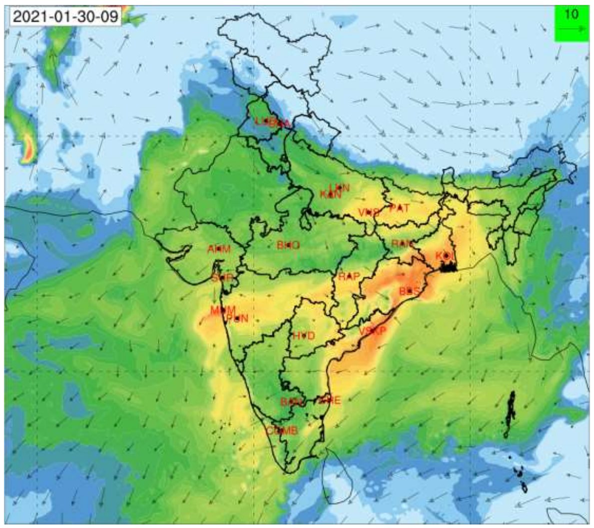
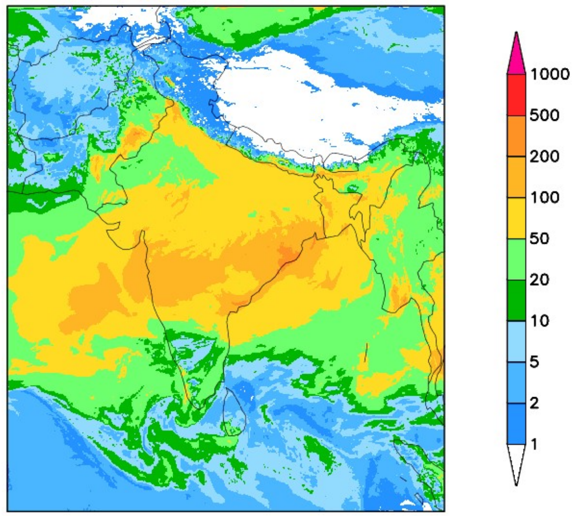
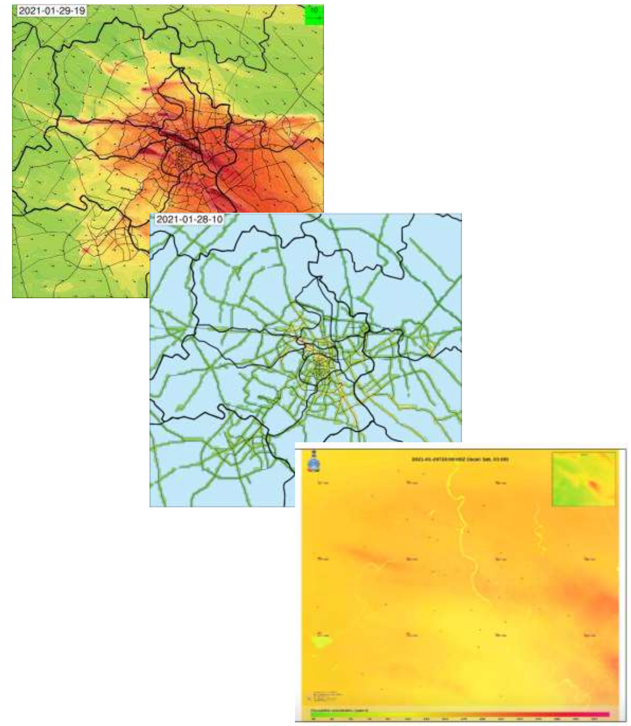
Recent Advances in Air Quality Forecasting in India

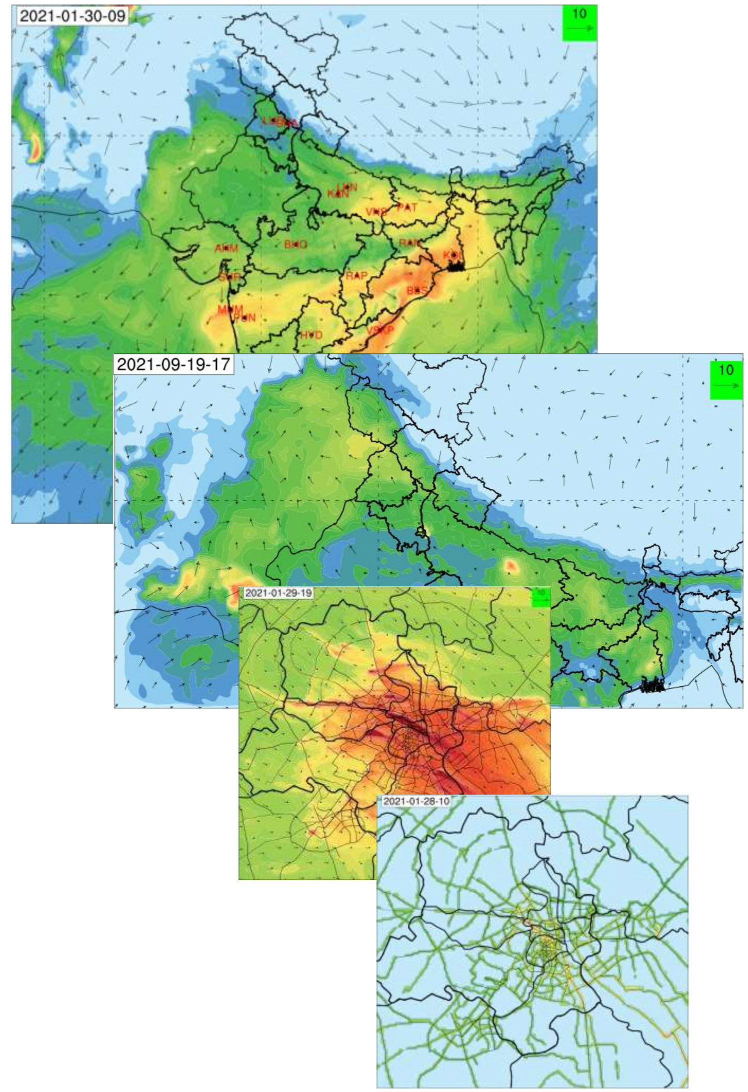






What Are We Forecasting

- **Scales**
  - Regional or mesoscale (10 km)
  - Urban or sub-regional (10 km to 400m)
  - Neighborhood or single site (400 m and less)
  - Forecast scale needs to match local air quality scale
- **Metrics**
  - Extremes of all sites in forecast zone
  - Multi-site average
  - Others
- **Pollutants of concern**
  - Major (PM10, PM2.5, O3, CO, SO2, and NOx)
  - Dust
  - Contribution from Dust, Fire
- **Critical forecast issues**
  - Timeliness (when do users need it)
  - Localized forecasts
  - Multi-day (three-to-ten day) forecasts are useful
  - Easy-to-understand format (AQ Index)



National Ambient Air Quality Standards

Environment (Protection) Seventh Amendment Rules, 2009

Sensitive Areas: Hill stations, health resorts, sancturies, national parks, national monuments and other areas where the nation conserves its clean environment even if that implies some curb on economic activity

Pollutant	Time Weighted Average	Concentration in Ambient Air		
		Industrial, Residential, Rural and other area	Ecologically sensitive areas (notified by Central Govt.)	Methods of Measurement
SO_2 (μgm^{-3})	Annual* 24 hours**	50 80	20 80	- Improved West and Goeke - UV - fluorescence
NO_2 (μgm^{-3})	Annual* 24 hours**	40 80	30 80	- Modified Jacob & Hochheiser (Na-Arsenic) - Chemiluminescence
PM_{10}, (μgm^{-3})	Annual* 24 hours**	60 100	60 100	- Gravimetric - TEOM - Beta Attenuation
$PM_{2.5}$, (μgm^{-3})	Annual* 24 hours**	40 60	40 60	- Gravimetric - TEOM - Beta Attenuation
Ozone (μgm^{-3})	8 hours 1 hour	100 180	100 180	- UV photometric - Chemiluminescence - Chemical Method
Lead (μgm^{-3})	Annual* 24 hours**	0.5 1.0	0.5 1.0	- AAS/ICP method after sampling on EPM2000 or equivalent filter paper - ED-XRF using Teflon filter
CO (mgm^{-3})	8 hours 1 hour	2000 4000	2000 4000	- Non-dispersive Infra Red (NDIR) spectroscopy
NH3 (μgm^{-3})	Annual* 24 hours**	100 400	100 400	-Chemiluminescence -Indophenol Blue Method
Benzene (μgm^{-3})	Annual*	5	5	- Gas Chromatography based continuous analyzer - Absorption and Desorption followed by GC analysis
Benzo(a)Pyrene - particulate phase only (ngm^{-3})	Annual*	1	1	- Solvent extraction byHPLC/GC analysis
Arsenic (ngm^{-3})	Annual*	6	6	- AAS/ICP method after sampling on EPM2000 or equivalent filter paper
Nickel (ngm^{-3})	Annual	20	20	- AAS/ICP method after sampling on EPM2000 or equivalent filter paper

How do we know if Air Quality is poor?

AQI is an overall scheme that transforms individual air pollutant (e.g. SO_2, CO, PM_{10}) levels into a single number, which is a simple and lucid description of air quality for the citizens.

AQI relates to health impacts and citizens can avoid the unnecessary exposure to air pollutants;

AQI indicates compliance with National Air Quality Standards;

AQI prompts local authorities to take quick actions to improve air quality;

AQI guides policy makers to take broad decisions; and

AQI encourages citizens to participate in air quality management.

AQI

AIR QUALITY INDEX

AQI values	Levels of health concern
0 – 50	Good
51 – 100	Satisfactory
101 – 200	Moderately-polluted
201 – 300	Poor
301 – 400	Very Poor
401 - 500	Severe

Equation for Calculating an Air Pollutant AQI Index Value

$$I_P = \left(\frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} \right) [Cp - BP_{Lo}] + I_{Lo}$$

Ip = Index magnitude for air pollutant P

Cp = concentration for pollutant P

I_{Hi} = AQI value corresponding to BP_{Hi}

I_{Lo} = AQI value corresponding to BP_{Lo}

BP_{Hi} = breakpoint that is greater than Cp

BP_{Lo} = breakpoint that is less than Cp

AQI categories and breakpoint concentrations with averaging times

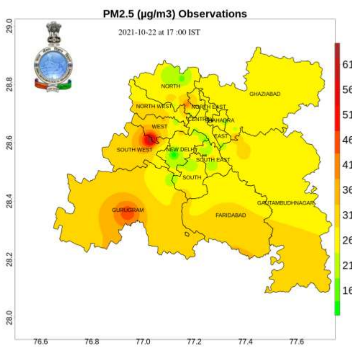
(units: $\mu g/m^3$ unless mentioned otherwise)

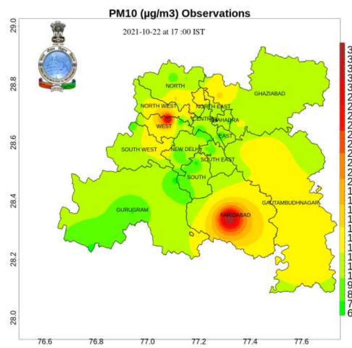
AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 24-hr	O_3 8-hr	CO 8-hr (mg/m^3)	SO_2 24-hr	NH_3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6 –1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1- 10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

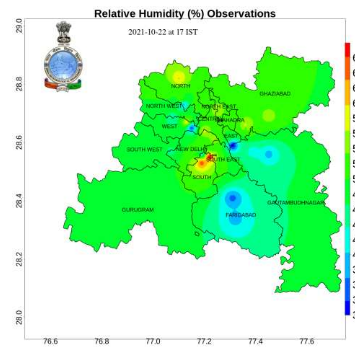
AQI	Possible Health Impacts
Good	minimal impact
Satisfactory	minor breathing discomfort to sensitive people
Moderate	breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor	breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure
Very Poor	respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe	respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases

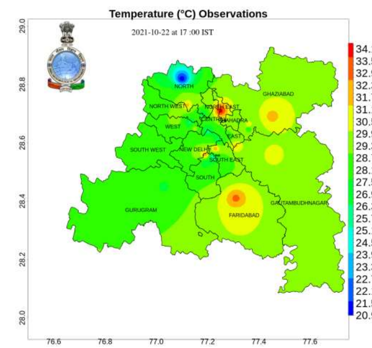
The higher the AQI, greater the air pollution and health concerns

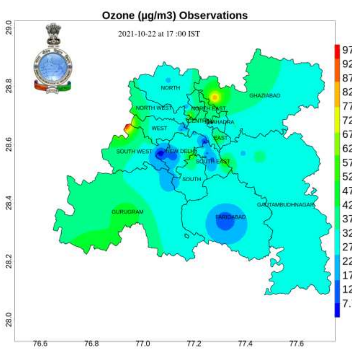
Web-based AQI, Pollutants and Meteorological Parameters dissemination: Urban Meteorology

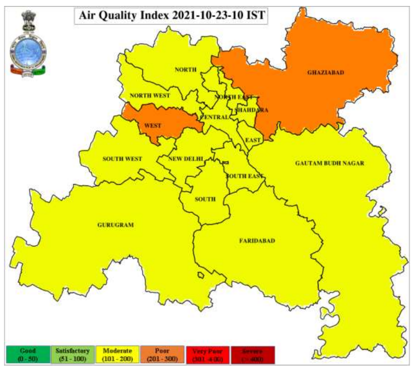


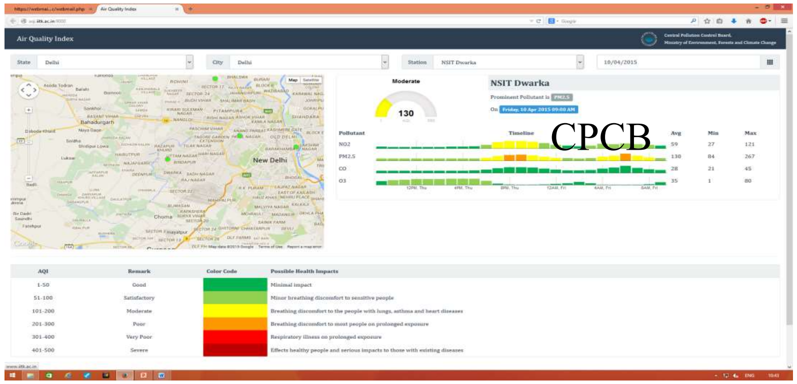










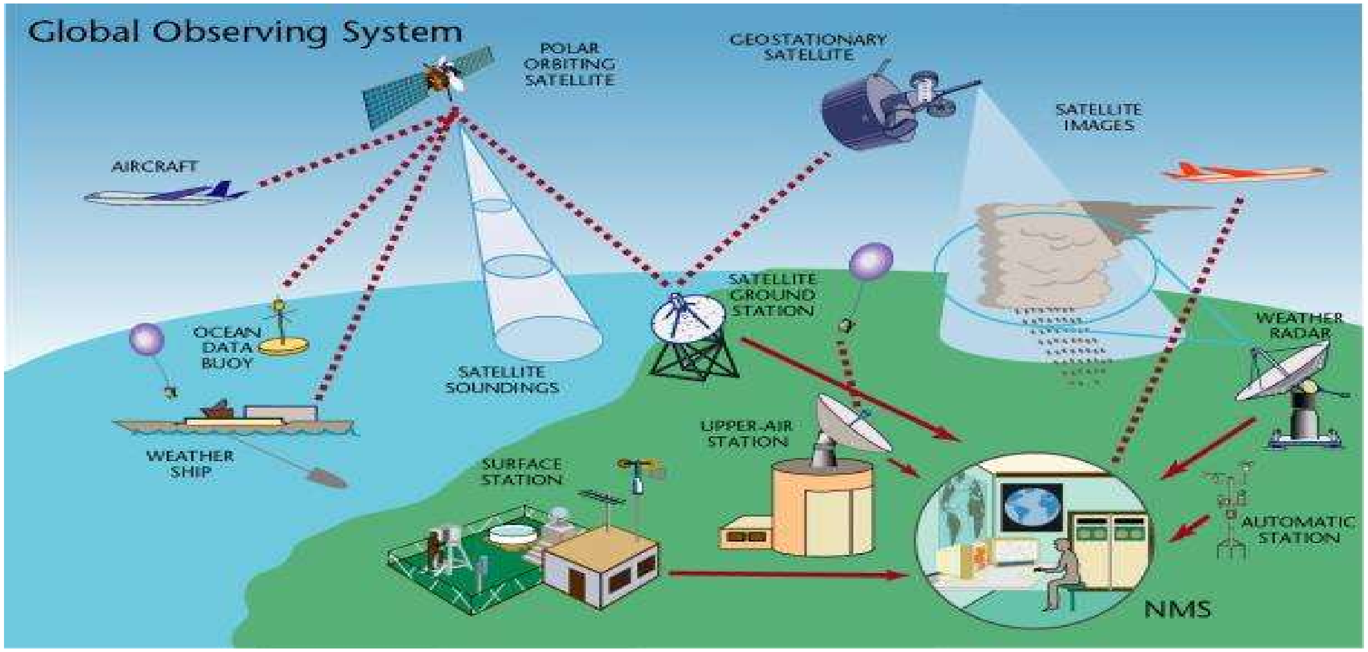


Environmental monitoring

Environmental monitoring can be defined as the systematic sampling of air, water, soil, and biota in order to observe and study the environment, as well as to derive knowledge from this process

Ambient Environment Monitoring

Ambient air quality, Air pollution emissions
Water Resources Monitoring
Sediment, Soil and Biological Monitoring



Major Air Quality Forecasting Techniques

1. Simple Empirical Approaches

2. Parametric (Statistical) models

3. Advanced, Physically-Based Approaches

1. Simple Empirical Approaches

(a) Persistence: Today's observed pollutants levels are tomorrow's forecast value

Strengths: Computationally fast; accurate during stationary conditions; low operational cost
Limitation: Cannot handle abrupt change of weather, emissions, and air quality; low accuracy

(b) Climatology: Based on the hypothesis that air quality is highly dependent on weather, and air quality climatology

Strengths: Computationally fast; helps guide and bound forecasts derived from other methods; Simple to use and requires little expertise; low operational cost
Limitation: Cannot handle abrupt change of air quality; low accuracy

(c) Empiricism : Based on the assumption that thresholds (i.e., criteria) of forecasted meteorological variables can indicate future high pollutant concentrations

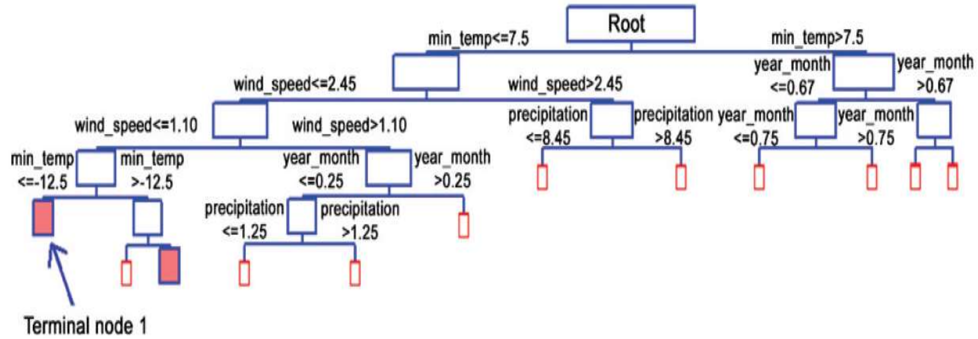
Strengths: Computationally fast; an effective screening method for high pollution events; simple to use; low operational cost
Limitation: Cannot forecast exact concentrations; does not work for pollutants that depend weakly on weather; moderate accuracy

2. Parametric (Statistical) models

(a) Classification and Regression Tree (CART): Uses decision tree

Strengths: Computationally fast; works well for a given site; automatically differentiates between days with similar pollutant concentrations; requires modest expertise; low operational cost; moderate/high accuracy

Limitation: Cannot accurately predict extreme concentrations; limited use due to limited observations and large local-scale variations of concentrations



(b) Regression Methods : uses a regression equation to predict concentrations based on values of various meteorological and air quality parameters

$$Y_j = b_0 + \sum_{i=1}^{k} b_i X_{ij} + e_j \qquad for\ j = 1, 2, \ldots N$$

where, Y_j is dependent variable to be predicted

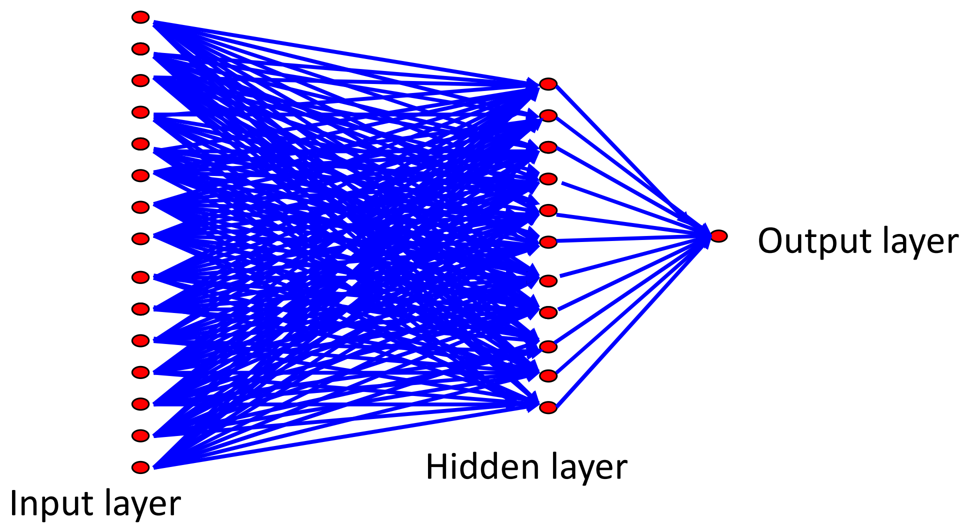
X_1 , X_2 , …X_k are independent variables

b_0 , b_1 , b_2 , …b_k are regression parameter (unknown), calculate using least square method

Strengths: Computationally fast; works well for a given site; commonly used and easy to operate; produces generally good forecasts; requires modest expertise; moderate operational cost; moderate/high accuracy

Limitation: Cannot accurately predict extreme concentrations; the linear regression cannot handle non-linearity of the chemical system; limited use due to limited observations and large local-scale variations of concentrations

(c) Artificial Neural Networks (ANNs) : Use simplified mathematical models of brain-like systems to enable a structure to simulate intelligent behaviour in computers



Strengths: Capacity to learn from data; works well for a given site; can handle nonlinear and chaotic chemical system at a site; requires modest expertise; moderate operational cost; moderate/high accuracy; computationally fast

Limitation: Cannot accurately predict extreme concentrations; limited use due to limited observations and large local-scale variations of concentrations; poor generalization performance; moderate/high accuracy and operational cost

(d) Fuzzy Logic Method (FL): Uses a form of algebra with a range of values in terms of logical variables that can have continuous values between 0 and 1 (false or true, respectively) to represent varying degrees of truthfulness and falsehood (i.e., partially true or false).

Strengths: Capacity to represent inherent uncertainties of human knowledge; can handle non-linearity and chaotic chemical system; requires modest expertise; moderate/high accuracy; moderate operational cost

Limitation: Limited use due to limited observations and large local-scale variations of concentrations; poor generalization performance; needs a substantial amount of observational data; the computational complexity due to large number of inappropriate rules

The statistical approaches usually require a large quantity of historical measured data under a variety of atmospheric conditions.

Status Worldwide: Various statistical approaches have been applied to air quality forecasting since the late 1970s. These include multiple linear regression (e.g., Wolff and Lioy, 1978; Stadlober et al., 2008; Genc et al., 2010), CART (e.g.,Burrows et al., 1995), ANNs (e.g.,Pérez and Reyes, 2006; Li and Hassan, 2010), FL systems (e.g., Shad et al., 2009; Alhanafyet al., 2010), nonlinear regression (NLR) (e.g.,Cobourn and Hubbard, 1999), hybrid NLR (Cobourn, 2007), and KF (e.g.,Chenevez and Jensen, 2001; Hoi et al., 2008).

Status in India: Multiple linear regression (MLR) (e.g., Goyal et al., 2006), Principle component analysis with MLR (Kumar and Goyal, 2011), ANNs (Goyal and Kumar, 2011), PCA with ANNs (Kumar and Goyal, 2013), FL system (Mishra et al., 2015; Prasad et al., 2016)

3. Advanced physically-based approaches

(a) Deterministic Models: Deterministic models of air quality explicitly represent all major meteorological, physical, and chemical processes that lead to the formation and accumulation of air pollutants by solution of the conservation equations for the mass of various species and transformation relationships among chemical species and physical states

(i) Offline coupled meteorology and air quality models (e.g., WRF-CMAQ; WRF-SILAM) (doesn't permit aerosol feedbacks to radiation and photolysis)
(ii) Online coupled meteorology and air quality models (e.g, WRF-Chem) (permits aerosol feedbacks to radiation and photolysis)

Strengths: Prognostic time- and spatially-resolved concentrations under both typical and atypical scenarios and in areas that are not monitored; scientific insights into pollutant formation processes, accounts for the air parcel history including transport issues; does not require a large quantity of measurement data; moderate/high accuracy

Limitation: Biases due to imperfect and missing model treatments and inaccuracies and uncertainties in meteorological and emissions predictions and model inputs; Computationally expensive; a need for a high speed computer system; high-level of expertise; moderate/high operational cost

(b) Deterministic models with Bias Correction Techniques: Air quality models are combined with a statistical model

Strengths: Combines merits of deterministic models and statistical models(or other techniques); high accuracy

Limitation: Bias correction may be effective only for systematic biases and may hinder model improvement needs; computationally expensive and complex; a need for a high speed computer system; high-level of expertise; high operational cost

(c) Ensemble and Probabilistic Methods: It shifts from purely deterministic forecasts to probabilistic forecast

Strengths: Improved forecast skills compared to a single member; can handle uncertainties in AQF; provides an estimate of likelihood of an occurrence of an event on a scale from 0 to 1

Limitation: Observational errors are not always accounted for; inherent limitations associated with individual ensemble model member; accuracy sensitive to weighting factors; computationally very expensive and complex; a need for supercomputer system; high-level of expertise; very high operational cost

The advanced physically-based approaches are computationally very expensive and complex.

Status Worldwide: Since 1990s, real time air quality forecasting (RT-AQF) systems based on CTMs have been developed rapidly and are currently in operation in many countries, including Australia, Canada, India, Japan, U.S., France, Denmark, Germany, Norway, U.K., Spain, Belgium, Turkey, the Netherlands, Chile, and China.

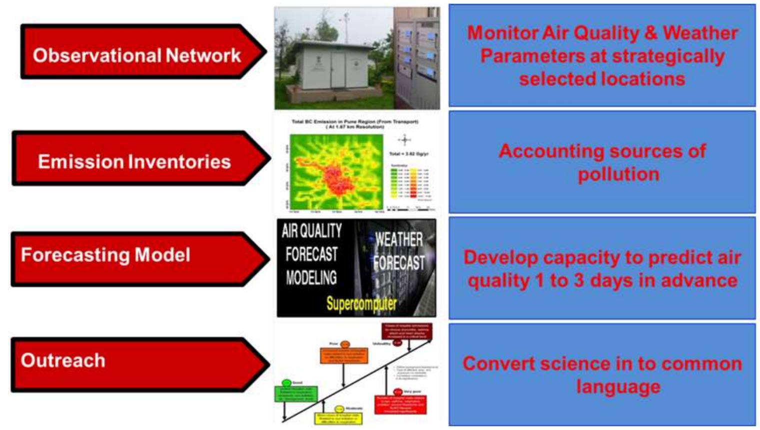
Status in India: Two RT-AQF systems based on WRF-Chem (online coupled meteorology and air quality models) and WRF-SILAM (offline coupled meteorology and air quality models) are currently in operational from year 2019 in India. The resolutions of WRF-SILAM and WRF-Chem are 5 KM and 10 KM respectively covering the whole country. In addition, RT-AQF system based on WRF-Chem is also available at a very high resolution (400 m) over Delhi/NCR region.

Air Quality Monitoring and Prediction

The system for air quality forecasting and research (SAFAR) has been operationalized by IMD to monitor and forecast air quality in Delhi during Commonwealth Games 2010. This is a joint project of IMD, IITM and NCMRWF (Institutions of MoES).

The similar air quality monitoring and prediction system implemented at Pune, Mumbai and Ahmedabad.

Each city has a network of 10 Air Quality Monitoring System

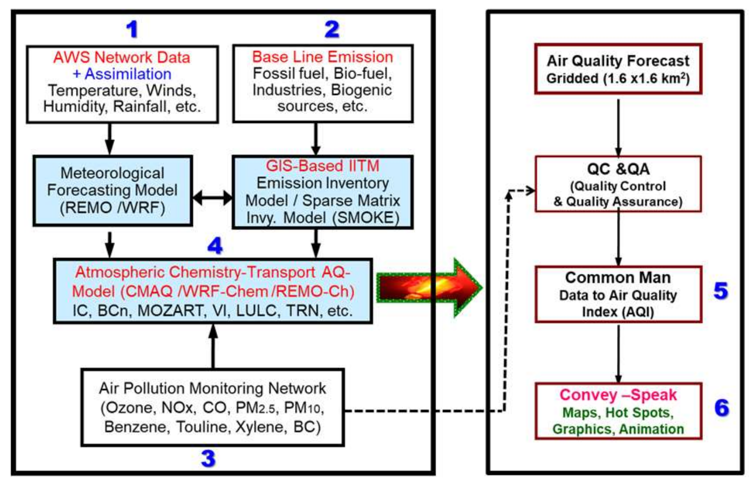


Pollutants Monitored and Prediction

Ozone, Nitrogen Oxides, Carbon Monoxide, Particulate Matter (PM_{10}, $PM_{2.5}$), Sulphur Dioxide, Benzene, Toluene, Xylene, Black Carbon, Carbon Dioxide

UV Radiation

SAFAR: Air Quality Forecasting System



Air Quality Early Warning System

1. Integrated AQEWS system based on IITM WRF-Chem
   a) 10 Km regional air quality forecast (10-days in advance)
   b) 400 m forecast for NCR-Delhi (3-days in Advance)

2. Air Quality forecasting system based on IMD-SILAM
   a) 3 Km regional air quality forecast (3-days in advance)
   b) ENFUSER street level forecast for NCR-Delhi (3-days in advance)

Salient Features:

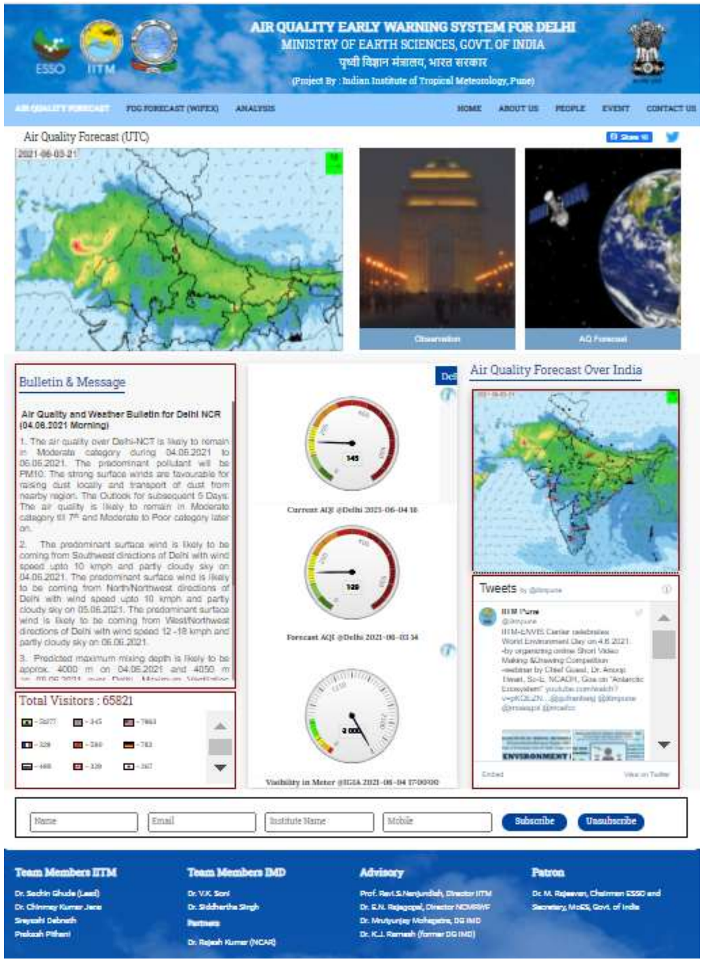
The advanced warning system provides:

a) air quality forecast at 400 meters for Delhi region for 3-days and outlook for next 7-days
b) air quality forecast for entire India and specifically for several non-attainment cities (Pune, Mumbai, Bangalore, Kolkata, Varanasi, Lucknow, Hyderabad, Patna ………)
c) real time observations of air quality over Delhi region, fire counts, AOD
d) details about natural aerosols like dust (from satellite and model forecast)
e) Near real-time fire information over India
f) forecast of the contribution of non-local fire emissions,
g) Weather Information
h) Day to day verification of forecast product.

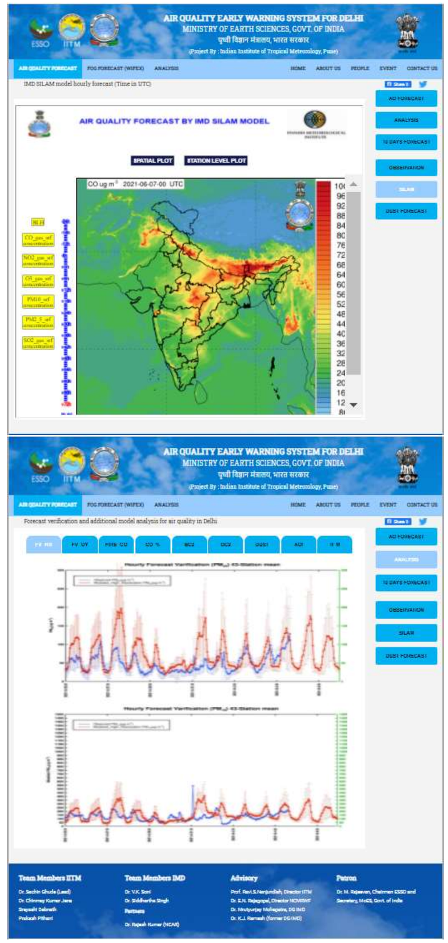
i) Public Dissimilation system: Dedicated website launched for Public for air quality forecast: https://ews.tropmet.res.in/.

Public dissemination system (ews.tropmet.res.in)

For general public



For advanced user



Weather
https://mausam.imd.gov.in/

Apps

MAUSAM

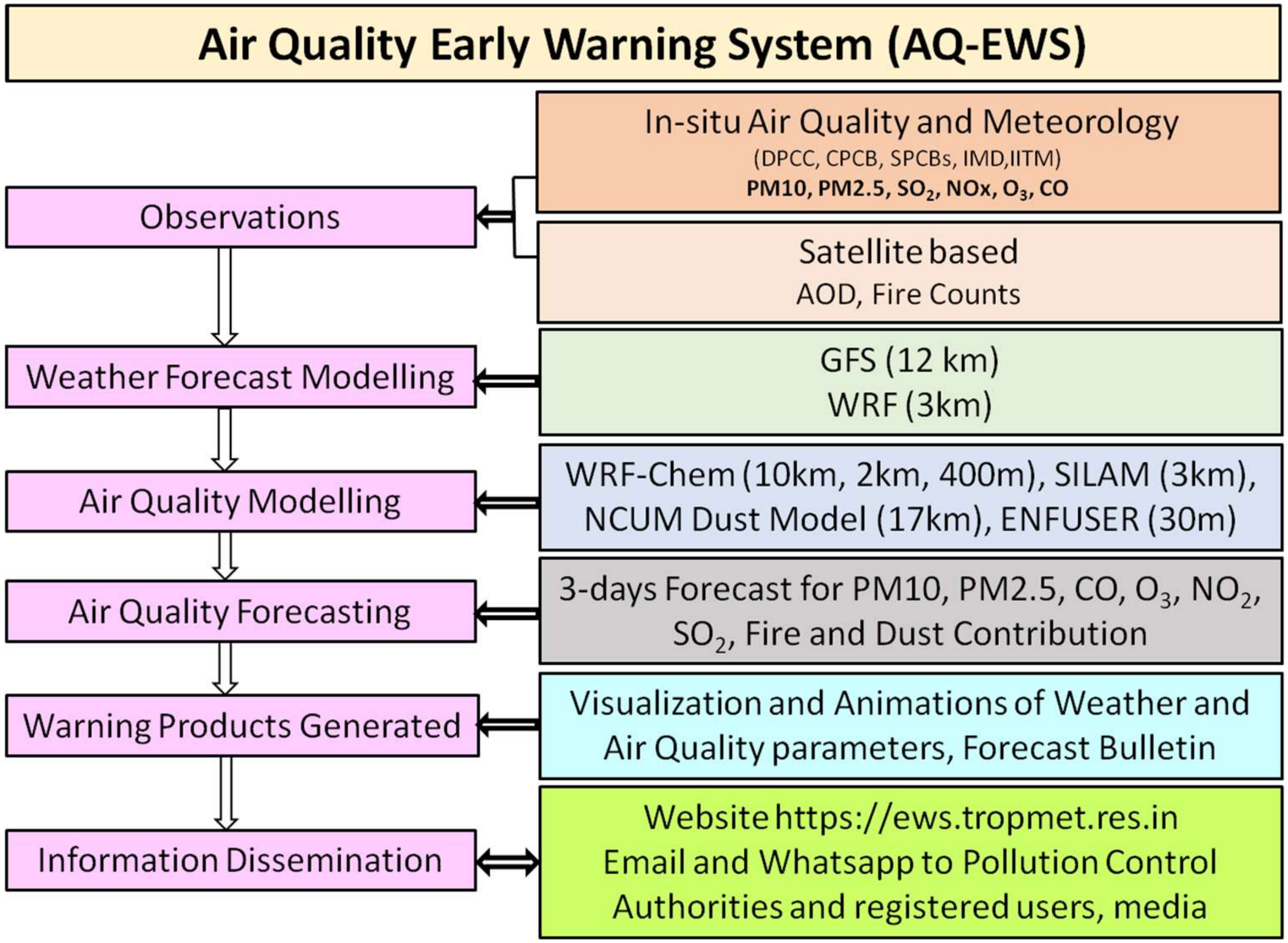
Damini Lightning

Meghdoot Agro

Social Media

https://city.imd.gov.in/citywx/crowd/enter_th_datag.php

Air Quality Forecast: Modelling Systems



Air Quality Early Warning System (AQ-EWS)
In-situ Air Quality and Meteorology
(DPCC, CPCB, SPCBs, IMD,IITM)
PM10, PM2.5, SO2, NOx, O3, CO
Observations
Satellite based
AOD, Fire Counts
Weather Forecast Modelling
GFS (12 km)
WRF (3km)
Air Quality Modelling
WRF-Chem (10km, 2km, 400m), SILAM (3km), NCUM Dust Model (17km), ENFUSER (30m)
Air Quality Forecasting
3-days Forecast for PM10, PM2.5, CO, O3, NO2, SO2, Fire and Dust Contribution
Warning Products Generated
Visualization and Animations of Weather and Air Quality parameters, Forecast Bulletin
Information Dissemination
Website https://ews.tropmet.res.in
Email and Whatsapp to Pollution Control Authorities and registered users, media

SILAM (System for Integrated Modeling of Atmospheric Composition)

IMD Setup

Running:

- Hourly AQ Forecast
- 3 KM WRF forecast (IMD)

Boundary conditions:

- SILAM Global Suit

Emissions:

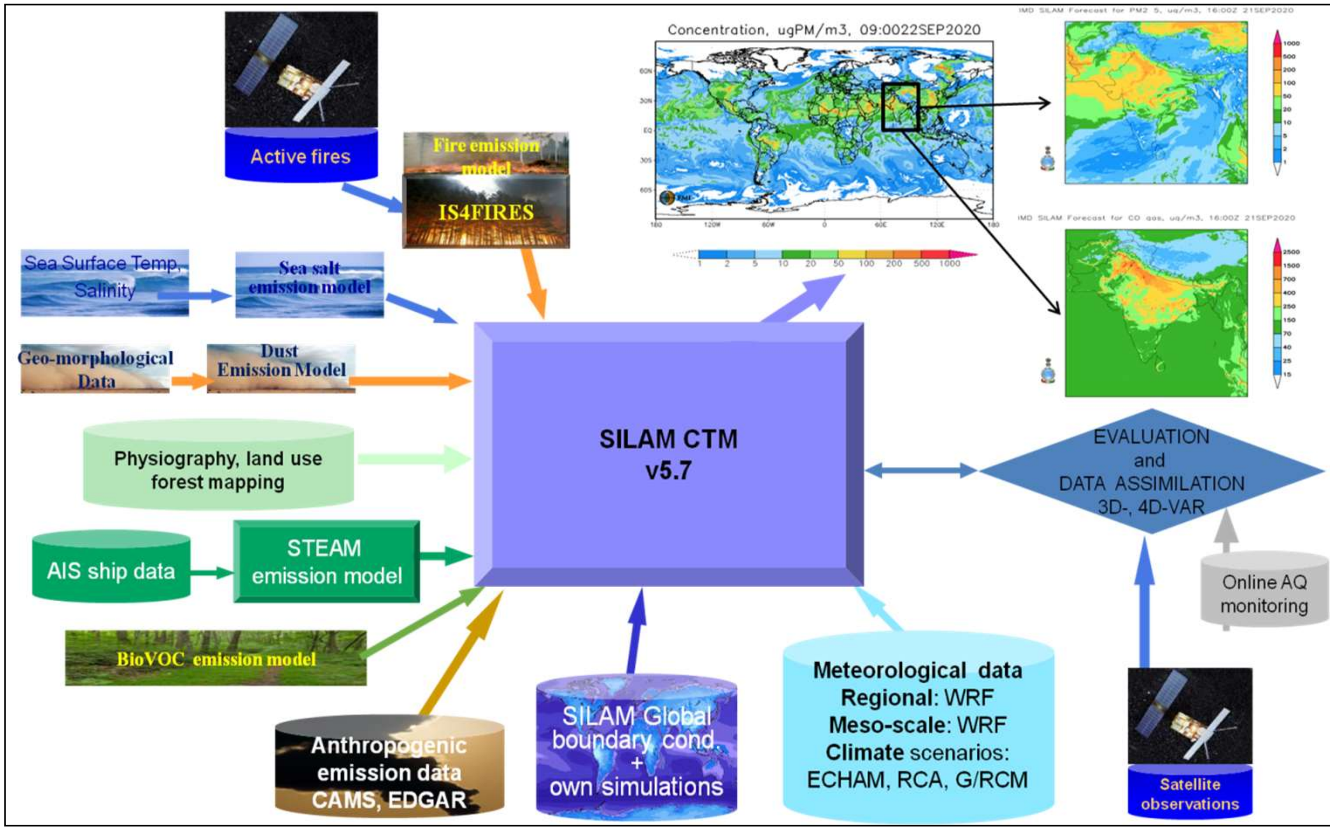
- CAMS-GLOB v2.1, 0.1-deg supplemented with EDGAR v4.3.2 for coarse and mineral-fine anthropogenic PM.
- GEIA v1 lightning climatology
- MEGAN-MACC biogenic climatology for isoprene and monoterpene.
- Natural (dynamic): Silam desert dust, Silam sea salt, Silam marine DMS.
- MoES-SAFAR Emission Inventories

Aerosol Process:

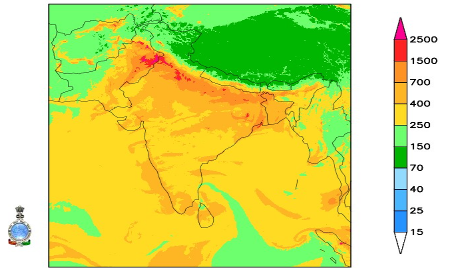
- Simple equilibrium scheme for secondary inorganic aerosols, VBS for secondary organics
- CBM5 chemistry supplemented with secondary organics, DMAT_SULPHUR sulphur oxidation.

Validation

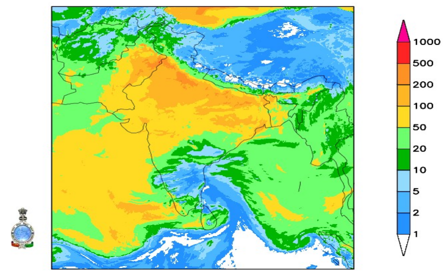
- In-situ data



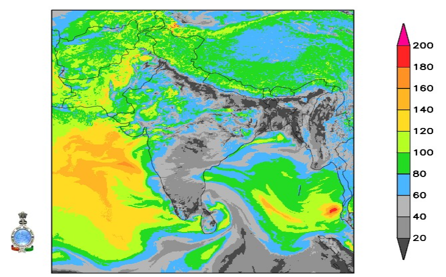
IMD SILAM Forecast for CO gas, ug/m3, 00:00Z 12NOV2020

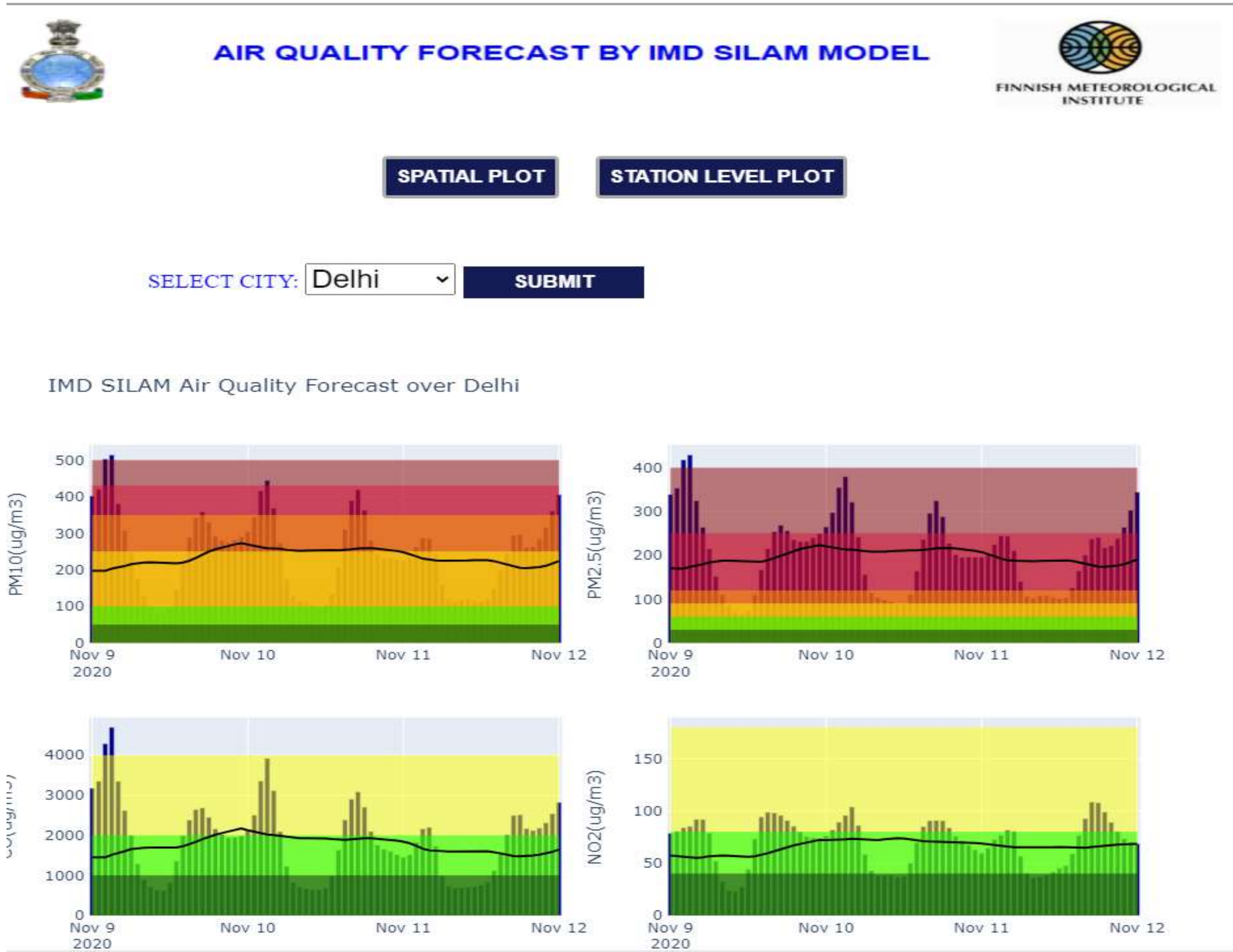


IMD SILAM Forecast for PM2 5, ug/m3, 00:00Z 12NOV2020



IMD SILAM Forecast for O3 gas, ug/m3, 00:00Z 12NOV2020



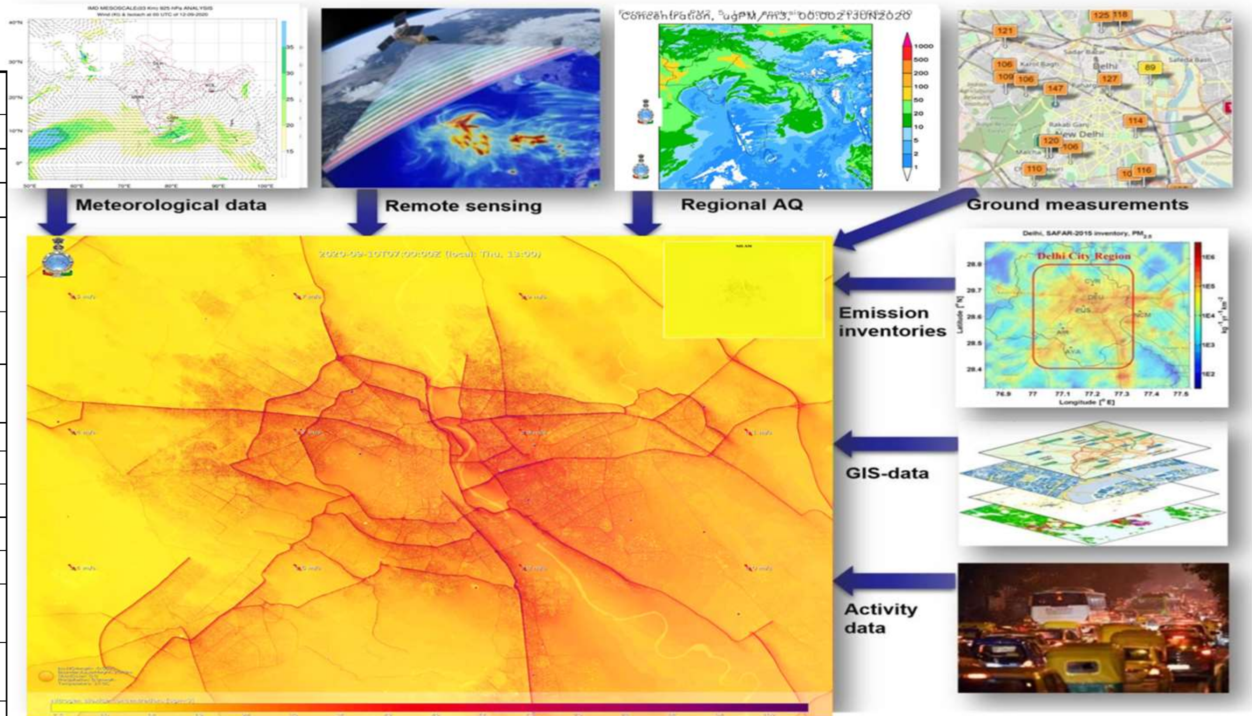


FMI-IMD ENFUSER

https://nwp.imd.gov.in/enfuser_imd.php

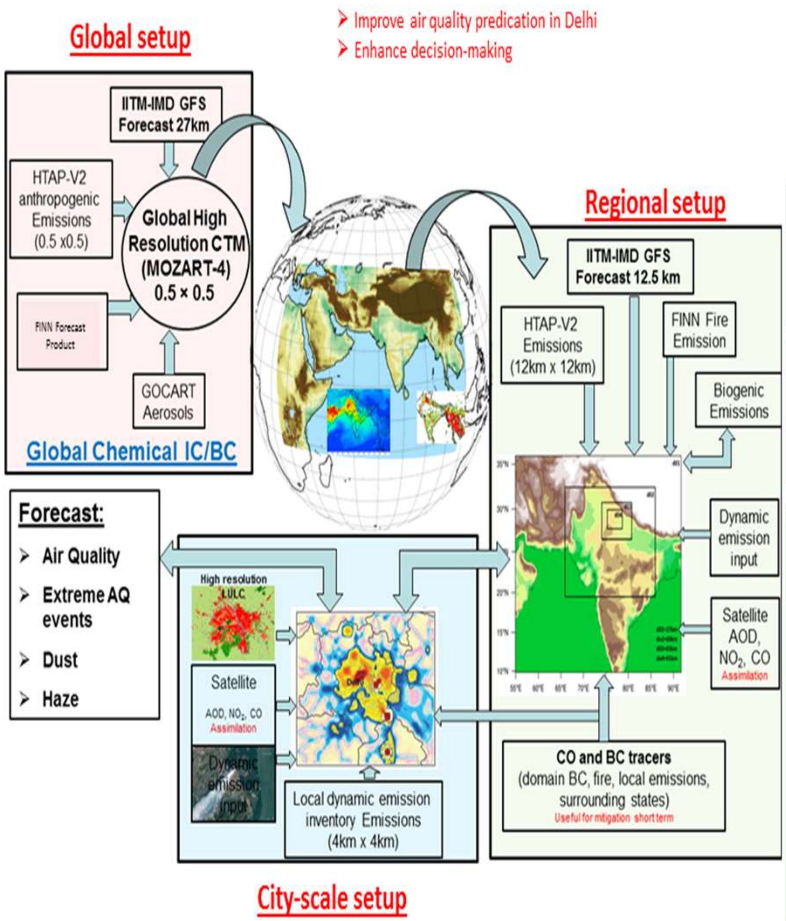
Name	Resolution [m]	Source
OSM land-use, surface*	5	OpenStreetMap
OSM land-use, functional	10	OpenStreetMap
Satellite image	10	Sentinel 2 MSI (TCI)
Satellite image, near-infrared	10	Sentinel 2 MSI (B08 band)
Elevation	30	NASA SRTM
Population	300	Global Human Settlement
Built land-use	30	Global Human Settlement
Road network	5	Several
Elevation gradient	30	Several
Vegetation index	10	Several
Enhanced population	50	Several
Building height	5	Several
Population density at radius X	200	
Property X density at radius Y	200	
Household emission inventory proxy	20	Many
Traffic flow estimates for roads	5	Many

https://nwp.imd.gov.in/silam/SO2_gas_srf.php



Domain range, Latitude	28.362N - 28.86N
Domain range, Longitude	76.901E - 77.56E
Spatial resolution	27m (inner areas with higher resolution can be added)
Temporal resolution	1h averages
Modelled species	NO2, PM2.5, PM10, O3, coarse PM, SO2, CO
Modelling time span	>48h per model run, updated several times a day
Main output formats	netCDF, statistics as CSV
Secondary output formats	animations (avi), gif, Figures (PNG)
Output storage	Local (compressed) and optionally AWS S3 cloud storing

WRF-Chem System Architecture



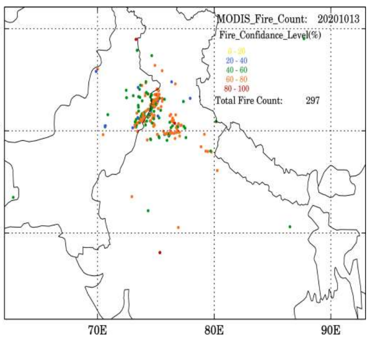
- Complete system that will provide chemistry and air quality forecast from Global, National, Regional and city Scale.
- Chemical data assimilation for accurate initial conditions.
- Analog-ensemble to provide both deterministic and probabilistic air quality predictions.
- Implementation of tagged tracers to get source apportionment and scenarios in forecast.
- Near-real time fire emissions and 3-member ensemble predictor for next 3 days (for crop residue burning)
- Real-time Emission processers

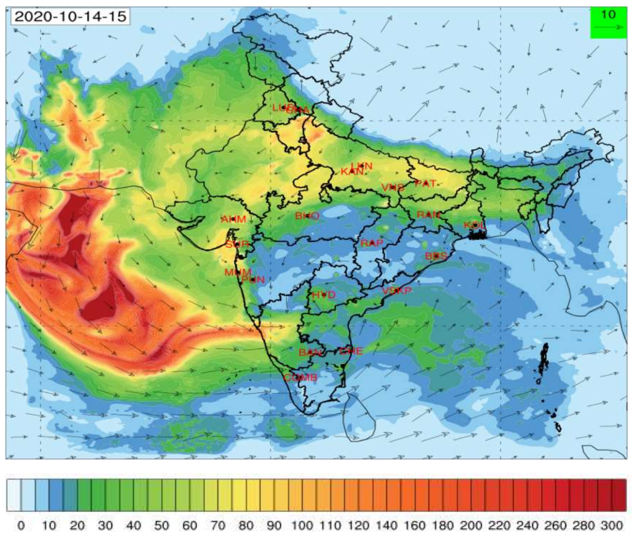
Technological integration of the EWS system:

- **Integrated chemical data assimilation system (3D-VAR -GSI).**
  - **MODIS AOD at 06 UTC and at 09 UTC AOD is assimilated at 09 UTC.**
  - **Surface PM2.5 data assimilation from dense monitoring network**
- **Near-real time stubble fire emission from MODIS fire count at assimilation cycle**
  - **Fires data from MODIS (1km) +VIRS (370 m)**
- **On-line WRF-Chem Chemistry Transport Mdoel**
- **EDGAR emissions and MoES 400 meter emission inventory.**
- **Updated LULC maps with more category for urban buildup**
- **High resolution land surface data assimilation (HRDAS).**
- **System is driven by analysis and forecast product (Ensemble-Kalman filtering) produced by the Indian Institute of Tropical Meteorology-Global Forecasting System (IITM-GFS, T1534) spectral model initial and boundary conditions at 12.5 km grid resolution available at every three hours**

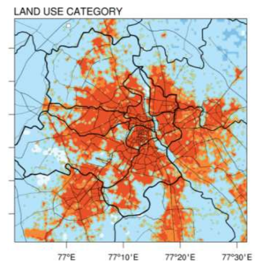
Quick Overview of operational air quality forecasting setup:

Hourly $PM_{2.5}$ forecast at 10 km based on WRF-Chem

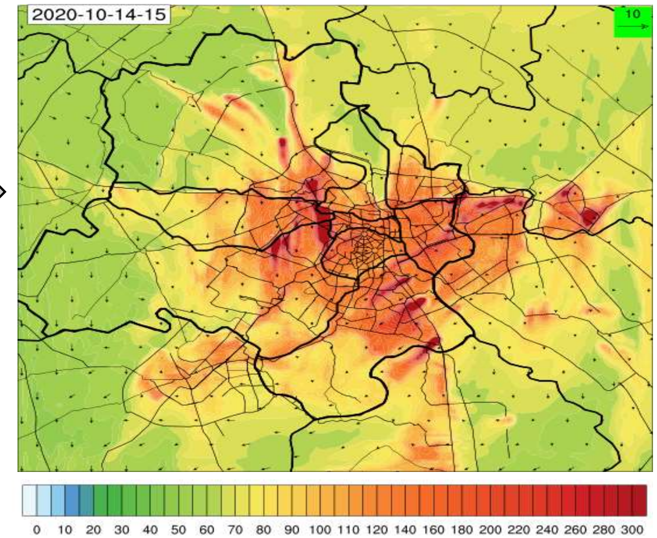




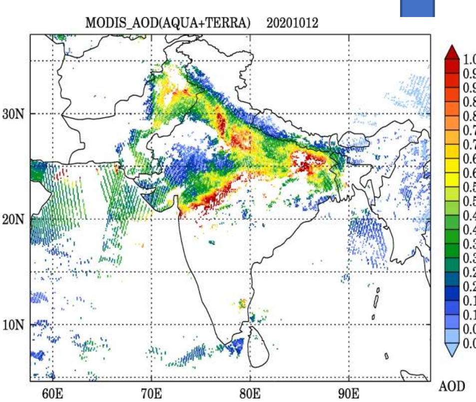
Dynamical downscaling frame-work

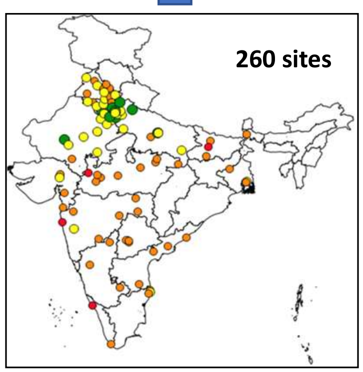


forecast at 400 m

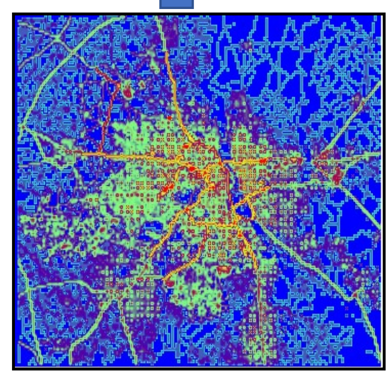


Assimilation at 9 UTC



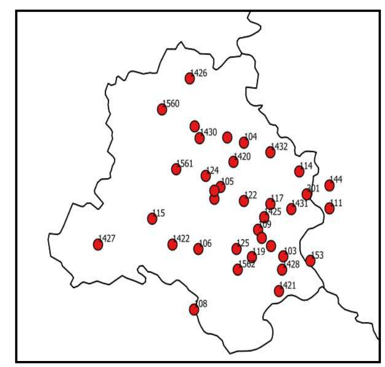


Driving meteorological IITM-Global Forecasting System (IITM-GFS, T1534, Ensemble-Kalman filtering) spectral model at 12.5 km grid resolution available at every three hours

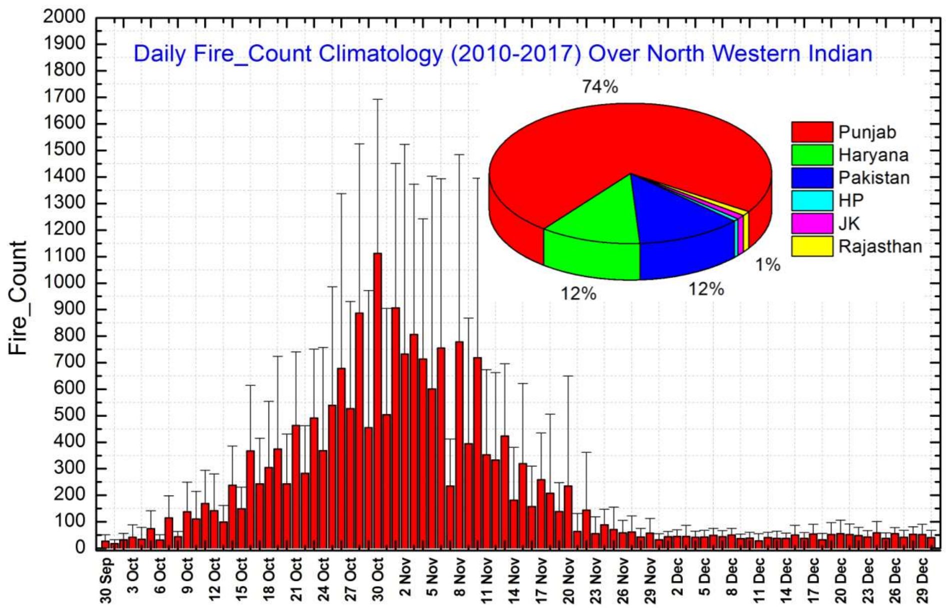


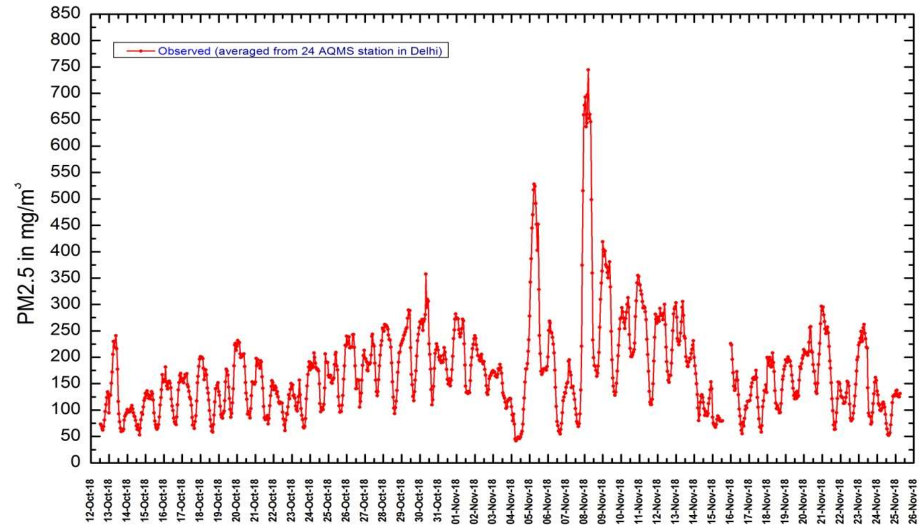
Emission inventory @ 400 m

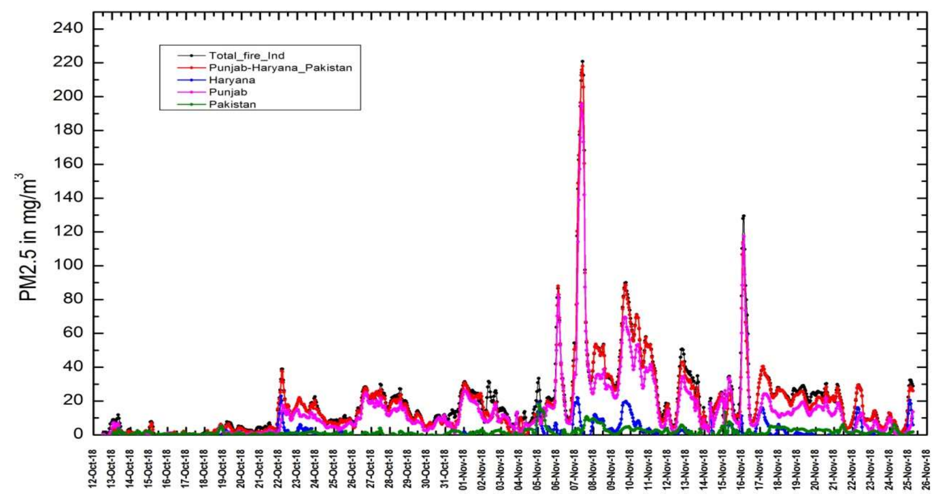
Assimilation at 9 UTC and 18 UTC



Contribution of Fire emissions to $PM_{2.5}$ in Delhi

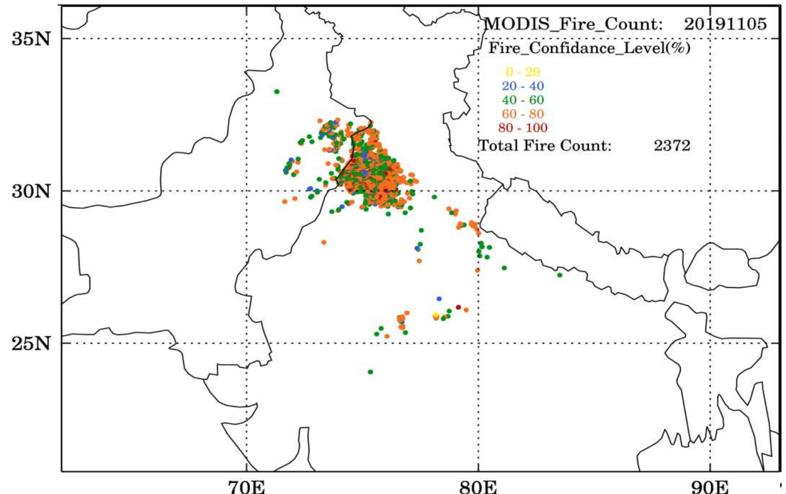


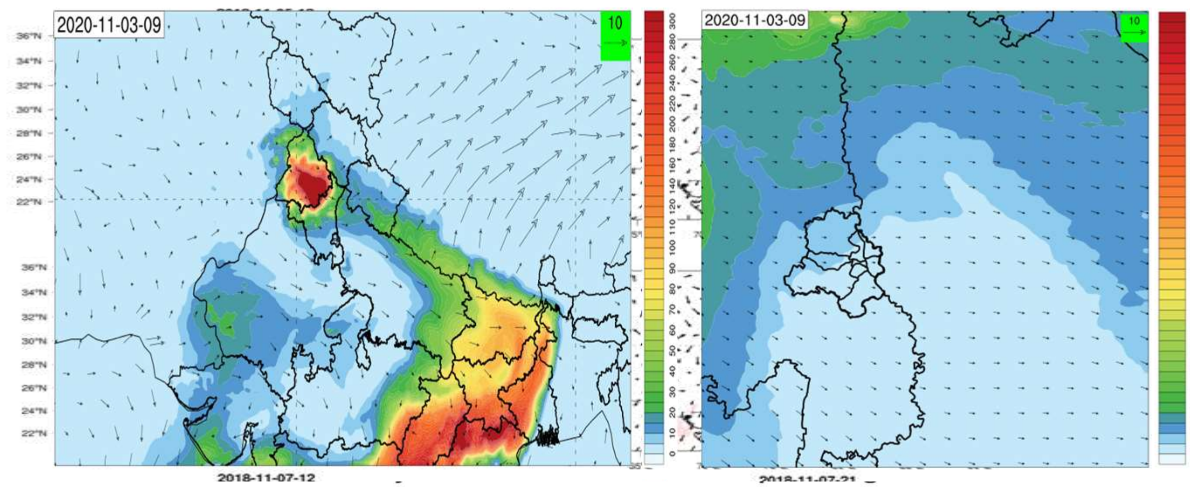


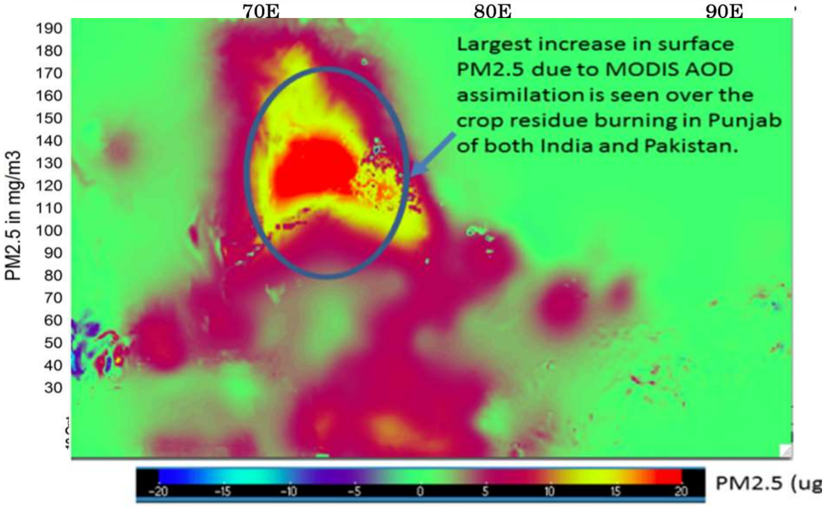


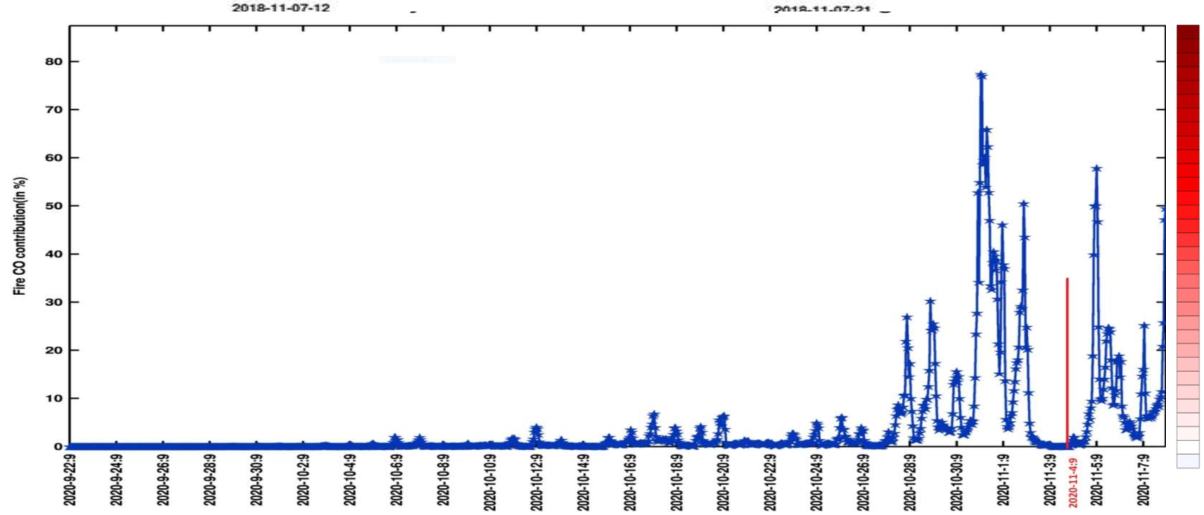
Kulkarni, Ghude, Soni et al., (EST, 2020)

Improvement in $PM_{2.5}$ Prediction after inclusion of satellite data on crop-fire



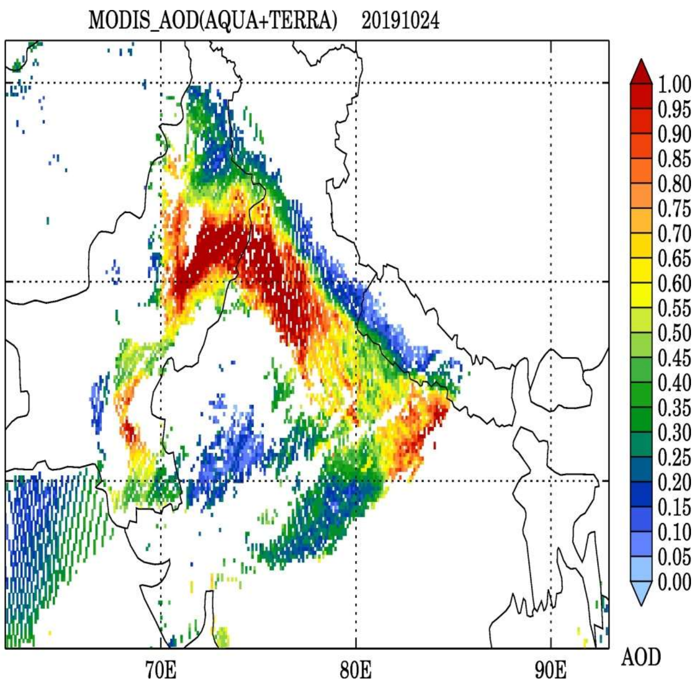


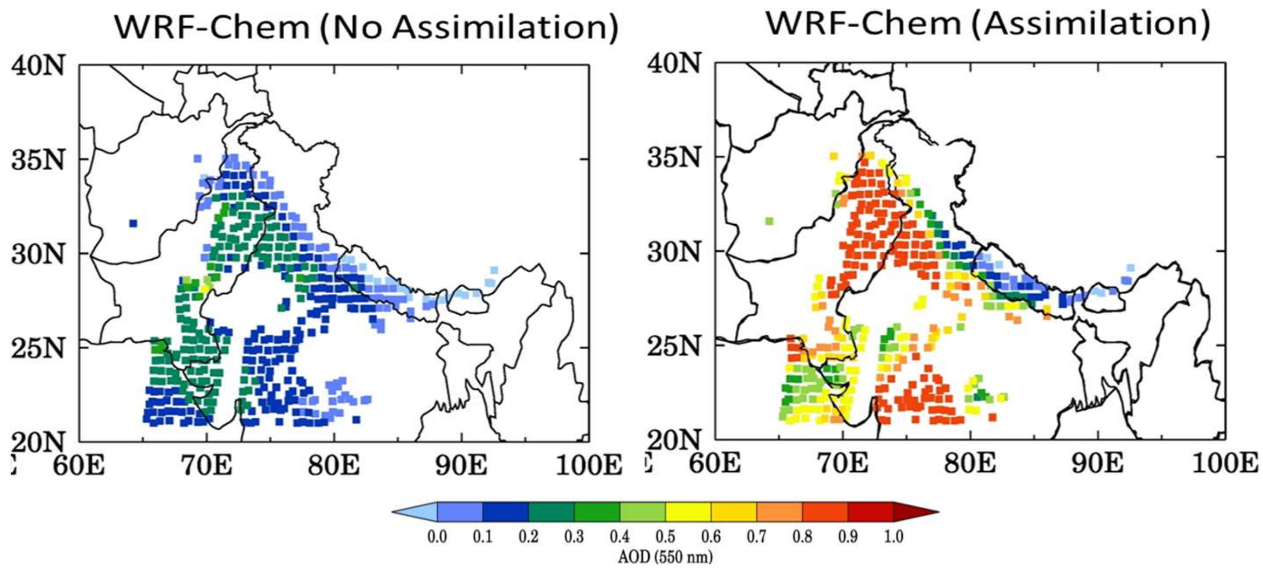


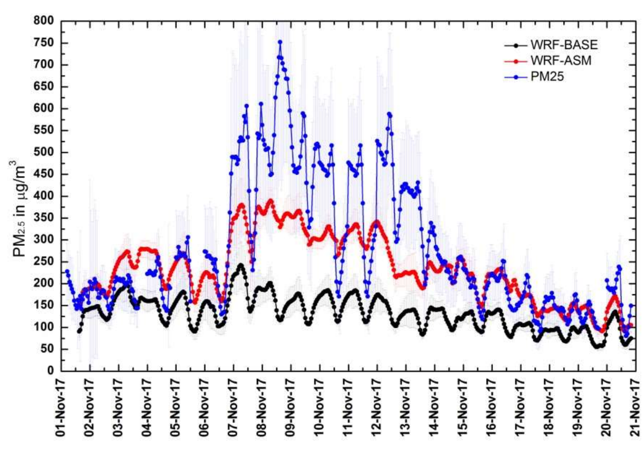


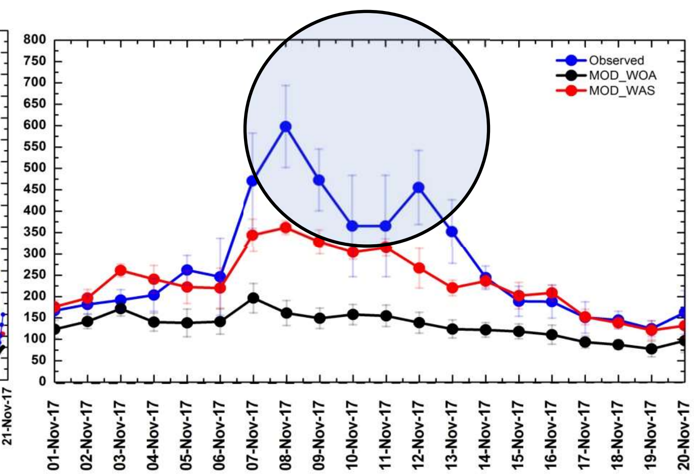
Kulkarni, Ghude et al., (EST, 2020)

MODIS AOD (TERA+AQUA)



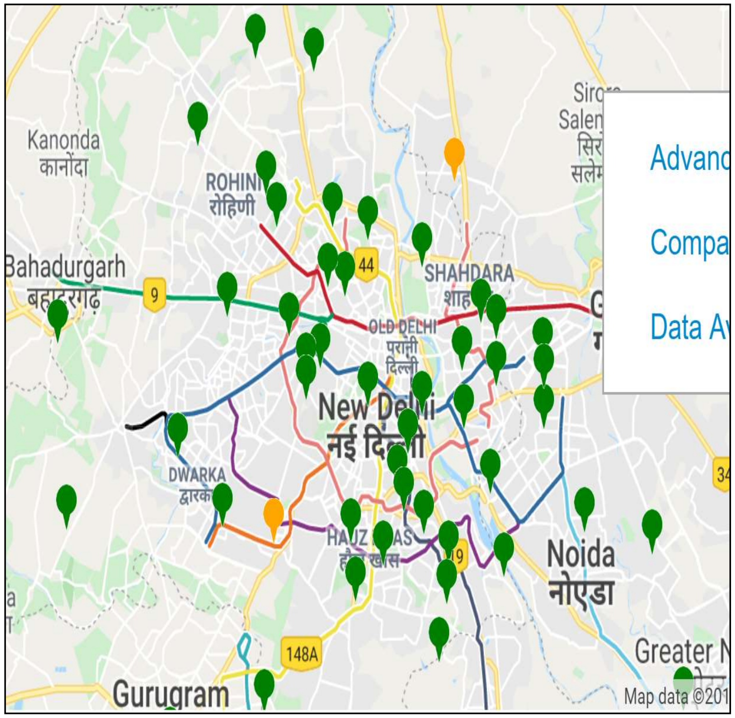


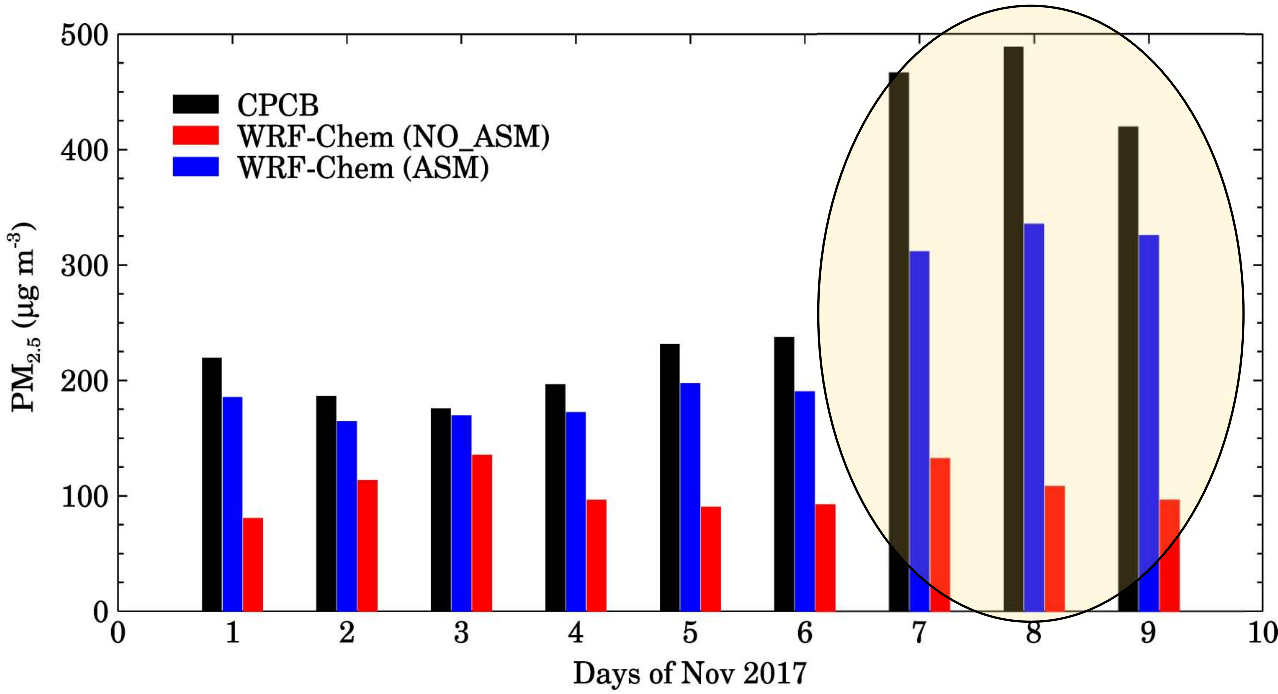




Ghude, Kumar et al., (CS, 2020) Kumar, Ghude et al., (JGR, 2020)

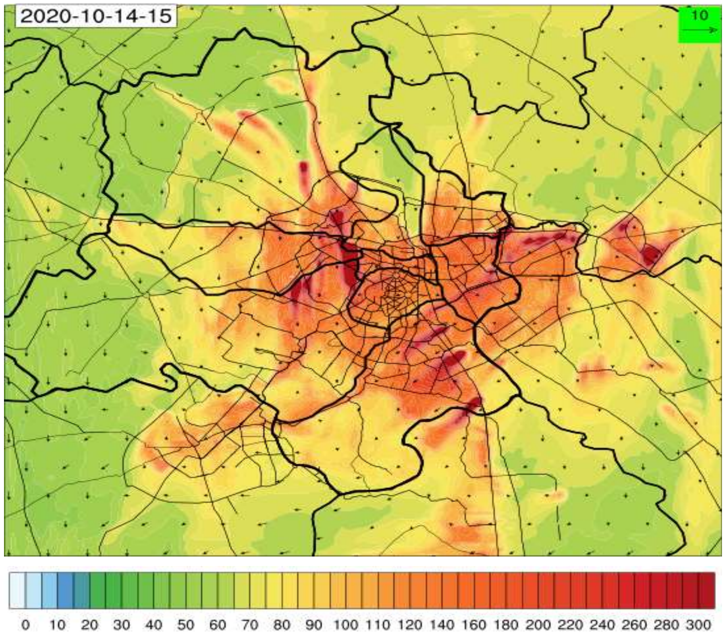
Surface $PM_{2.5}$ assimilation

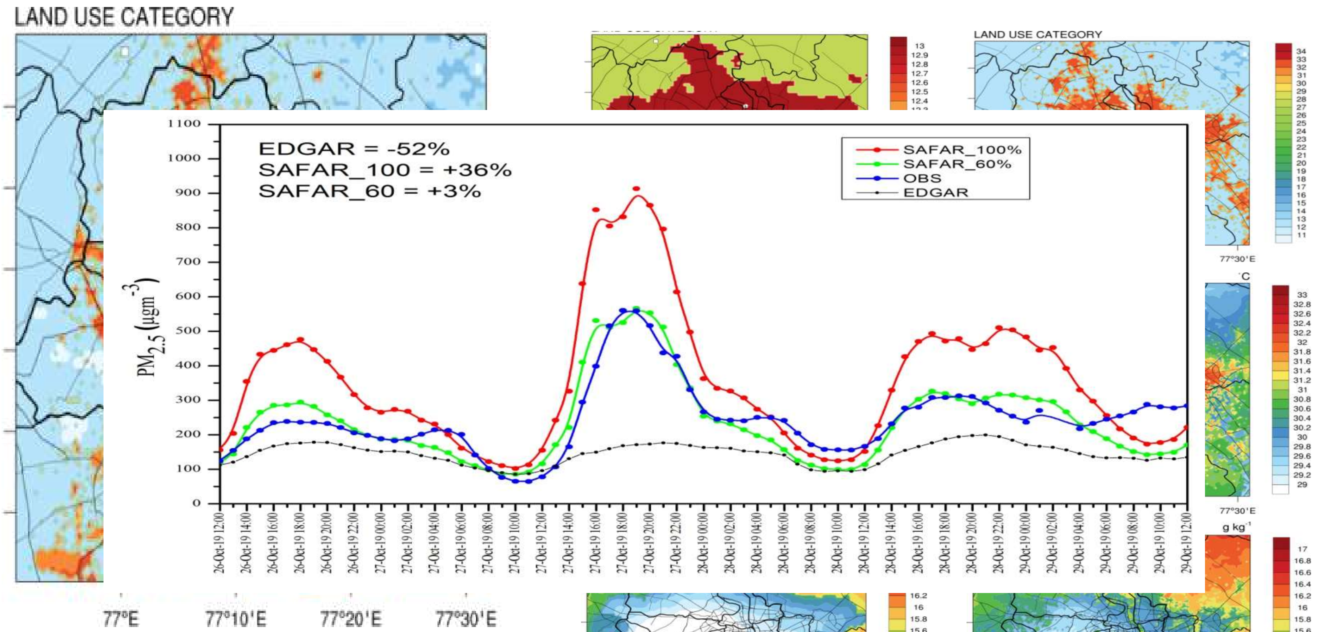


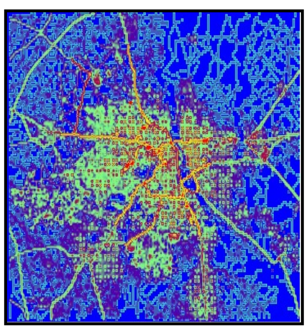


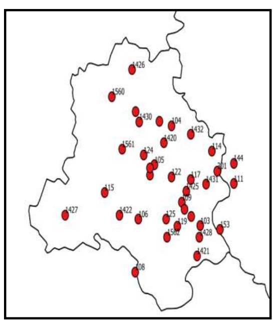
43 AQMS (CPCB,DPCC, IITM/IMD)

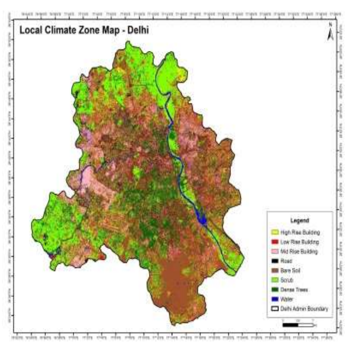
forecast at 400 m

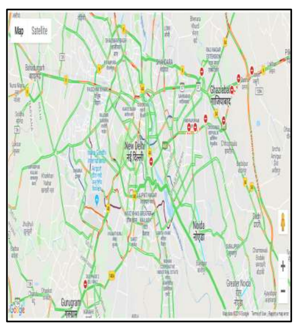


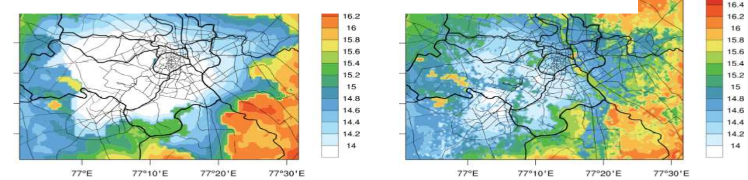


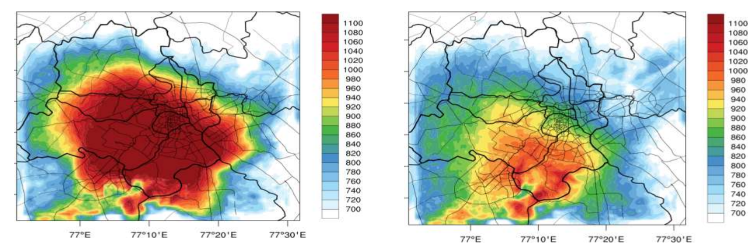












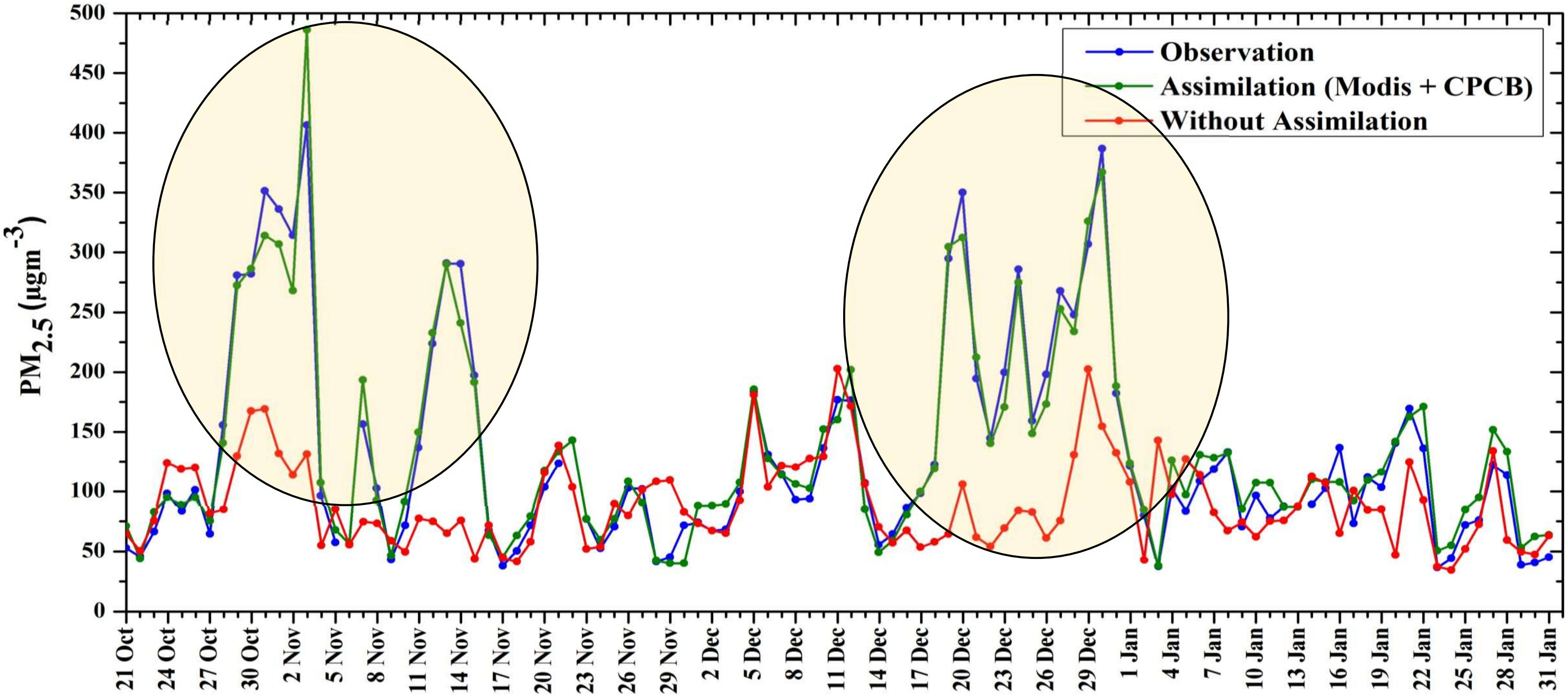
Emission inventory @ 400 m

Diurnal variation from traffic

Sentinel-2 Satellite

Urban area reclassified in to low, medium and high intensity areas and updated in the MODIS LULC

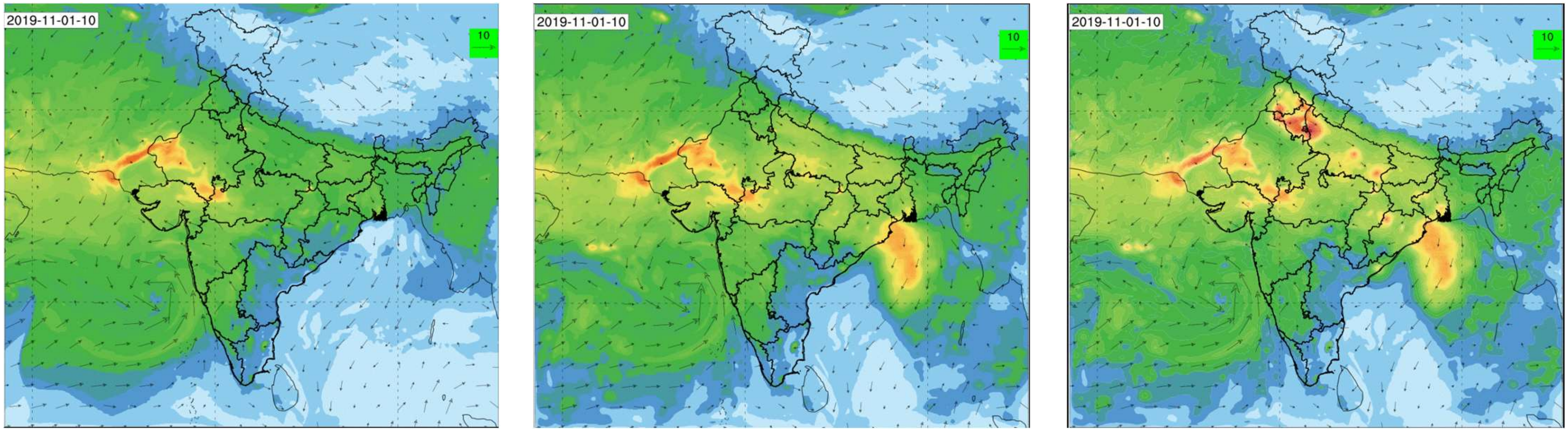
Improvement in $PM_{2.5}$ initial conditions due to satellite (MODIS) and Surface $PM_{2.5}$ (43-Stations) at assimilation Cycle (T=0)



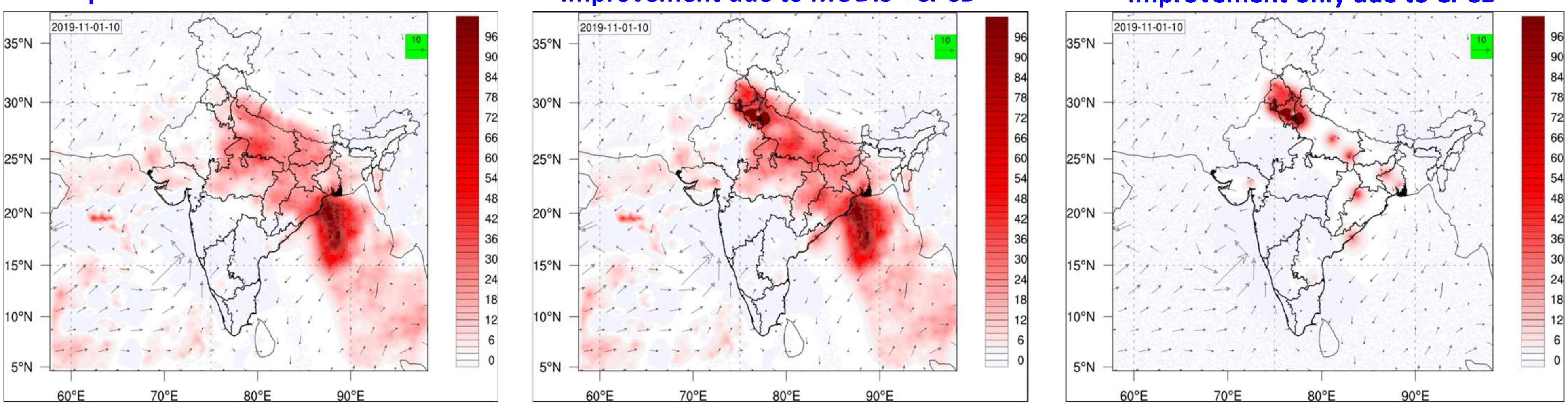
Scientific Report, 2020 (under review)

Satellite (MODIS) and surface data (230 stations) assimilation for improving short term air quality forecast over South Asia @10 KM

MODEL | **MODEL+MODIS** | **MODEL+MODIS+CPCB**

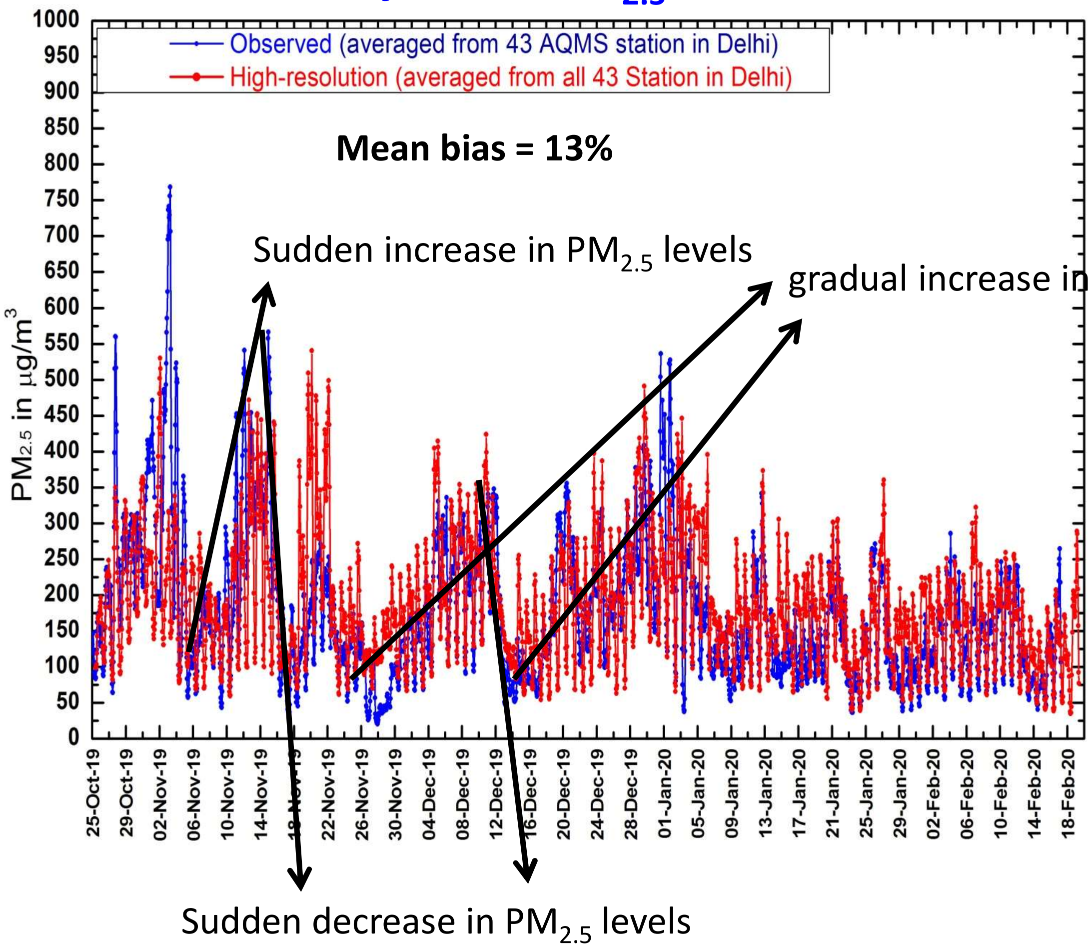


Improvement due to MODIS | **Improvement due to MODIS +CPCB** | **Improvement only due to CPCB**

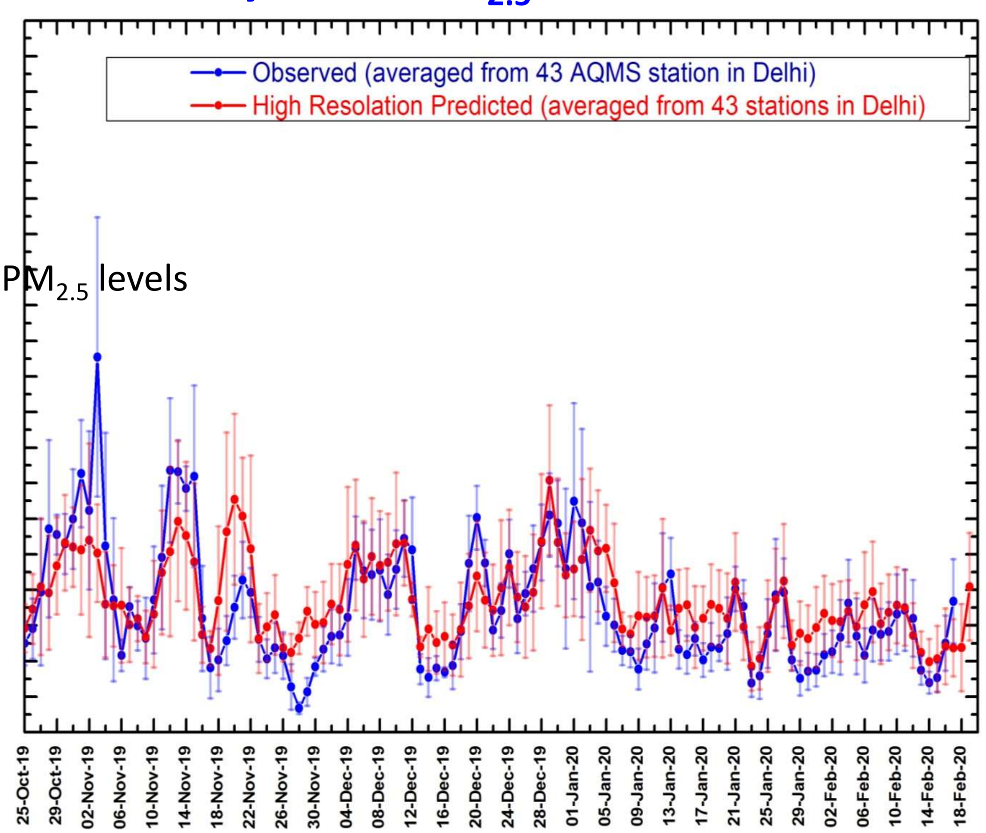


Forecast Evaluation @ 400 meter resolution (Winter 2019-2020)

Hourly mean $PM_{2.5}$ concentration



Daily mean $PM_{2.5}$ concentration



Forecast Evaluation (Skill score 2019-2020 Winter)

Statistic name	What it measures	Equation %
Accuracy (A)	Percent of forecasts that correctly predicted the event or non-event.	A=(a+d)/(a+b+c+d) *100
False Alarm Rate (FAR)	The percent of times a forecast of high pollution did not actually occur.	FAR = (b/(a+b)) *100
POD or HE (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
CIS Threat schore	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

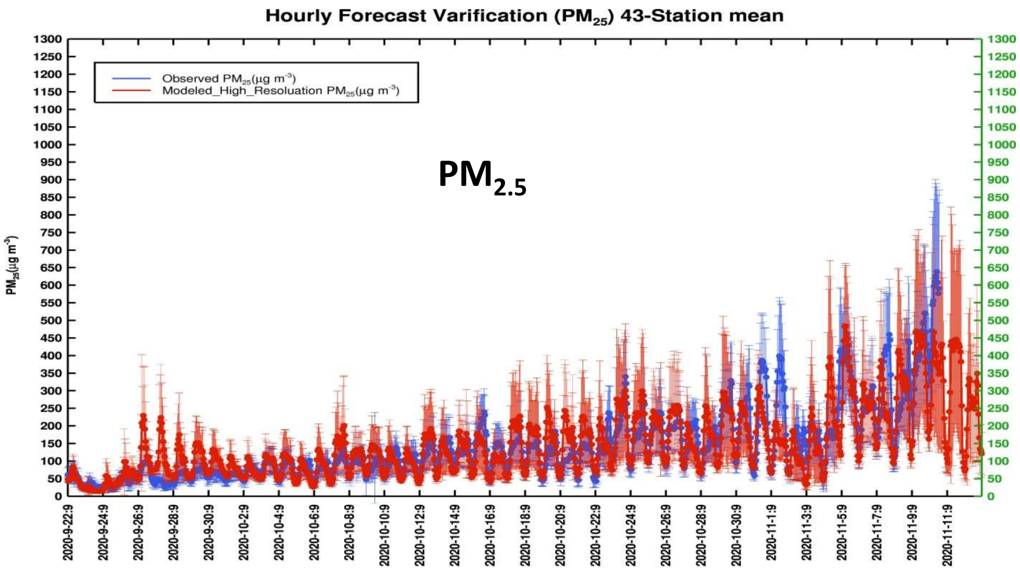
PM25 AQI Category	Variables	400 meter			
		FAR	POD	CSI	Accuracy
Unhealthy (200-above)	1st day	0.11	1.00	0.88	0.88
	2nd day	0.09	0.99	0.90	0.90
	3rd day	0.09	0.98	0.88	0.88
Very-Unh (300-above)	1st day	0.28	0.98	0.70	0.72
	2nd day	0.25	0.94	0.71	0.75
	3rd day	0.23	0.89	0.70	0.74
Severe (400-above)	1st day	0.35	0.34	0.29	0.82
	2nd day	0.15	0.35	0.33	0.85
	3rd day	0.25	0.21	0.19	0.82

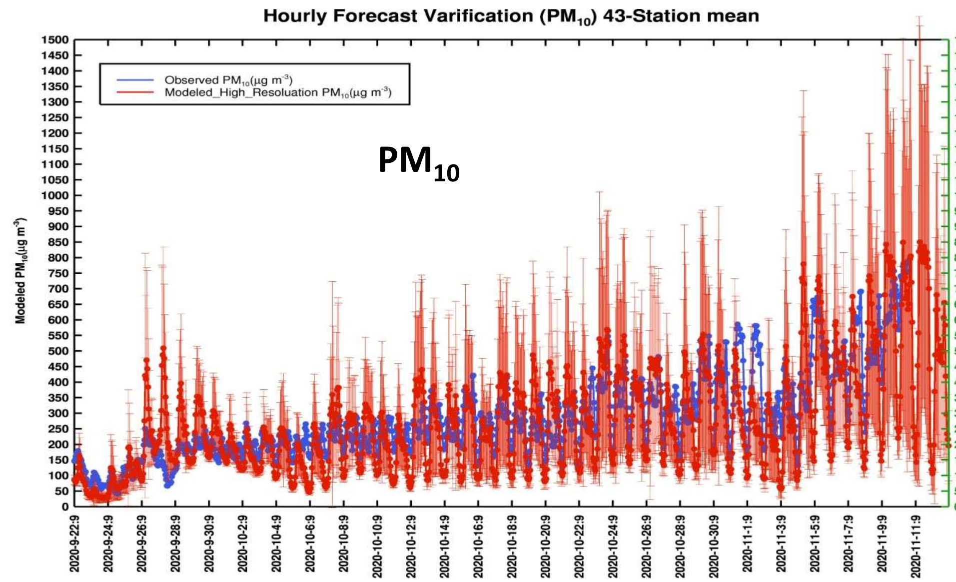
Observation

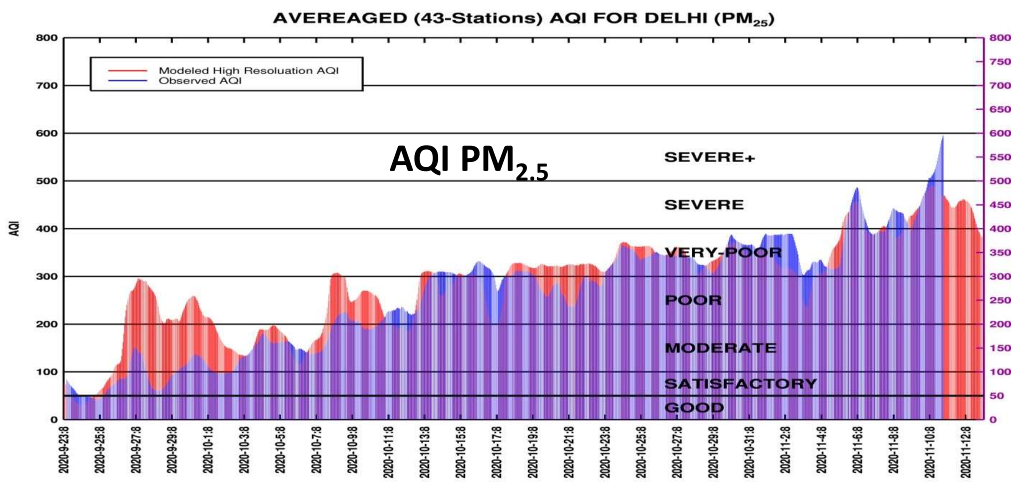
Forecast	YES	NO
YES	a	b
NO	c	d

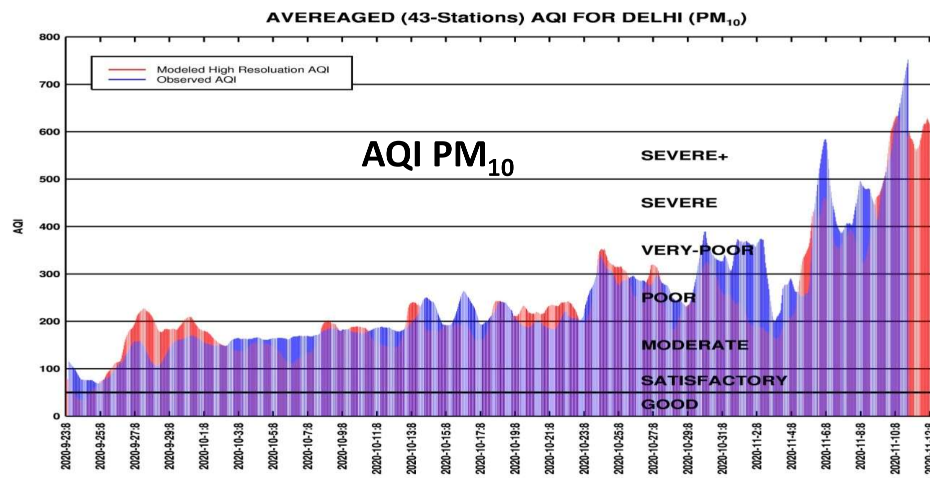
- **For unhealthy category HR is above 90%, CSI is above 80% and FAR is less than 10%.**
- **For very-unhealthy category HR is 85-90%, CSI is about 70% and FAR is less than 20-30%.**
- **For sever category although the accuracy is excellent, POD & CSI is moderate, but no much increase is seen in FAR.**
- **FAR show decrease on day 2 & day 3 of forecast**

Real-time Forecast Evaluation @ 400 meter resolution

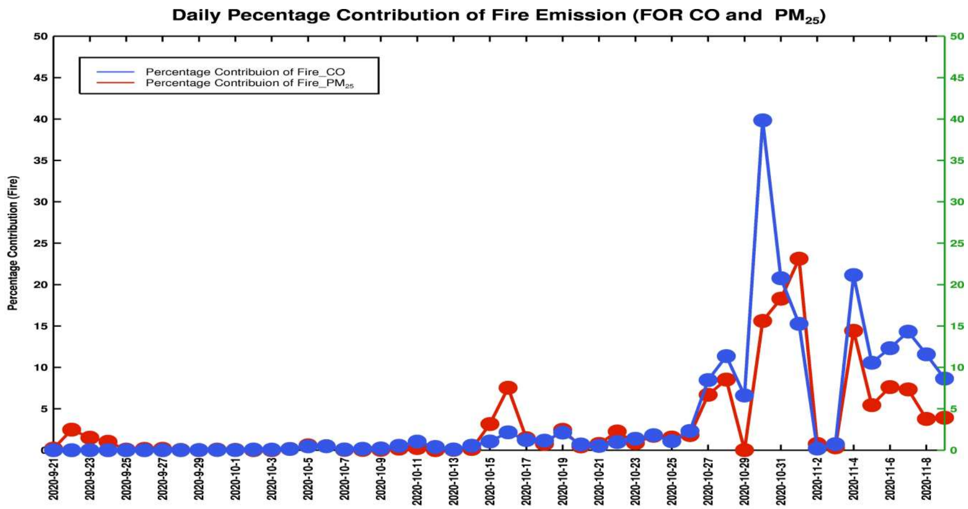


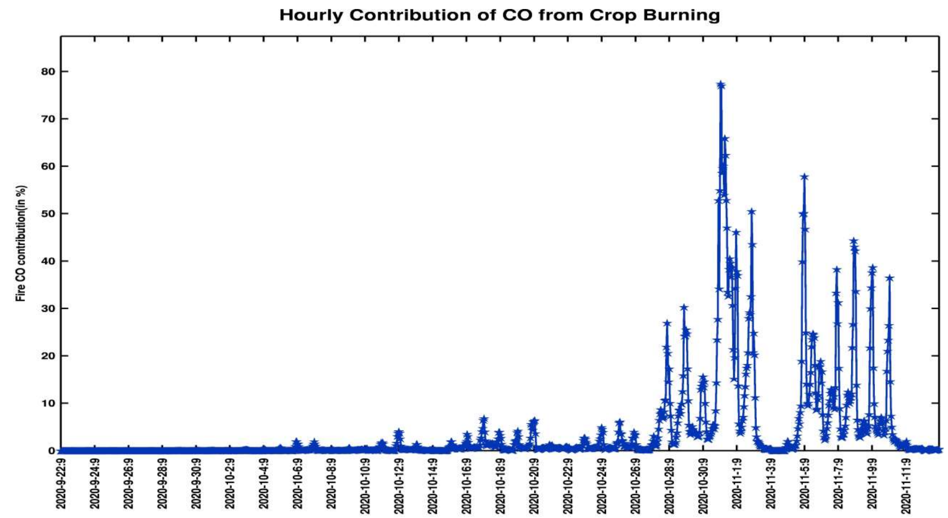


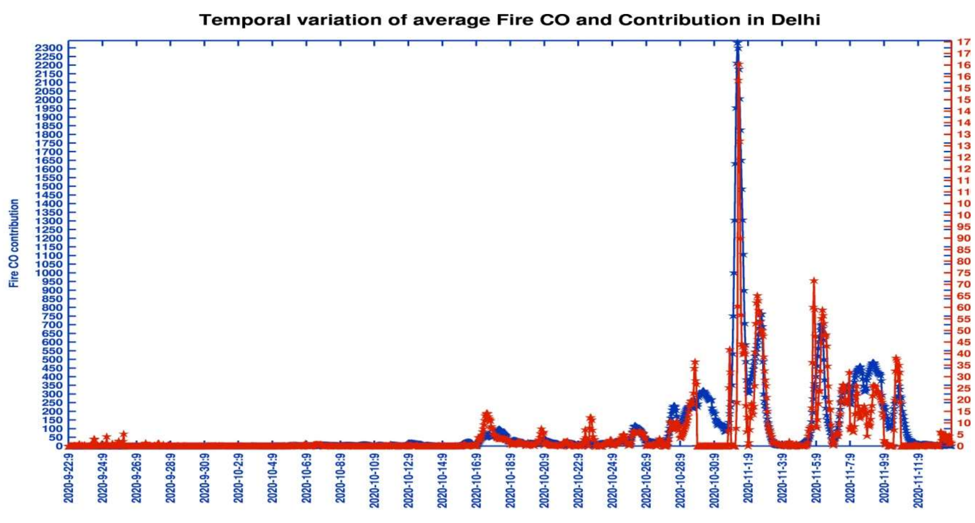


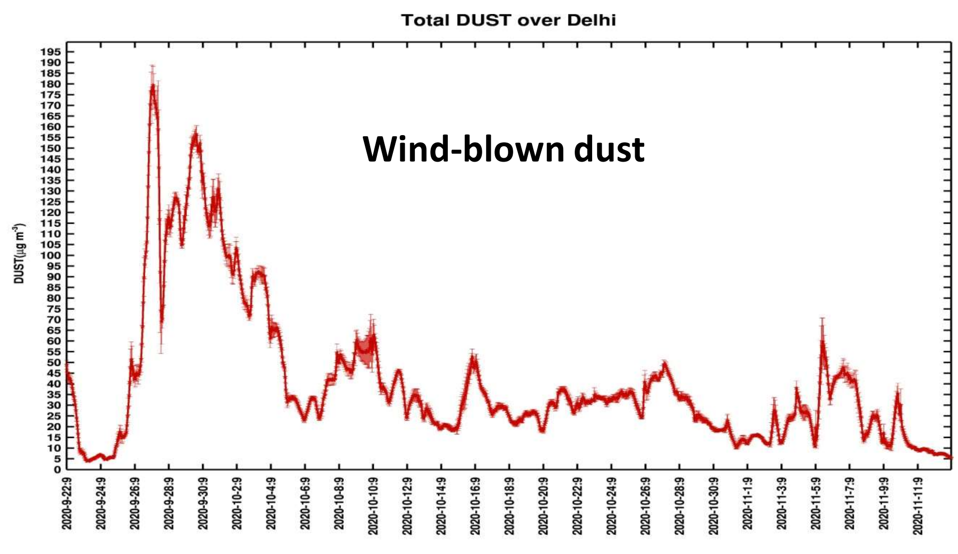


Stubble burning contribution

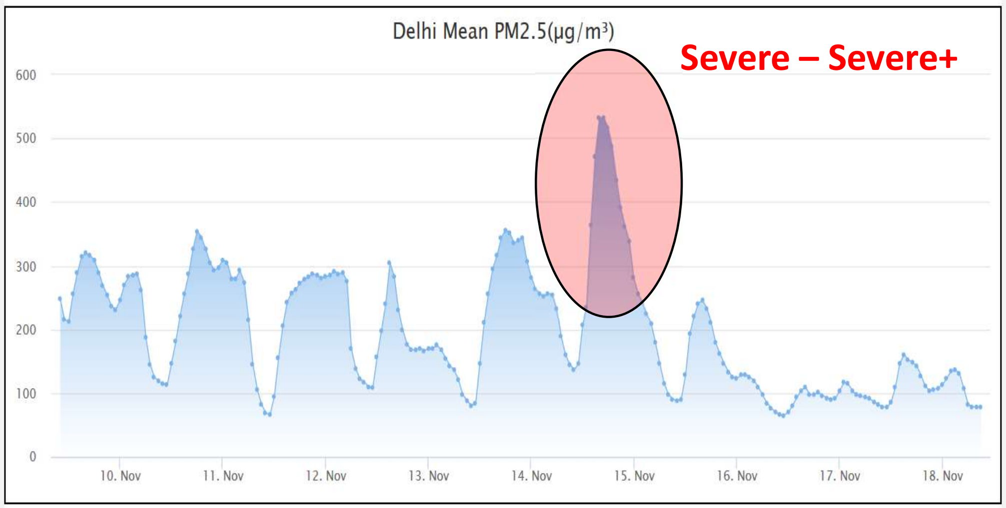


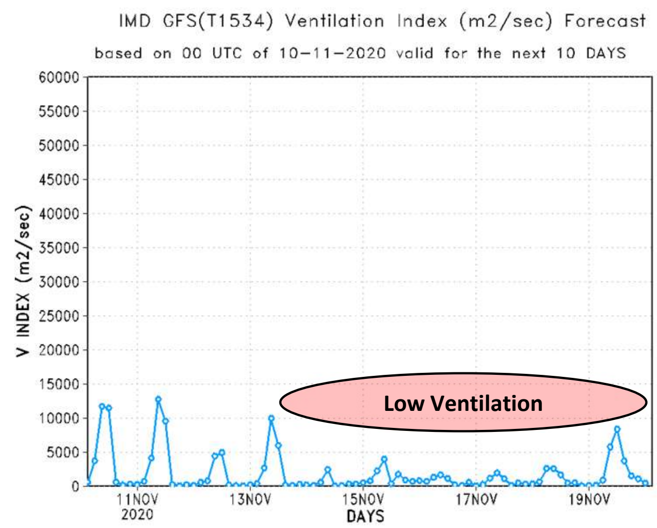


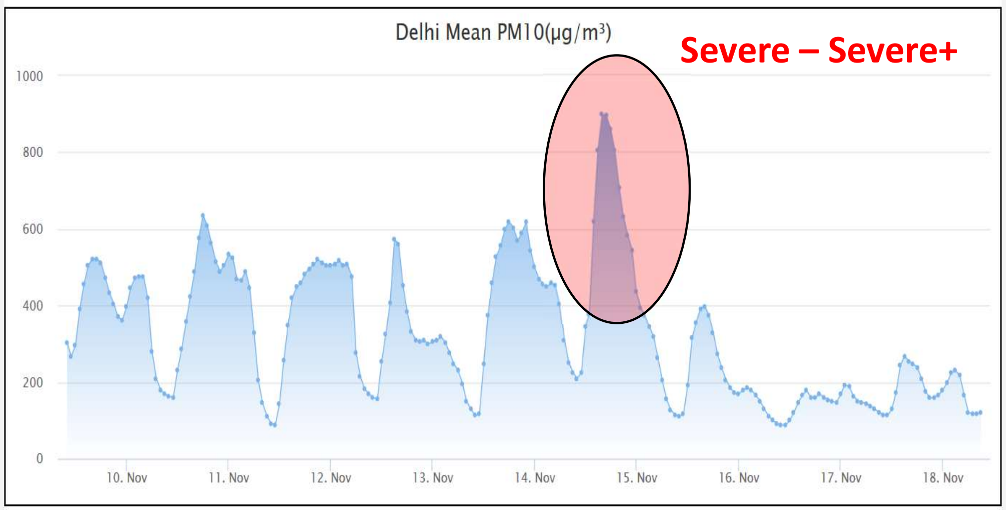


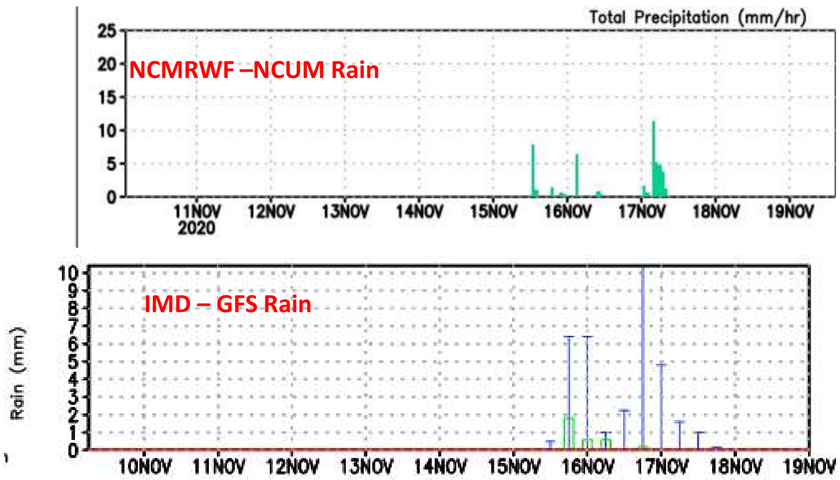


Air Quality Forecast for Diwali, 14-15 November, 2020 (no restriction)



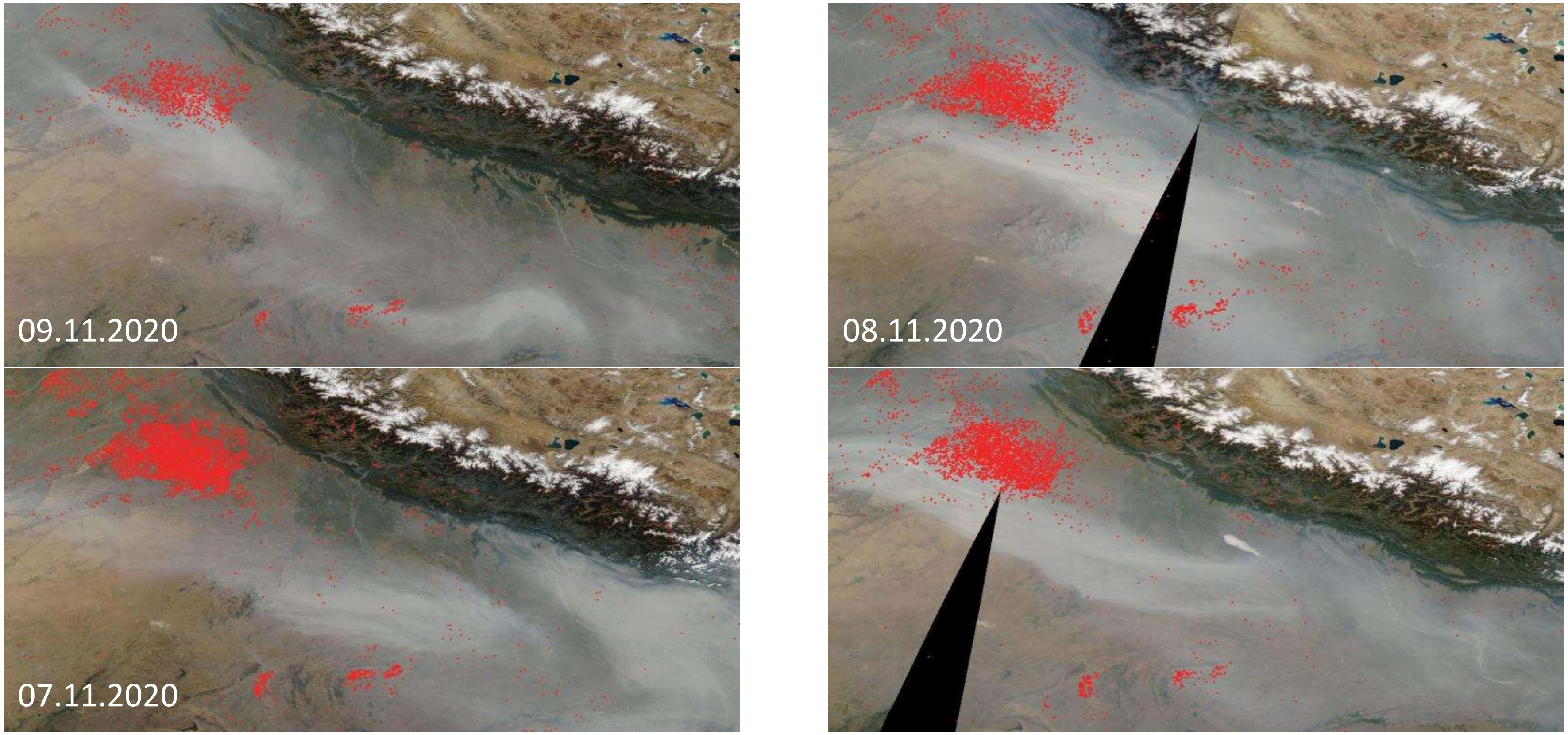


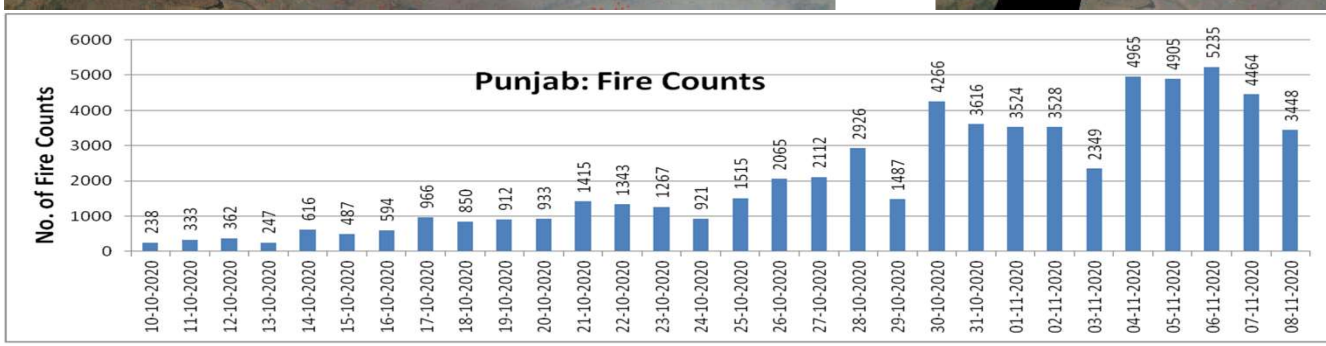




Satellite based Environment Monitoring

- Satellite data can help forecasters
  - Estimate aerosol concentrations in areas without continuous $PM_{2.5}$ monitors
  - Track aerosols from
    - Regional haze episodes
    - Wildfires
  - Estimate upwind $PM_{2.5}$ concentrations or aerosol loading
- Aerosol optical depth (AOD) provides this information
  - A satellite-derived measure of light extinction through the atmosphere
  - Proportional to the number of particle in the atmospheric column


09.11.2020
08.11.2020
07.11.2020


Punjab: Fire Counts
No. of Fire Counts
6000
5000
4000
3000
2000
1000
0
238
333
362
247
616
487
594
966
850
912
933
1415
1343
1267
921
1515
2065
2112
2926
1487
4266
3616
3524
3528
2349
4965
4905
5235
4464
3448
10-10-2020
11-10-2020
12-10-2020
13-10-2020
14-10-2020
15-10-2020
16-10-2020
17-10-2020
18-10-2020
19-10-2020
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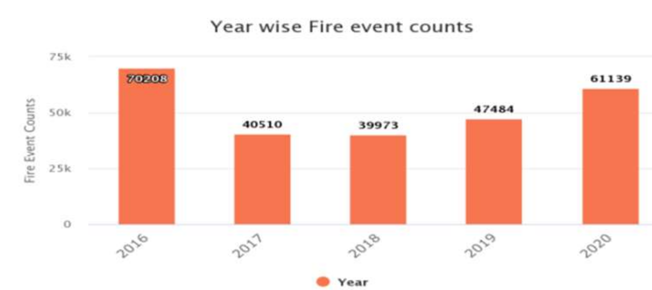
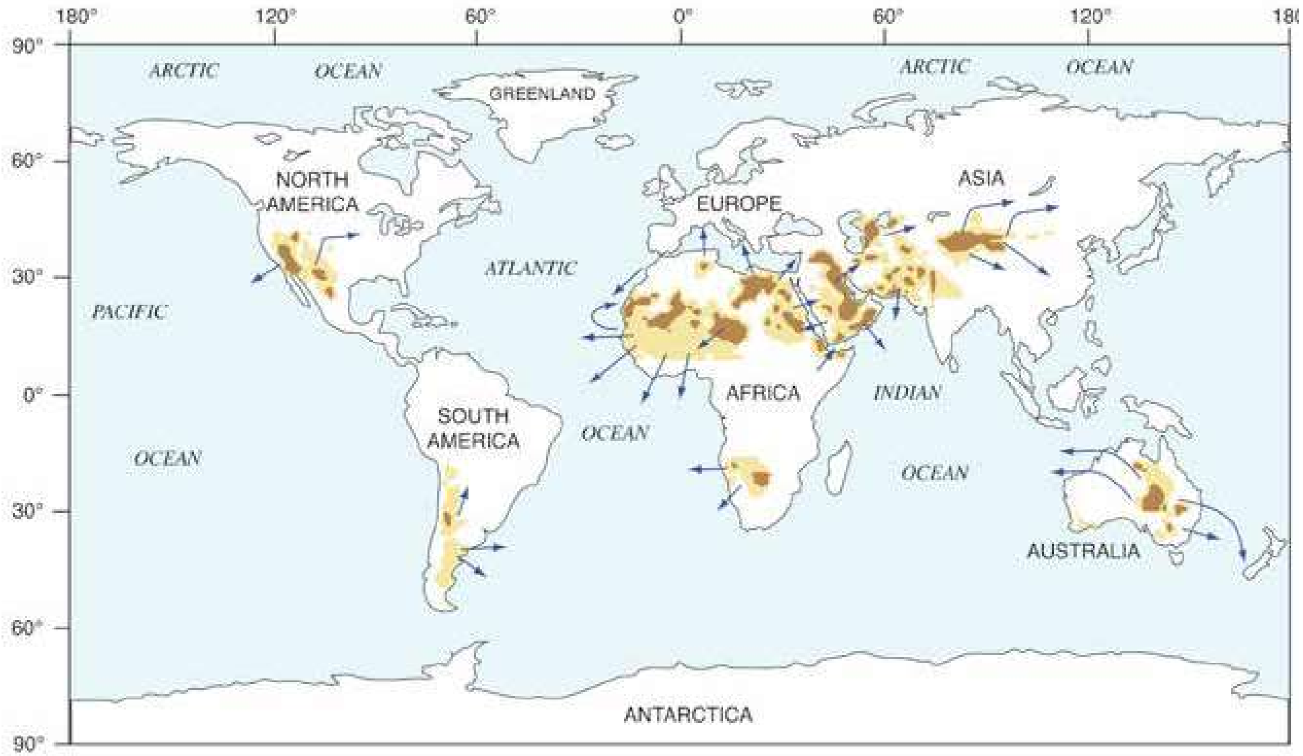
07-11-2020
08-11-2020

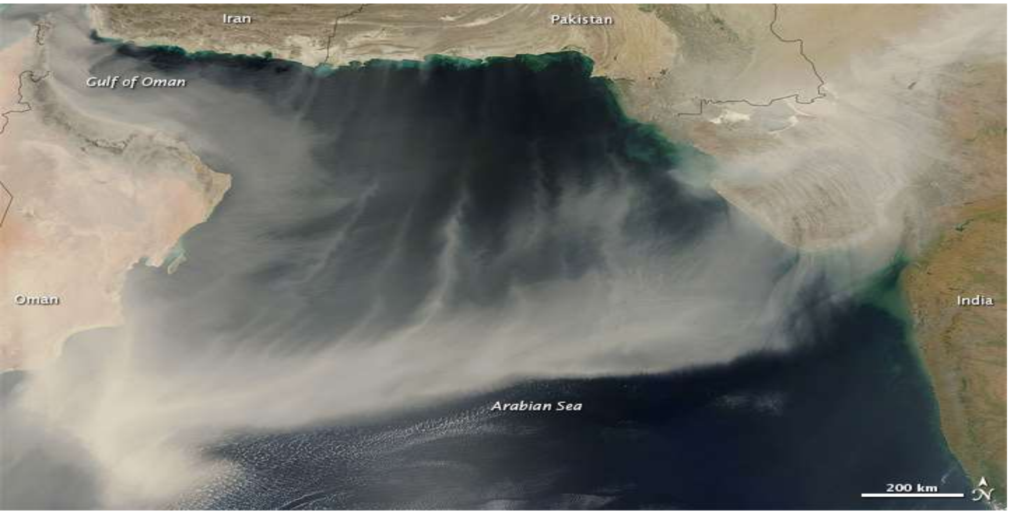

Year wise Fire event counts
Fire Event Counts
75k
50k
25k
0
70208
40510
39973
47484
61139
2016
2017
2018
2019
2020
Year

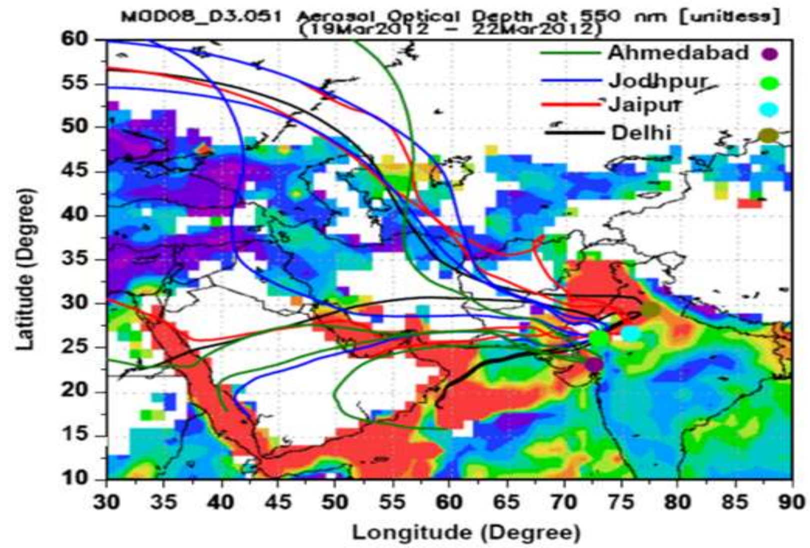
Global Dust sources and Dust Transport Pathways

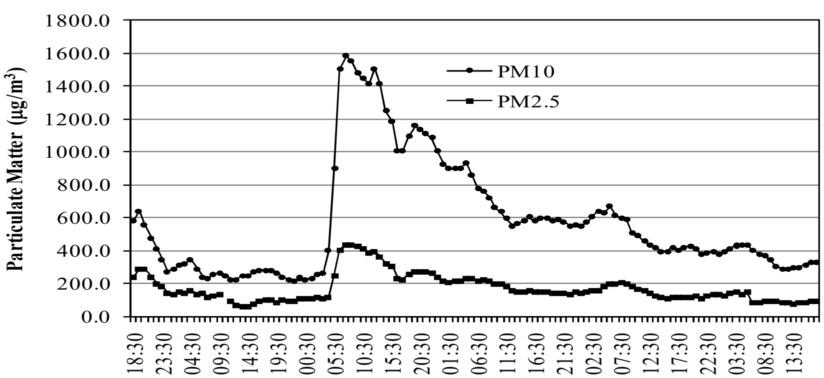


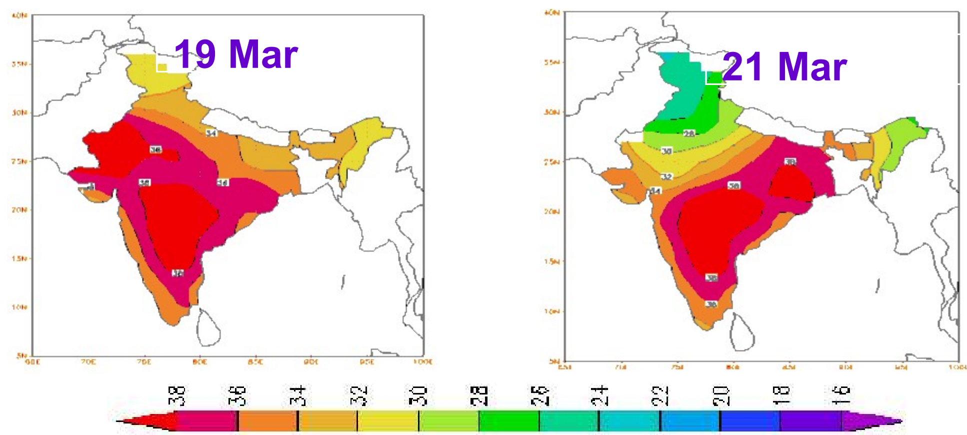
The main routes of desert dust transport and location of the major dust sources are: (i) Sahara Desert; (ii) Arabian Peninsula; (iii) Asia; (iv) North America; (v) South America; and (vi) Southern Africa. *Source: Muhs et al, 2014*

151 UNCCD country Parties are affected directly by SDS and 45 country Parties are classified as SDS source areas. Most locations are in the low-latitude drylands, but dust sources can develop in almost any environment, often through human influence. Unsustainable use or agricultural land, deforestation, overgrazing, high latitudes, depletion of water sources and industrial activities can all trigger SDS.



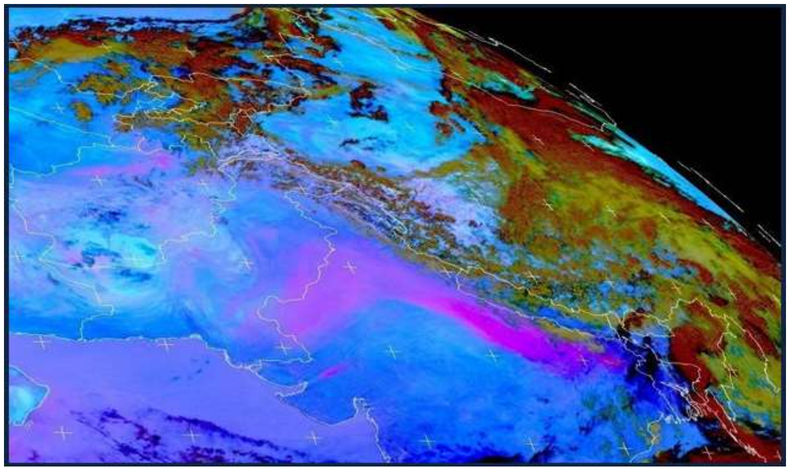


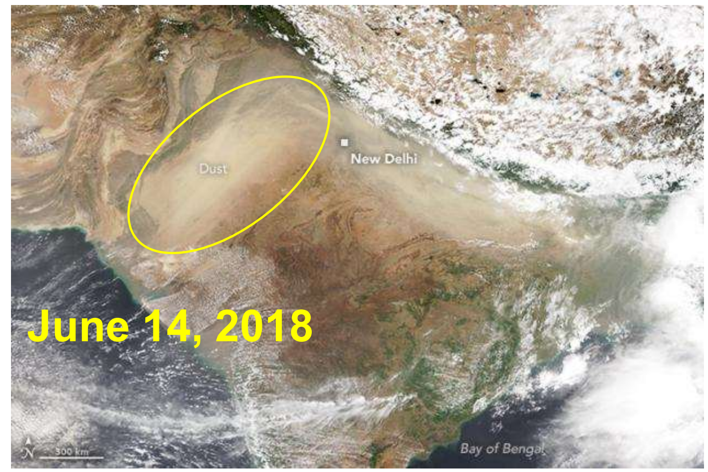


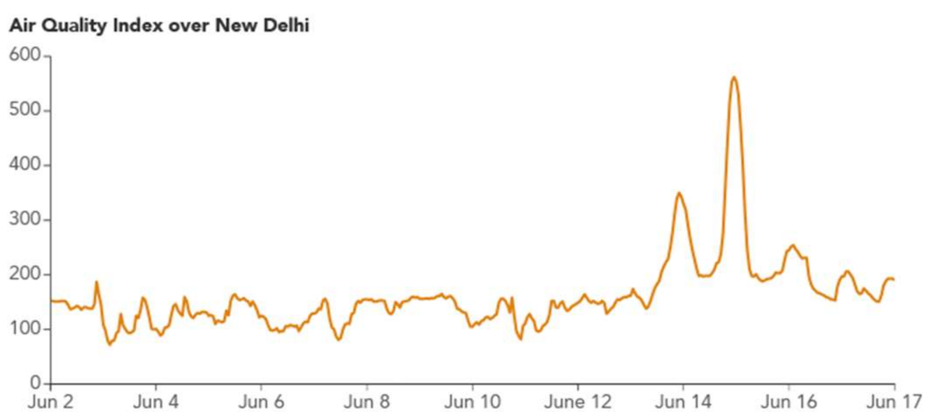


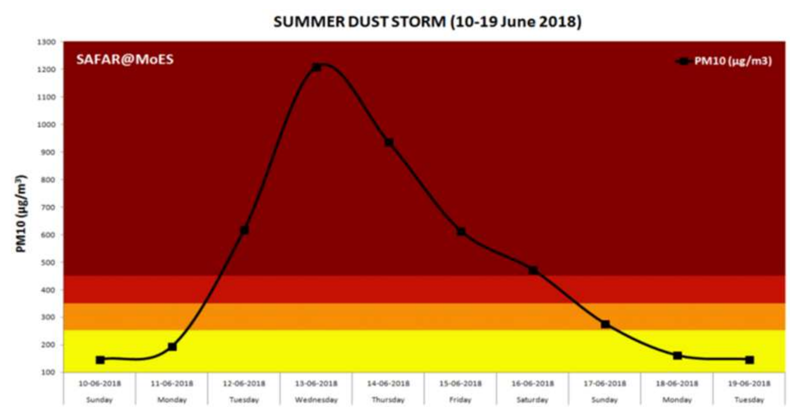
Soni et al (2014), Science of Total Environment
Soni et al (2018), Mausam

Dust Transport in 11-14 June 2018









Surface PM10 Concentration at Delhi

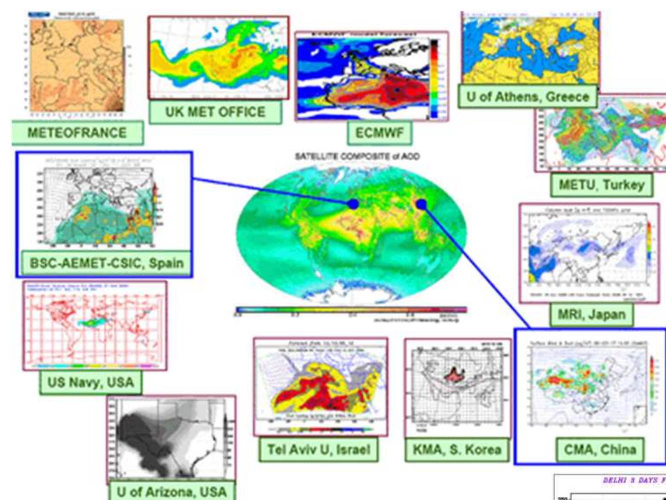
Sand and Dust Storm Warnings

The WMO Sand and Dust Storm Project was initiated in 2004 and its Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) was launched by the Fifteenth World Meteorological Congress in 2007.

WMO SDS-WAS Regional Centre for Northern Africa, Middle East and Europe, coordinated by a Regional Centre in Barcelona, Spain,

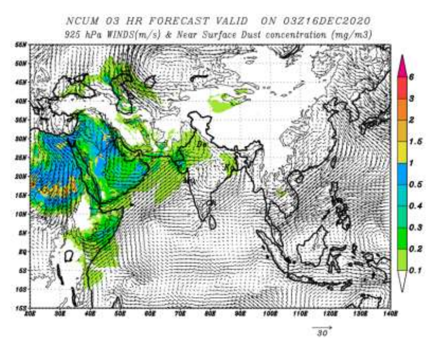
WMO SDS-WAS Regional Centre for Asia, coordinated by a Regional Centre in Beijing, China, hosted by the CMA

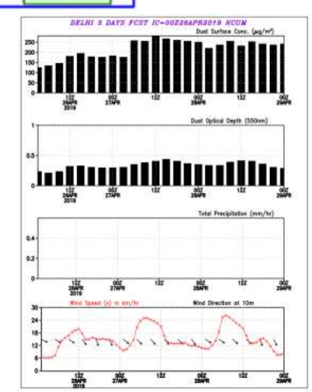
WMO SDS-WAS Regional Centre for the Americas, hosted by the Caribbean Institute for Meteorology and Hydrology (CIMH) in Barbados, will focus on the health implications of airborne dust.



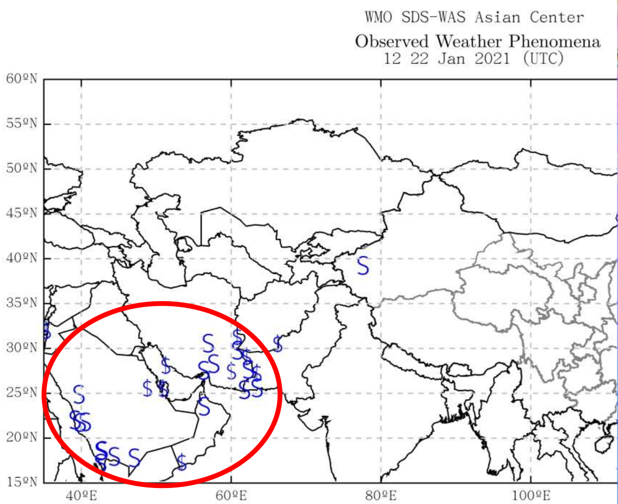
Data Shared with IMD (Dust Conc., Dust AOD, Obsns)

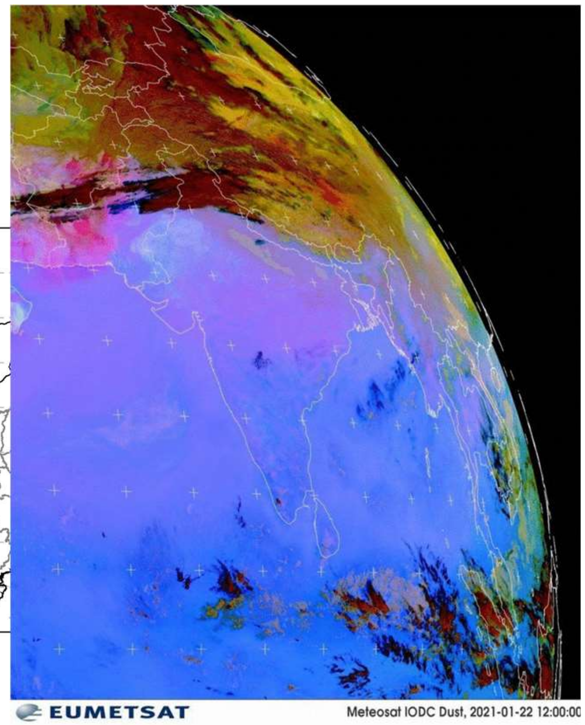
CMA	**ECMWF**
FMI	**NCEP**
KMA	**ENSEMBLE**
JMA	
HKO	

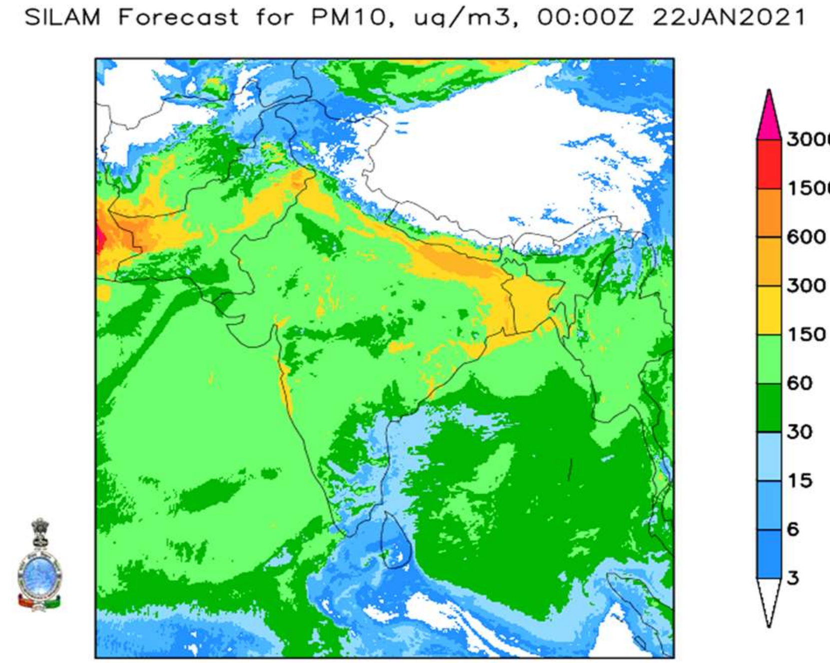




https://ews.tropmet.res.in/ncmrwf.php


WMO SDS-WAS Asian Center
Observed Weather Phenomena
12 22 Jan 2021 (UTC)
60ºN
55ºN
50ºN
45ºN
40ºN
35ºN
30ºN
25ºN
20ºN
15ºN
40ºE
60ºE
80ºE
100ºE


EUMETSAT
Meteosat IODC Dust, 2021-01-22 12:00:00


SILAM Forecast for PM10, ug/m3, 00:00Z 22JAN2021
3000
1500
600
300
150
60
30
15
6
3

Q 1. Wind speed influences Air Quality. (T/F)

Q 2. Ozone is good up above but bad at surface. (T/F)

Q 3. Concentration of ozone is maximum at mid day. (T/F)

Q 4. The rage of AQI 401-500 means…………..category.

Q 5. Sea spray is a…………….type of aerosol. (Primary/Secondary).