15
10
5
0
01-Jan
02-Jan
03-Jan
04-Jan
05-Jan
06-Jan
07-Jan
08-Jan
09-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
20-Jan
Time(days)
Average of nh3
Average of NH3 (Âµg/mÂ³)

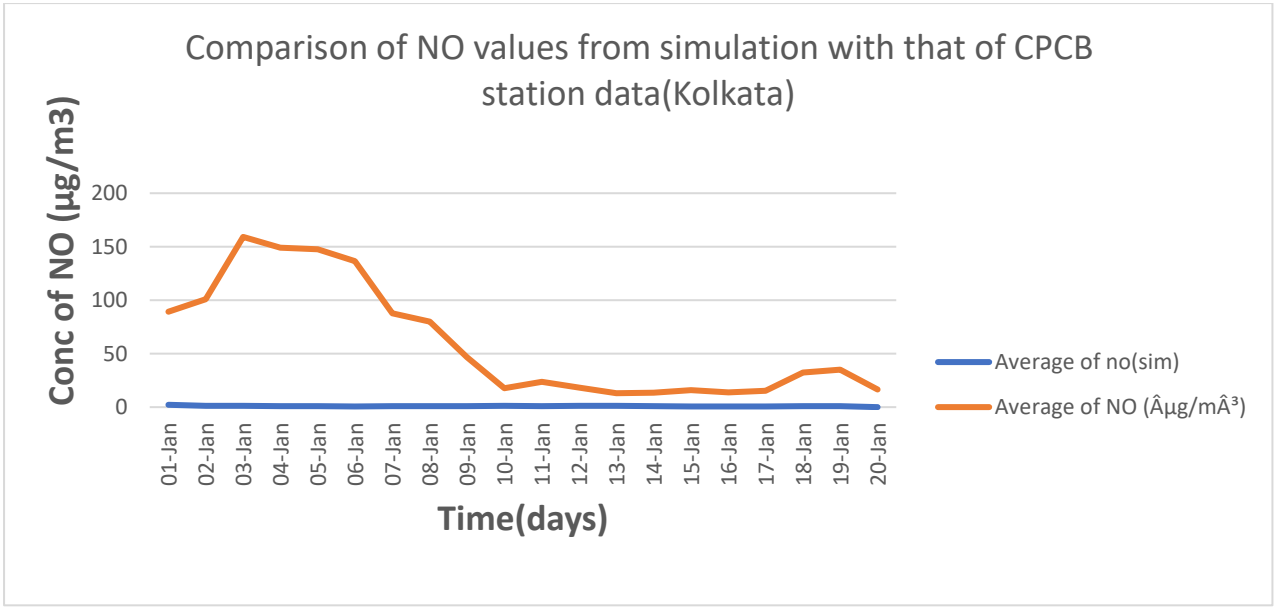

Comparison of PM10 values from simulation with that of CPCB station data(TATA Stadium Joraphokhar)
Conc of PM10 (µg/m3)
700
600
500
400
300
200
100
0
01-Jan
02-Jan
03-Jan
04-Jan
05-Jan
06-Jan
07-Jan
08-Jan
09-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
20-Jan
Time(days)
Average of PM10
Average of PM10 (Âµg/mÂ³)

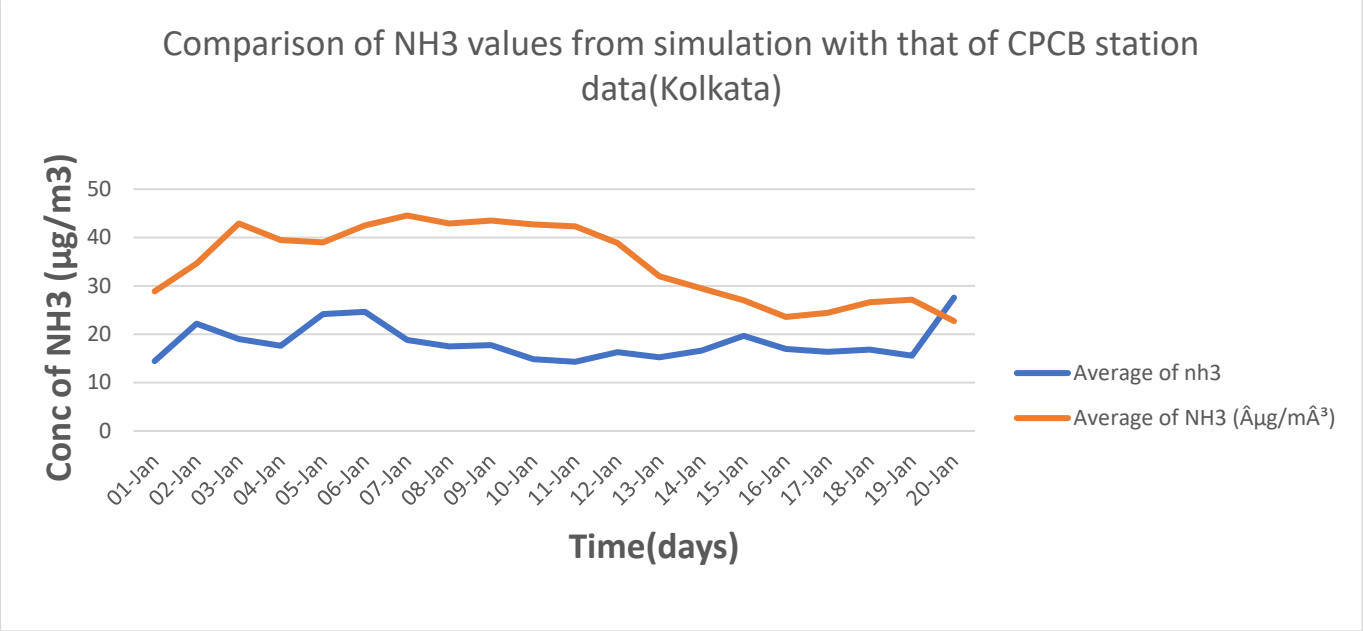


C)Jadhavpur-Kolkata monitoring station




Comparison of PM10 values from simulation with that of CPCB station data(Kolkata)
Conc of PM10 (µg/m3)
700
600
500
400
300
200
100
0
01-Jan
02-Jan
03-Jan
04-Jan
05-Jan
06-Jan
07-Jan
08-Jan
09-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
20-Jan
Time(days)
Average of PM10(sim)
Average of PM10 (Âµg/mÂ³)


Comparison of NO values from simulation with that of CPCB station data(Kolkata)
Conc of NO (µg/m3)
200
150
100
50
0
01-Jan
02-Jan
03-Jan
04-Jan
05-Jan
06-Jan
07-Jan
08-Jan
09-Jan
10-Jan
11-Jan
12-Jan
13-Jan
14-Jan
15-Jan
16-Jan
17-Jan
18-Jan
19-Jan
20-Jan
Time(days)
Average of no(sim)
Average of NO (Âµg/mÂ³)



7.Discussion

7.1. Gas-Phase Pollutants Comparison

- **NH3,NO and NO2**: The model captured daily variations reasonably well, though underestimated peak concentrations.
- **O3**: Overprediction was observed during afternoon hours due to excessive photochemical activity.
- **SO2 &CO**: Simulated values aligned well with observations, indicating accurate emissions representation.

7.2. PM10 and PM2.5 Comparison

- **PM10 and PM2.5**: The model exhibited moderate agreement with CPCB data, with biases during high pollution episodes.
- Overestimation in regions with strong emission sources could suggest issues in emission inventory scaling.