**Performance of high resolution (400 m) PM2.5 forecast over Delhi**

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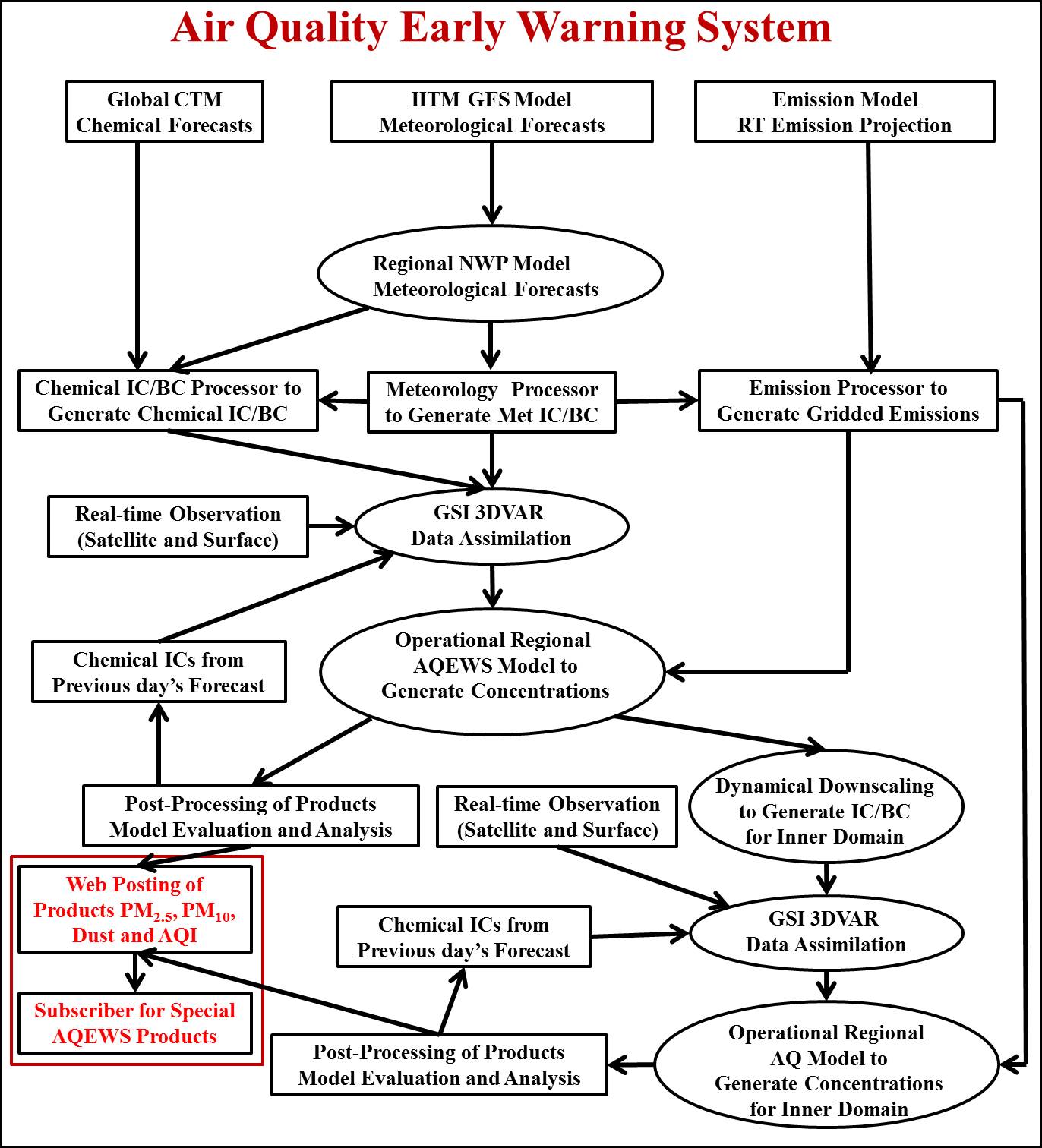
5Centre for Development of Advanced Computing, Pune 411 008, India

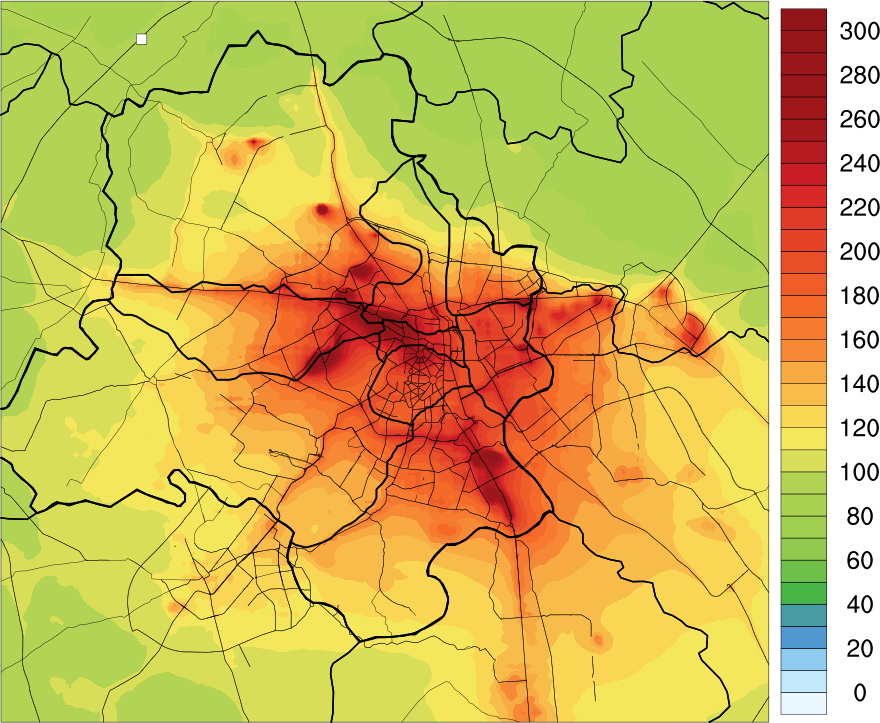
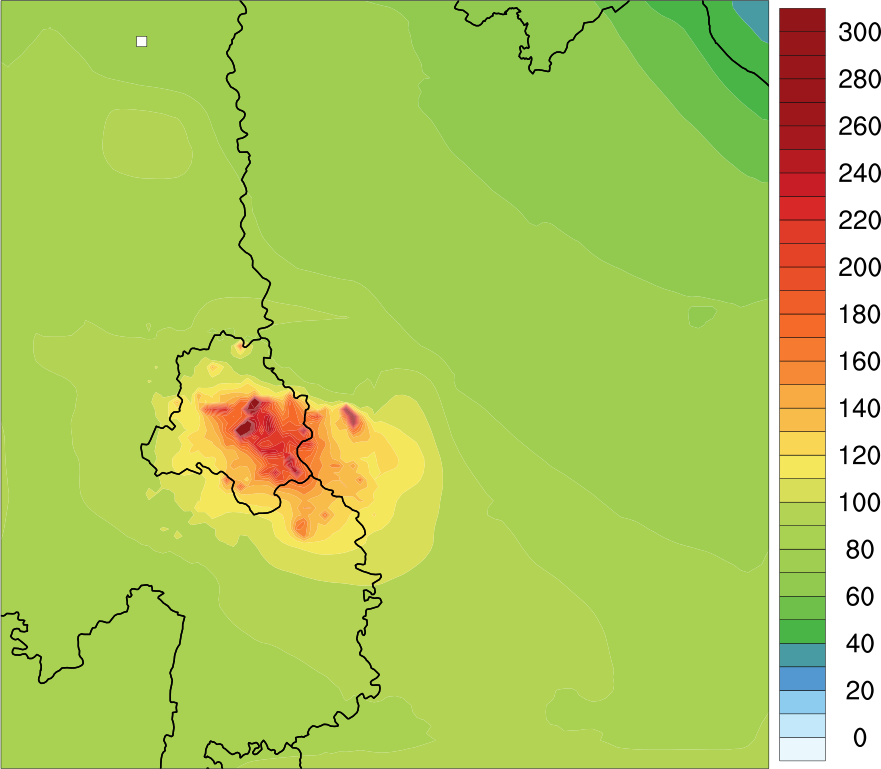
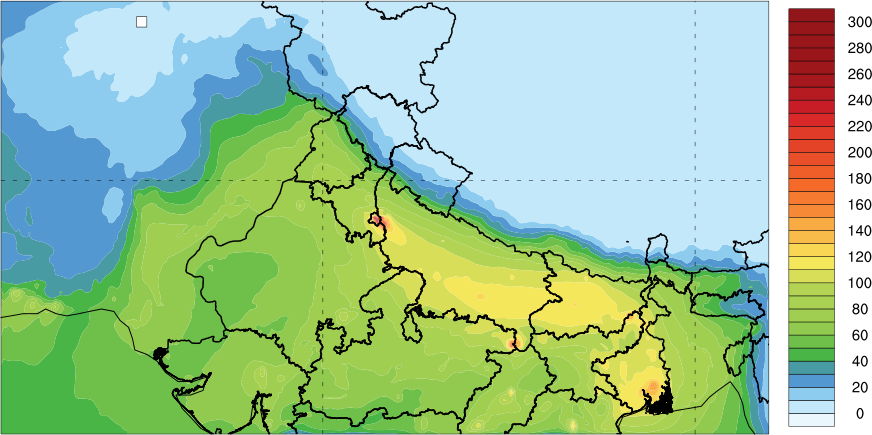
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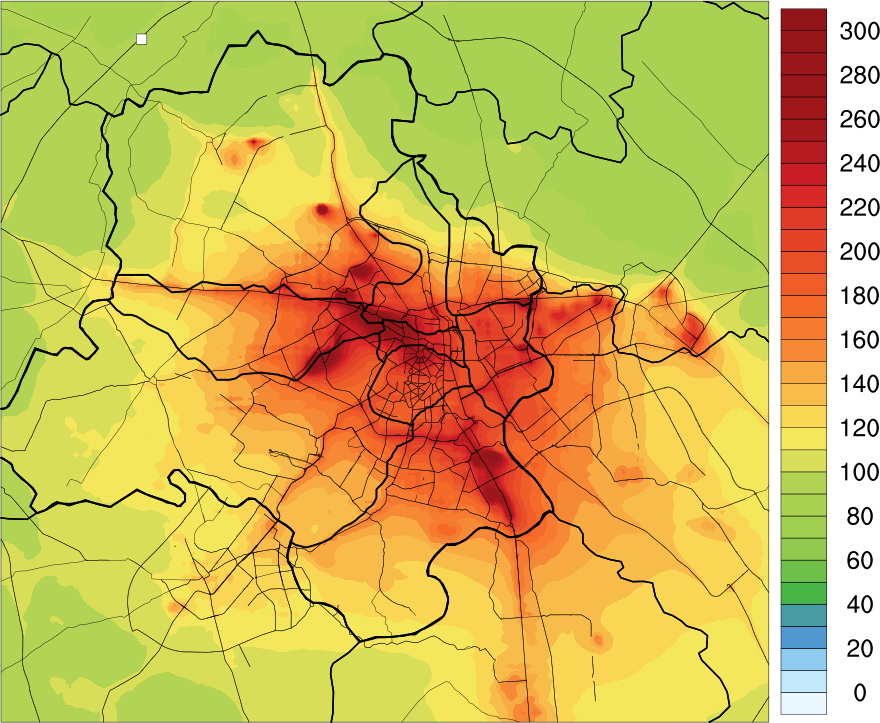
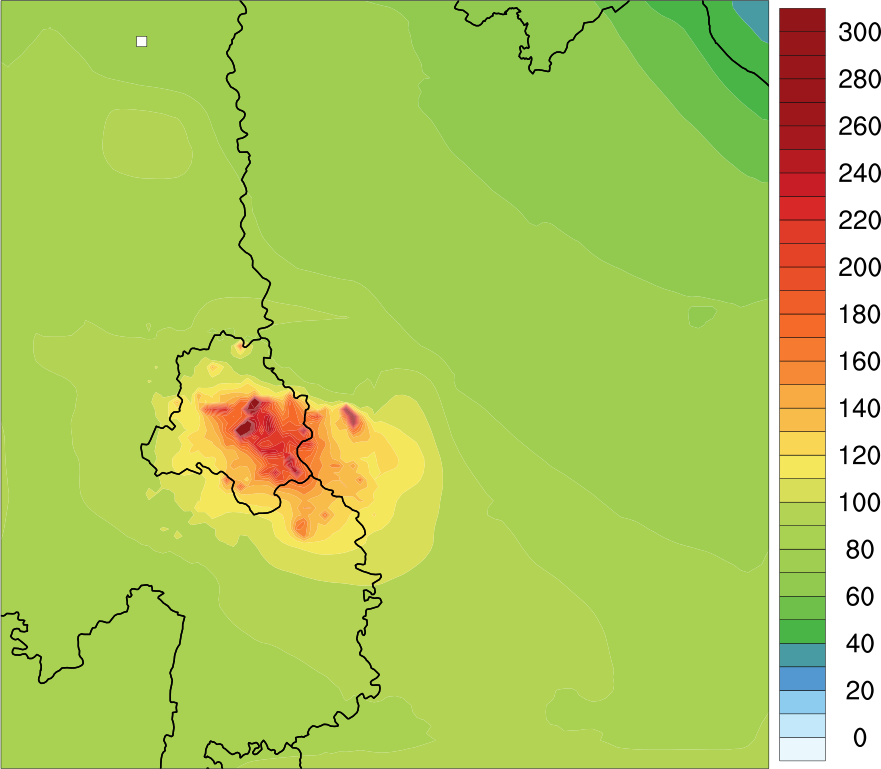
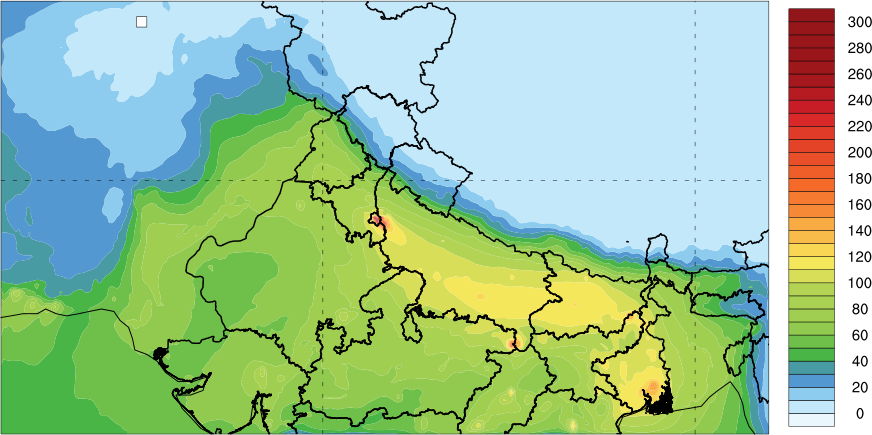


**D1**

**D2**

**D3**

**Figure S1:** Architecture of the very-high resolution air quality early warning system.

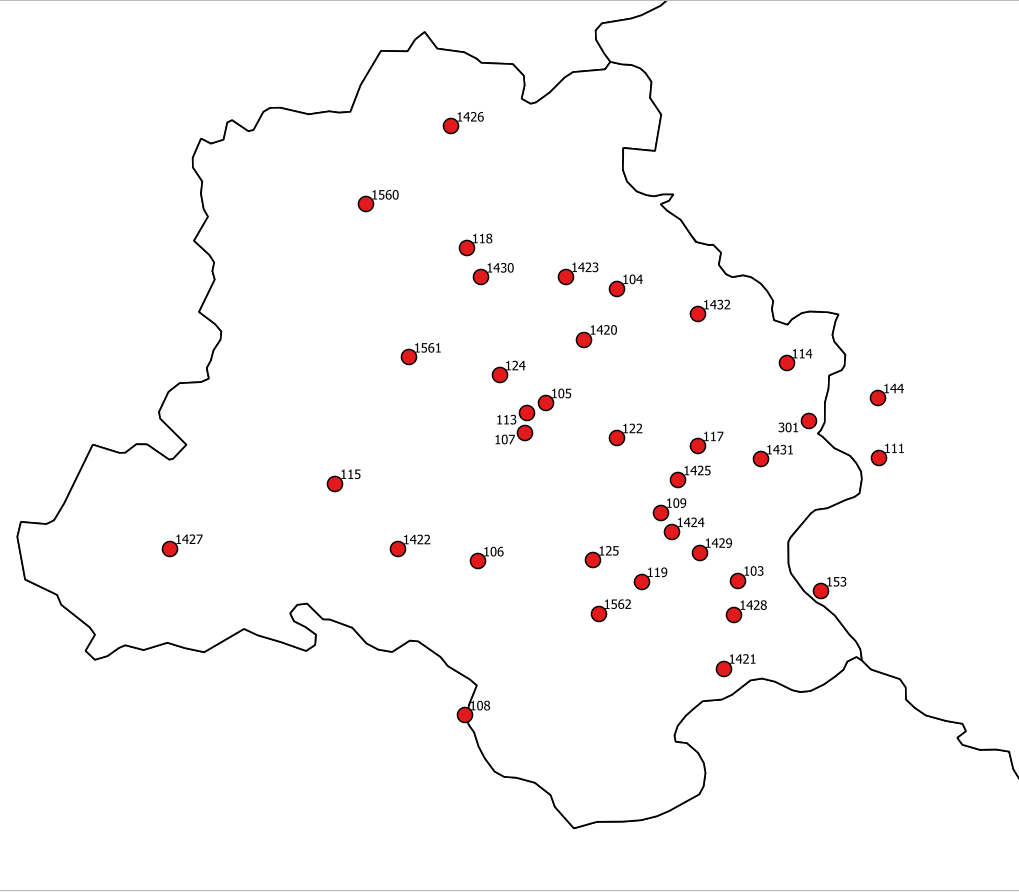


**D1**

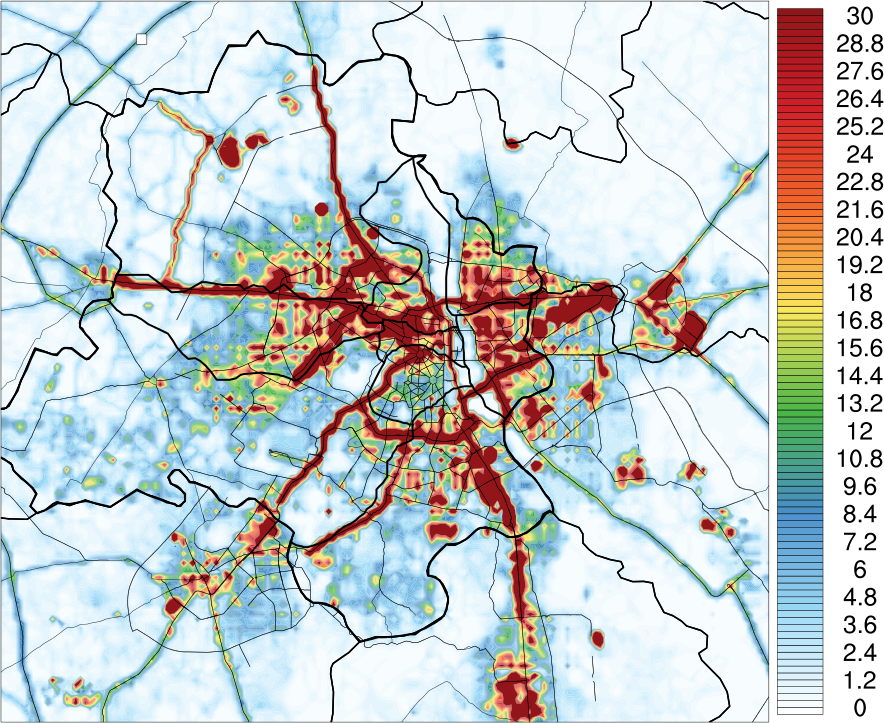
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**D3**

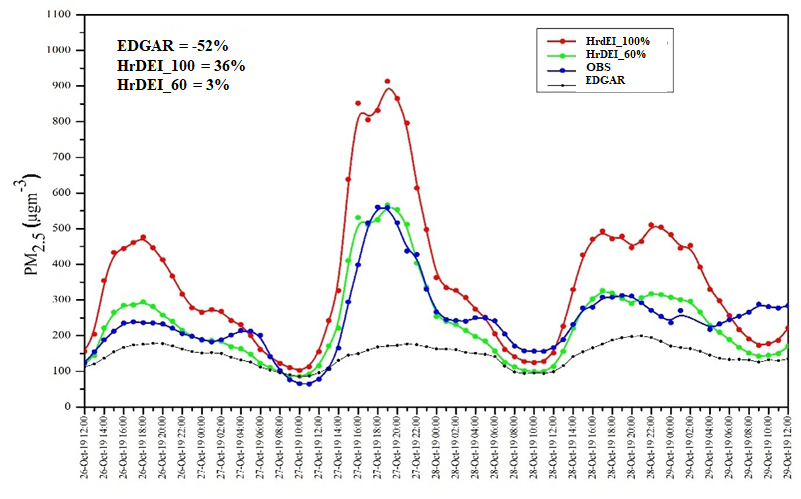
**Figure S2:** Map of model simulation domain (D1: 10 km horizontal grid spacing, D2: 2 km horizontal grid spacing and D3: 400 meter horizontal grid spacing). We have used ncl/6.6.2 software to create the images (https://www.ncl.ucar.edu/).



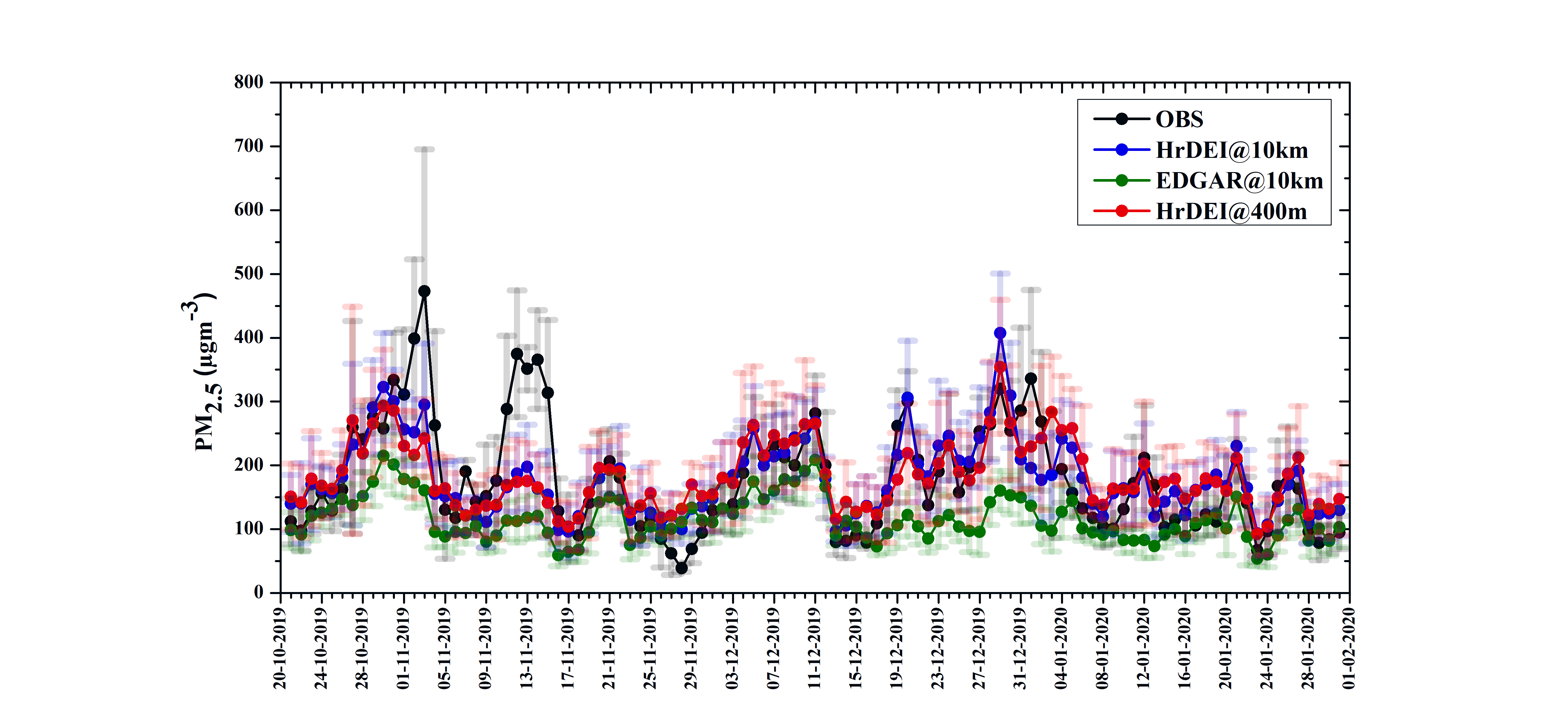
**Figure S3:** Geographical locations of 37 air quality monitoring stations (stations names associated with the numbers are provided in Table ST2)



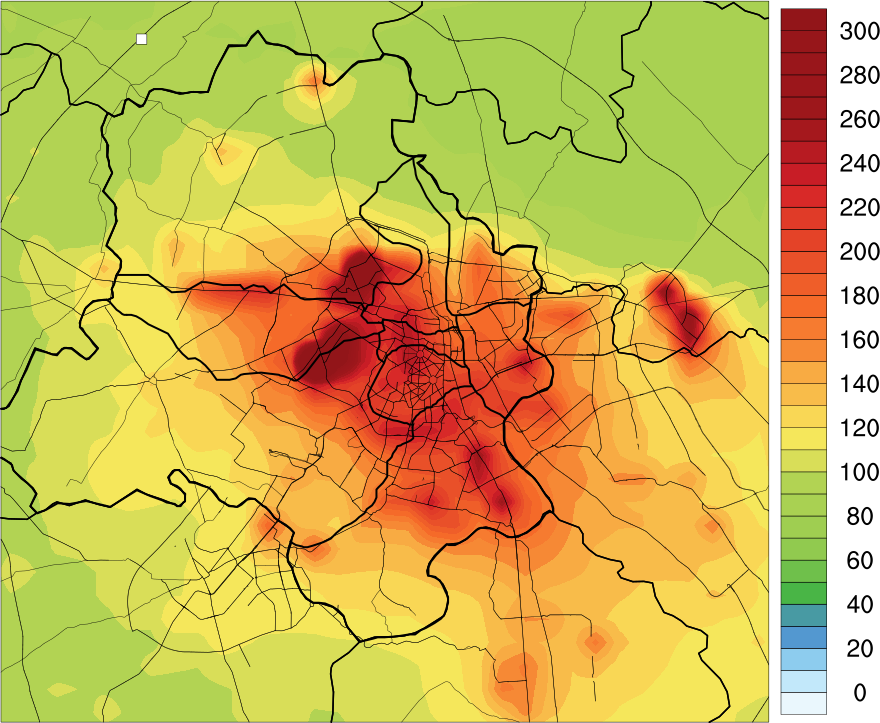
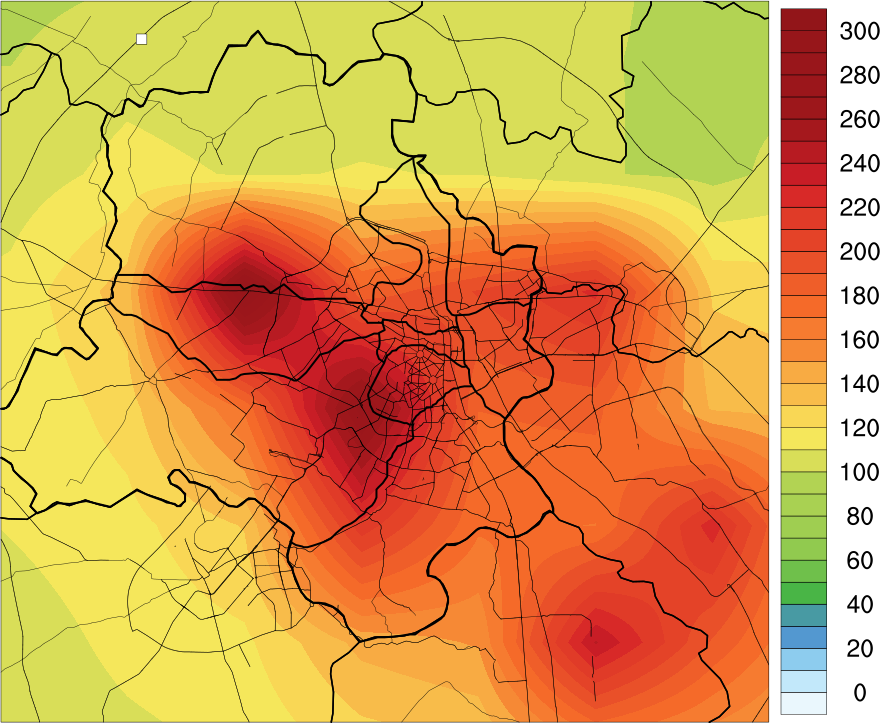
**Figure S4:** Spatial distribution of High-resolution Delhi Emission Inventory (HrDEI) of PM2.5 anthropogenic emissions (unit: 1010 kg/m2/s) at 400 m horizontal resolution. We have used ncl/6.6.2 software to create the image (https://www.ncl.ucar.edu/).



**Figure S5:** Sensitivity simulations for different emission inventory over Delhi.



**Figure S6**: Time-series of daily surface-level PM2.5 concentrations from a) observations (black line) (average of 37 stations across Delhi) b) model simulations with EDGAR emissions inventory and with 10 km x 10 km grid-spacing (green line) c) model simulations with High-resolution Delhi Emission Inventory (HrDEI) and with 10 km x 10 km grid-spacing (blue line) and d) model simulations with HrDEI emissions’ inventory and with 400 m x 400 m grid-spacing (red line) of 1st day forecast.



**10KM**

**2KM**

**Figure S7:** Spatial distribution of average PM2.5 of 1st day forecast for 400 meter grid spacing during 21 October 2019 to 01 February 2020 at 10 km grid spacing (left) and 2 Km Horizontal grid spacing (right). We have used ncl/6.6.2 software to create the images (https://www.ncl.ucar.edu/).



**Figure S8:** Correlation between hourly mean observed and predicted PM2.5 in Delhi.

**Table ST1:** Selected atmospheric physical and chemical parameterizations

|  |  |
| --- | --- |
| **Atmospheric Process** | **Parameterization** |
| Cloud Microphysics | WRF Single-Moment 6-class scheme (WSM6)1 |
| Short- and Long-wave radiation | Rapid Radiative Transfer Model for GCMs2 |
| Surface Layer | Monin-Obukhov (Janjic Eta)Scheme3,4 |
| Land Surface model | Unified Noah Land-surface model5 |
| Planetary Boundary Layer | MYNN2.56 |
| Cumulus | Grell-Freitas ensemble scheme7 |
| Gas-phase Chemistry | Model for Ozone and Related Tracers8 |
| Aerosol Processes | Goddard Global Ozone Chemistry Aerosol Radiation and Transport (GOCART)9 |

**Table ST2**: Performance statistics for mean PM2.5 forecast for different emission inventory and different grid spacing of 1st day forecast over Delhi.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **State**  **Variables** | **Emission Variables** | **MB** | **NMFB (%)** | **NMFE (%)** | **r** |
| **PM25\_hourly** | **EDGAR@10km** | **-63.1** | **-42.6** | **51.1** | **0.5** |
| **HrDEI@10km** | **-0.3** | **-0.2** | **33.1** | **0.6** |
| **HrDEI@400m** | **2.5** | **1.3** | **36.3** | **0.5** |
| **PM25\_daily** | **EDGAR@10km** | **-64.9** | **-43.8** | **47.8** | **0.5** |
| **HrDEI@10km** | **-1.0** | **-0.5** | **23.2** | **0.7** |
| **HrDEI@400m** | **1.8** | **1.0** | **25.6** | **0.6** |

**Table ST3:** Performance statistics for simulated PM2.5 at different monitoring sites in Delhi during 21 October 2019 to 01 February 2020 at 400 m horizontal grid-spacing.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| State | Station name | Latitude | Longitude | MB | NMB (%) | RMSE | R |
| Delhi | CRRI Mathura Road (103) | 28.5512005 | 77.2735737 | 158.7 | 87.6 | 249.9 | 0.4 |
| Burari Crossing (104) | 28.7256504 | 77.2011573 | -60.2 | -31.0 | 149.5 | 0.3 |
| North Campus DU (105) | 28.6573814 | 77.1585447 | 68.4 | 40.8 | 181.6 | 0.3 |
| IGI-Airport-T3 (106) | 28.5627763 | 77.1180053 | -12.6 | -8.1 | 106.0 | 0.4 |
| Pusa IMD (107) | 28.639645 | 77.146262 | 115.2 | 83.4 | 208.1 | 0.3 |
| DTU (118) | 28.7500499 | 77.1112615 | -95.6 | - 45.6 | 161.2 | 0.3 |
| R K Puram (124) | 28.674045 | 77.131023 | 59.4 | 37.2 | 154.0 | 0.4 |
| Shadipur (113) | 28.6514781 | 77.1473105 | 104.4 | 65.5 | 177.0 | 0.6 |
| NSIT Dwarka (115) | 28.60909 | 77.0325413 | -36.1 | - 20.7 | 92.4 | 0.5 |
| Mandir Marg (122) | 28.636429 | 77.201067 | 52.2 | 29.1 | 174.3 | 0.2 |
| Punjabi Bagh (125) | 28.563262 | 77.186937 | -0.5 | - 0.2 | 122.1 | 0.5 |
| Sirifort (119) | 28.5504249 | 77.2159377 | -12.4 | - 6.3 | 120.4 | 0.4 |
| Lodhi Road (109) | 28.5918245 | 77.2273074 | 34.4 | 23.3 | 127.8 | 0.3 |
| ITO (117) | 28.6316945 | 77.2494387 | 20.0 | 10.7 | 144.4 | 0.3 |
| Anand Vihar (301) | 28.646835 | 77.316032 | -52.3 | - 25.0 | 145.2 | 0.5 |
| Sector – 62 (111) | 28.6245479 | 77.3577104 | -33.5 | -17.3 | 133.8 | 0.3 |
| IHBAS-Dilshad-Garden (114) | 28.6811736 | 77.3025234 | 13.3 | 8.5 | 118.5 | 0.4 |
| Aya Nagar (108) | 28.4706914 | 77.1099364 | -23.8 | -15.7 | 110.8 | 0.4 |
| Vasundhara (144) | 28.6603346 | 77.3572563 | -31.5 | - 14.0 | 140.5 | 0.4 |
| Sector 125 (153) | 28.5447608 | 77.3231257 | -14.9 | - 7.5 | 140.9 | 0.3 |
| Ashok\_Vihar (1420) | 28.695381 | 77.181665 | 26.1 | 24.3 | 79.0 | 0.2 |
| DKSS\_Stadium (1421) | 28.498571 | 77.264840 | -48.0 | - 24.5 | 137.8 | 0.3 |
| Dwarka Sector8 (1422) | 28.57 | 77.07 |  |  |  |  |
| Jahangirpuri (1423) | 28.732820 | 77.170633 | -81.1 | - 35.9 | 151.5 | 0.3 |
| Jawaharlal Nehru Stadium (1424) | 28.580280 | 77.233829 | 3.0 | 1.5 | 116.8 | 0.5 |
| MDC National Stadium (1425) | 28.611281 | 77.237738 | 32.7 | 19.2 | 140.0 | 0.3 |
| Najafgarh (1427) | 28.570173 | 76.933762 | 46.1 | 85.3 | 59.3 | 0.1 |
| Narela (1426) | 28.822836 | 77.101981 | -49.4 | - 38.8 | 66.8 | 0.1 |
| Nehru Nagar (1429) | 28.567890 | 77.250515 | -9.2 | - 3.8 | 145.3 | 0.5 |
| Okhla Phase2 (1428) | 28.530785 | 77.271255 | 17.4 | 14.7 | 77.6 | 0.2 |
| Patparganj (1431) | 28.623748 | 77.287205 | 28.7 | 16.0 | 122.5 | 0.4 |
| Rohini (1430) | 28.732528 | 77.119920 | -88.6 | - 39.1 | 163.0 | 0.4 |
| Sonia Vihar (1432) | 28.710508 | 77.249485 | -44.6 | - 25.8 | 114.3 | 0.3 |
| Sri\_Aurbindo\_Marg (1562) | 28.531346 | 77.190156 | 2.6 | 3.1 | 53.5 | 0.1 |
| Mundak (1561) | 28.684678 | 77.076574 | 19.0 | 18.8 | 50.8 | 0.6 |
| New\_collectorate (1569) | 28.974801 | 77.213357 | -83.3 | - 46.4 | 142.2 | 0.4 |
| New\_mandi (1550) | 29.4723508 | 77.7194031 | -65.0 | - 44.9 | 109.6 | 0.4 |
| Bawana (1560) | 28.776200 | 77.051074 | -92.6 | - 41.9 | 163.4 | 0.4 |

**Table ST4:** Model performance goals used to evaluate the model performance for PM2.5 (Morris et al., 2005)

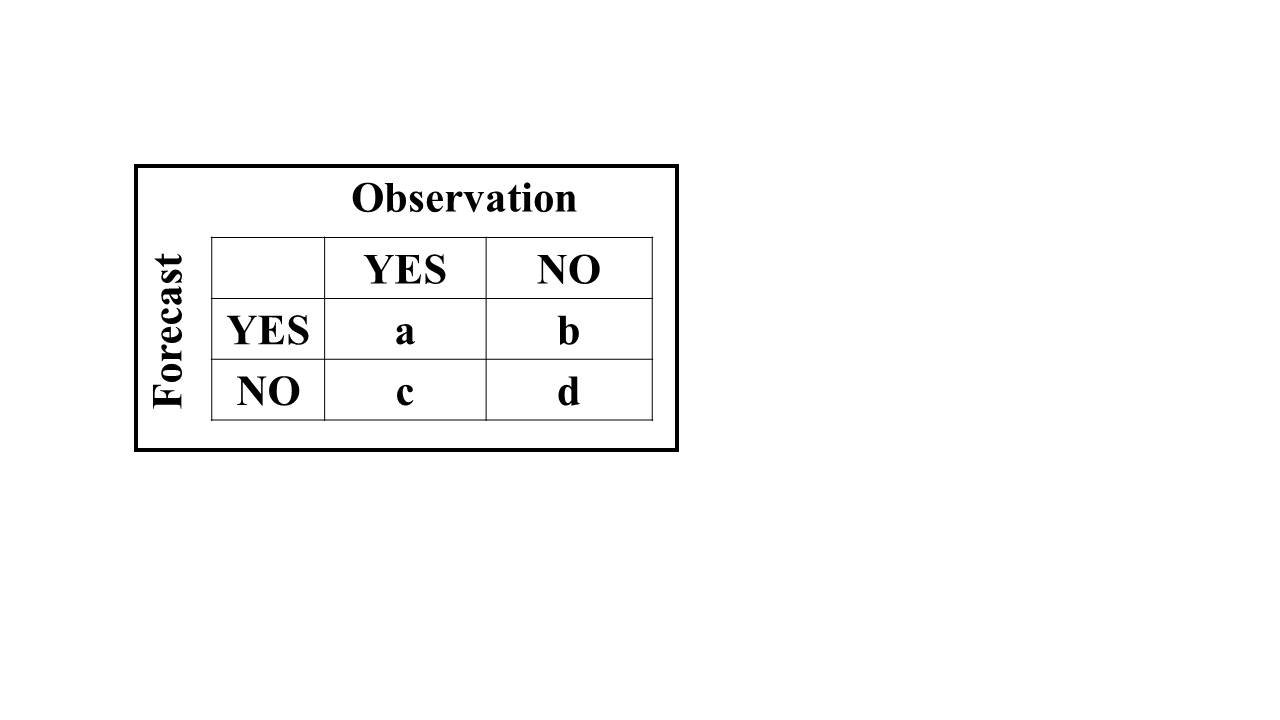
|  |  |  |
| --- | --- | --- |
| **Fractional Bias** | **Fractional Error** | **Comment** |
| ≤ ± 15% | ≤ 35% | A level of model performance that would be considered excellent |
| ≤ ± 30% | ≤ 50% | A level of model performance that would be considered good |
| ≤ ± 60% | ≤ 75% | A level of model performance that would be considered average and hope each PM species could meet for regulatory modeling |
| > ± 60% | > 75% | At or exceeding this level of performance indicates fundamental problems with the modeling system |

**Table ST5:** AQI category and corresponding break-point concentrations ranges for PM2.5 based on National Ambient Air Quality Standard (NAAQS)**.**

|  |  |  |
| --- | --- | --- |
| **AQI Category** | **AQI** | **PM2.5**  **Concentration range** |
| **Good** | **0 - 50** | **0 - 30** |
| **Satisfactory** | **51 - 100** | **31 - 60** |
| **Moderately** | **100 - 200** | **61 - 90** |
| **Poor** | **201 - 300** | **91 - 120** |
| **Very poor** | **301 - 400** | **121 - 250** |
| **Severe** | **401 +** | **250+** |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| State | PM25 AQI  Category | Variables | **10km** | | | **2km** | | | **400 meter** | | |
| **MB** | **NMFB (%)** | **NMFE (%)** | **MB** | **NMFB (%)** | **NMFE (%)** | **MB** | **NMFB (%)** | **NMFE (%)** |
| Delhi | Poor  (201-300) | 1st day | 51.1 | 18.4 | 19.3 | 66.2 | 23.2 | 23.3 | 62.9 | 22.1 | 22.3 |
| 2nd day | 30.4 | 11.4 | 20.8 | 56.1 | 20.0 | 22.6 | 53.6 | 19.2 | 22.2 |
| 3rd day | 16.3 | 6.2 | 23.2 | 42.4 | 15.4 | 20.9 | 44.6 | 16.2 | 20.2 |
| Very Poor  (301-400) | 1st day | 4.2 | 1.2 | 6.4 | 12.3 | 3.5 | 7.4 | 8.2 | 2.3 | 6.8 |
| 2nd day | -17.7 | -5.3 | 9.1 | 0.2 | 0.1 | 6.7 | -2.7 | -0.8 | 6.9 |
| 3rd day | -27.5 | -8.3 | 11.4 | -13.7 | -4.0 | 8.9 | -13.4 | -3.9 | 8.7 |
| Severe  (401-above) | 1st day | -47.1 | -11.1 | 15.6 | -55.5 | -13.3 | 16.2 | -58.0 | -13.9 | 16.3 |
| 2nd day | -89.0 | -22.1 | 22.2 | -70.2 | -17.1 | 17.5 | -70.8 | -17.2 | 17.8 |
| 3rd day | -105.0 | -26.7 | 26.7 | -86.2 | -21.4 | 21.8 | -83.6 | -20.7 | 20.9 |

**Table ST6:** Performance statistics of different PM2.5 AQI forecast category

**Table ST7:** A contingency table and equations used to calculate the different skill score for different category of AQI forecast.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Statistic name | What it measures | Equation | unit | How to interpret |
| **Accuracy (A)** | Percent of forecasts that correctly predicted the event or non-event. | A=(a+d)/(a+b+c+d) \*100 | % | Higher numbers are better |
| **False Alarm Rate (FAR)** | The percent of times a forecast of high pollution did not actually occur. | FAR = (b/(a+b)) \*100 | % | Smaller values are best |
| **Probability of Detection**  **(POD) or Hit rate** | Ability to predict high pollution events (i.e., the percentage of forecasted high pollution events that actually occurred). | POD = (a/(a+c)) \* 100 | % | Higher numbers are best |
| **Critical Success Index**  **(CSI), also called Threat**  **Score** | How well the high-pollution events were predicted. Useful for evaluating rarer events like high-pollution days. It is not affected by a large number of correctly forecasted, low pollution events. | CSI = (a/(a+b+c)) \* 100 | % | Higher numbers are best |

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