AIR QUALITY TRENDS IN INDIA
FROM SOURCE TO FORECAST

SAFAR-India

ISO 9001:2008 Accredited by Standard Certification Council-India
GURME, World Meteorological Organization (United Nations) Pilot

GUFRAN BEIG, **PROJECT DIRECTOR, SAFAR**

INDIAN INSTITUTE OF TROPICAL METEOROLOGY, PUNE
Ministry of Earth Sciences, Govt. of India

What Scientific Processes Control Air Quality ?

1. **Local Emissions**

    F **(Sources-26 and counting)**

2. **Local Weather**

    F **(T, H, WS, WD, BL, RF)**

3. **Transport**

    F **(LR to SR: Distant weather)**

SAFAR

TEN in One City
(Delhi, Pune, Mumbai and Ahmedabad)

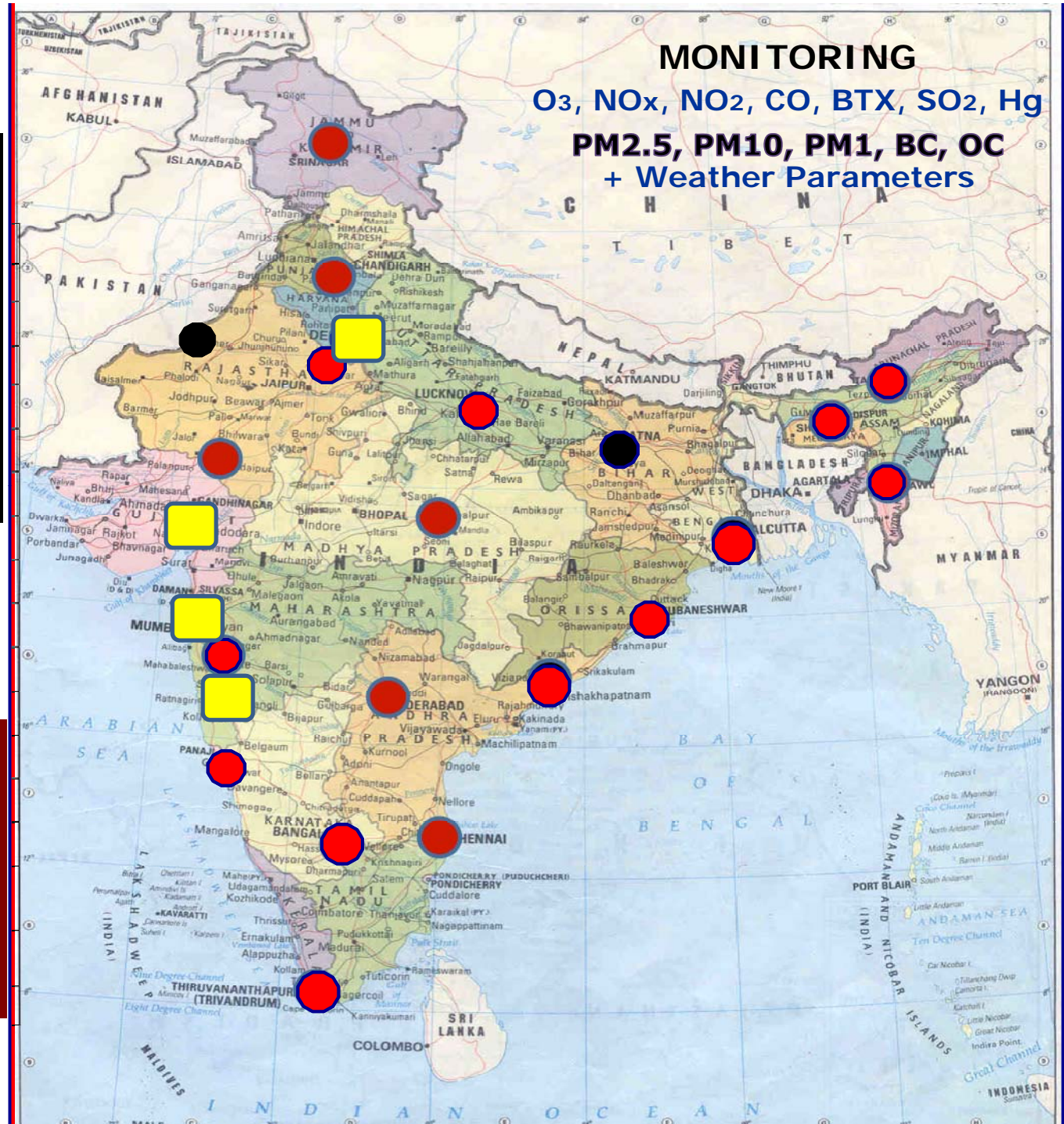**Monitoring PLUS Forecasting**

MAPAN

ONE in One City

ONLY Monitoring NO Forecasting

MONITORING
O_3, NO_x, NO_2, CO, BTX, SO_2, Hg
PM2.5, PM10, PM1, BC, OC
+ Weather Parameters

INDUSTRIAL AREA
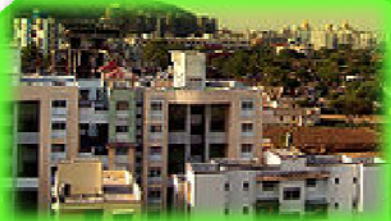
AIRPORT SITE

DOWNTOWN

Strategic Observational Network representative of a city (WMO -Guidelines)
AQMS and AWS

RESIDENTIAL AREA

COASTAL AREA

UPWIND-DOWNWIND
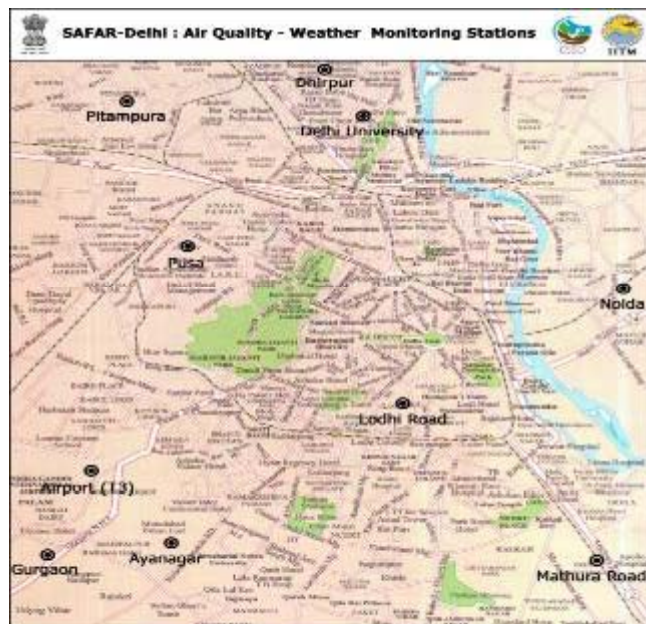
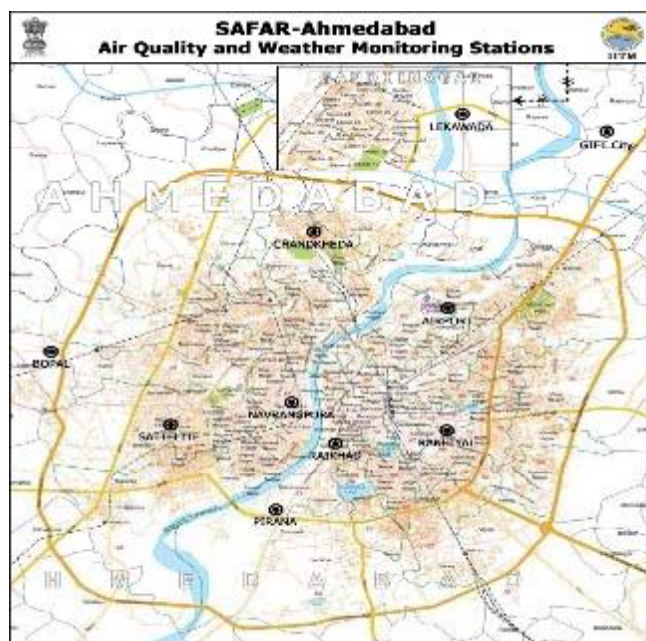BACKGROUND SITE

TRAFFIC JUNCTION

AGRICULTURAL

SAFAR-India (10 AQMS and 20 AWS at Each City)
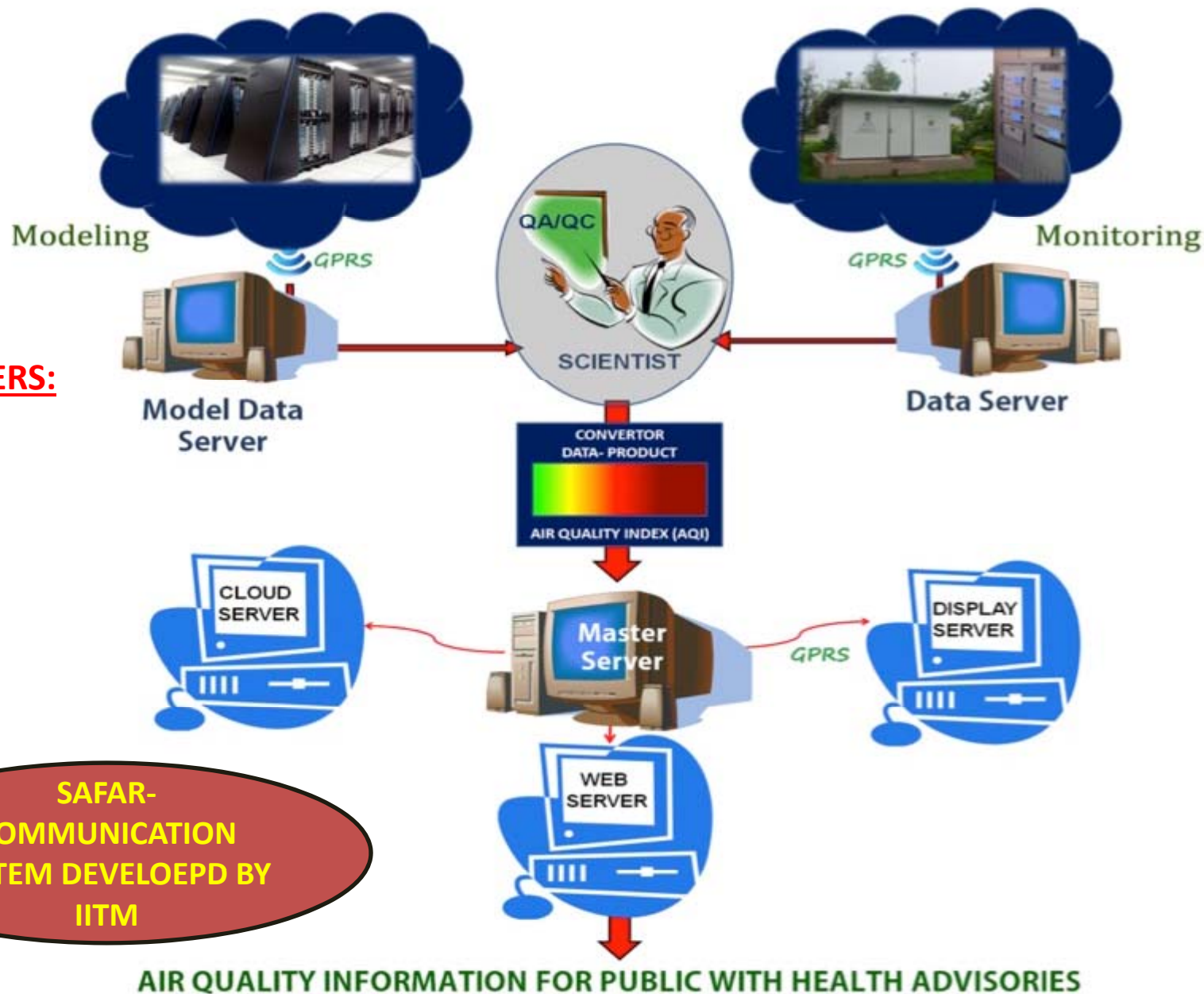

DELHI
MUMBAI

AHMEDABAD
PUNE

TECHNOLOGY FRAMEWORK OF SAFAR

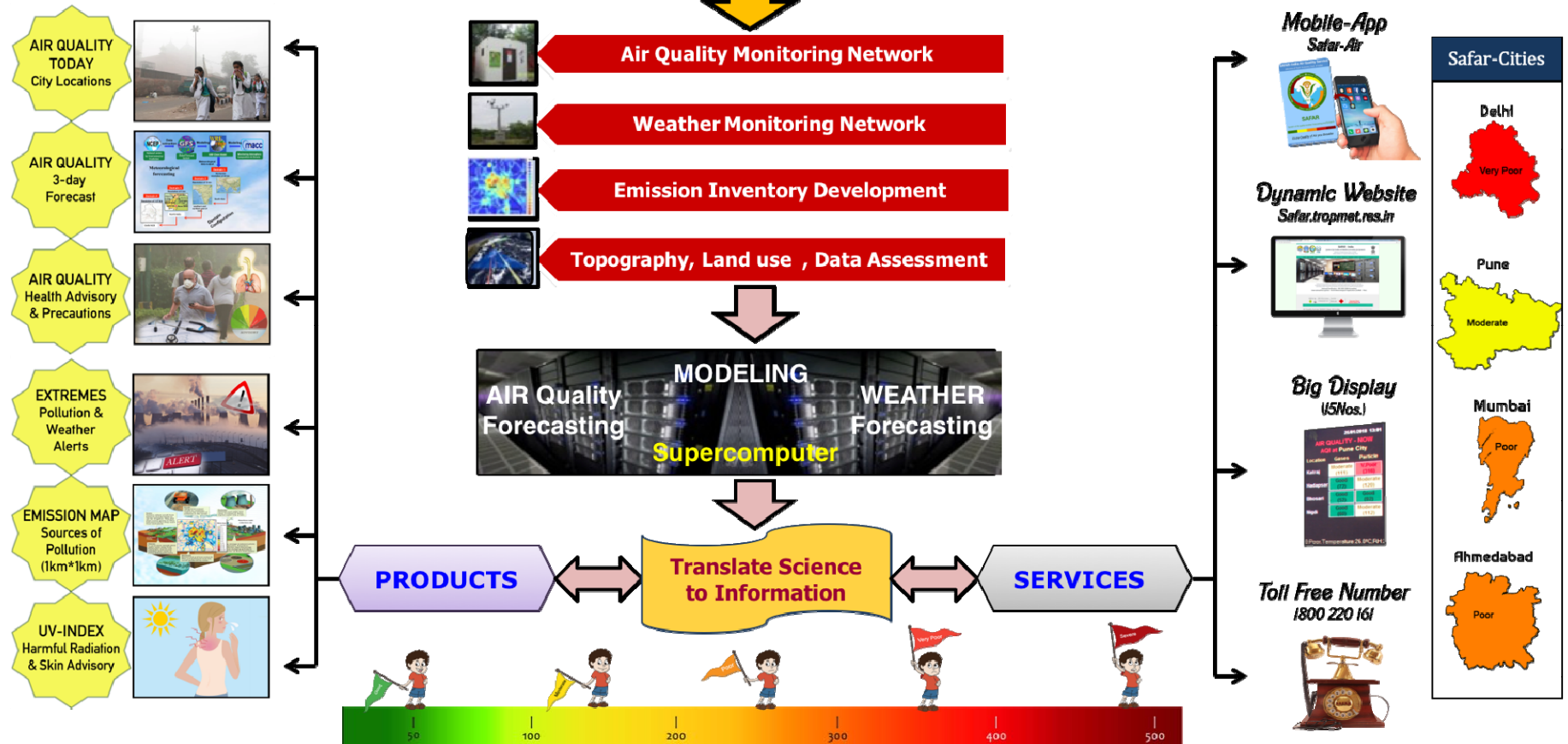**PARAMETERS:**
- PM10
- PM2.5
- PM1
- Ozone
- CO
- NOx
- BTX
- Weather

SAFAR-COMMUNICATION SYSTEM DEVELOEPD BY IITM

Modeling

GPRS

Model Data Server

QA/QC

SCIENTIST

GPRS

Monitoring

Data Server

CONVERTOR DATA- PRODUCT

AIR QUALITY INDEX (AQI)

CLOUD SERVER

Master Server

GPRS

DISPLAY SERVER

WEB SERVER

AIR QUALITY INFORMATION FOR PUBLIC WITH HEALTH ADVISORIES

SAFAR: INDIA'S SYSTEM OF AIR QUALITY AND WEATHER FORECASTING AND RESEARCH

Products (left column):

- **AIR QUALITY TODAY** City Locations
- **AIR QUALITY 3-day Forecast**
- **AIR QUALITY** Health Advisory & Precautions
- **EXTREMES** Pollution & Weather Alerts
- **EMISSION MAP** Sources of Pollution (1km*1km)
- **UV-INDEX** Harmful Radiation & Skin Advisory

Central flow:

- Air Quality Monitoring Network
- Weather Monitoring Network
- Emission Inventory Development
- Topography, Land use , Data Assessment

MODELING
AIR Quality Forecasting — WEATHER Forecasting
Supercomputer

PRODUCTS ⬌ **Translate Science to Information** ⬌ **SERVICES**

Services (right column):

- Mobile-App Safar-Air
- Dynamic Website Safar.tropmet.res.in
- Big Display (5Nos.)
- Toll Free Number 1800 220 161

Safar-Cities
- Delhi — Very Poor
- Pune — Moderate
- Mumbai — Poor
- Ahmedabad — Poor

Air quality index scale: 50, 100, 200, 300, 400, 500

SAFAR BENEFICIARIES
Common public, Mitigation strategist, Researcher, Academician, Civic authorities, Disaster Management, Health Professionals, and Farmers.

SCIENCE & RESEARCH
Research based understanding of linkages among emissions, weather, pollution and Human Health leading to a Developing framework of Decision Support System for socio-economic benefits.

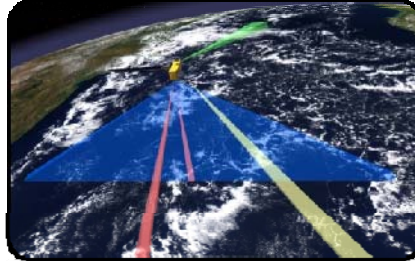# AIR QUALITY SAFAR-DISSIMINATION TOOLS
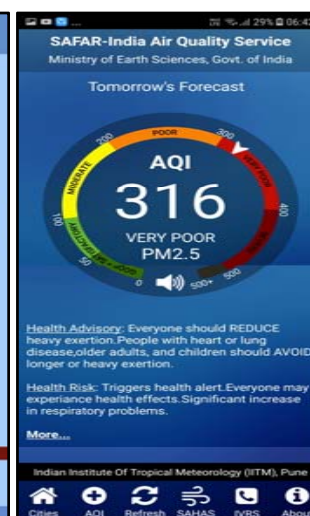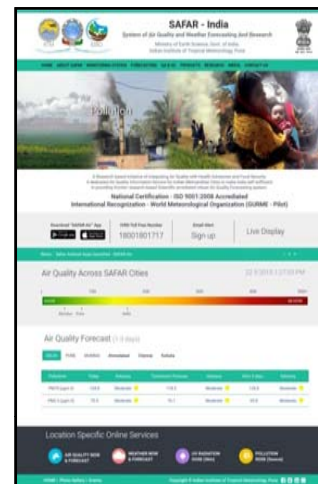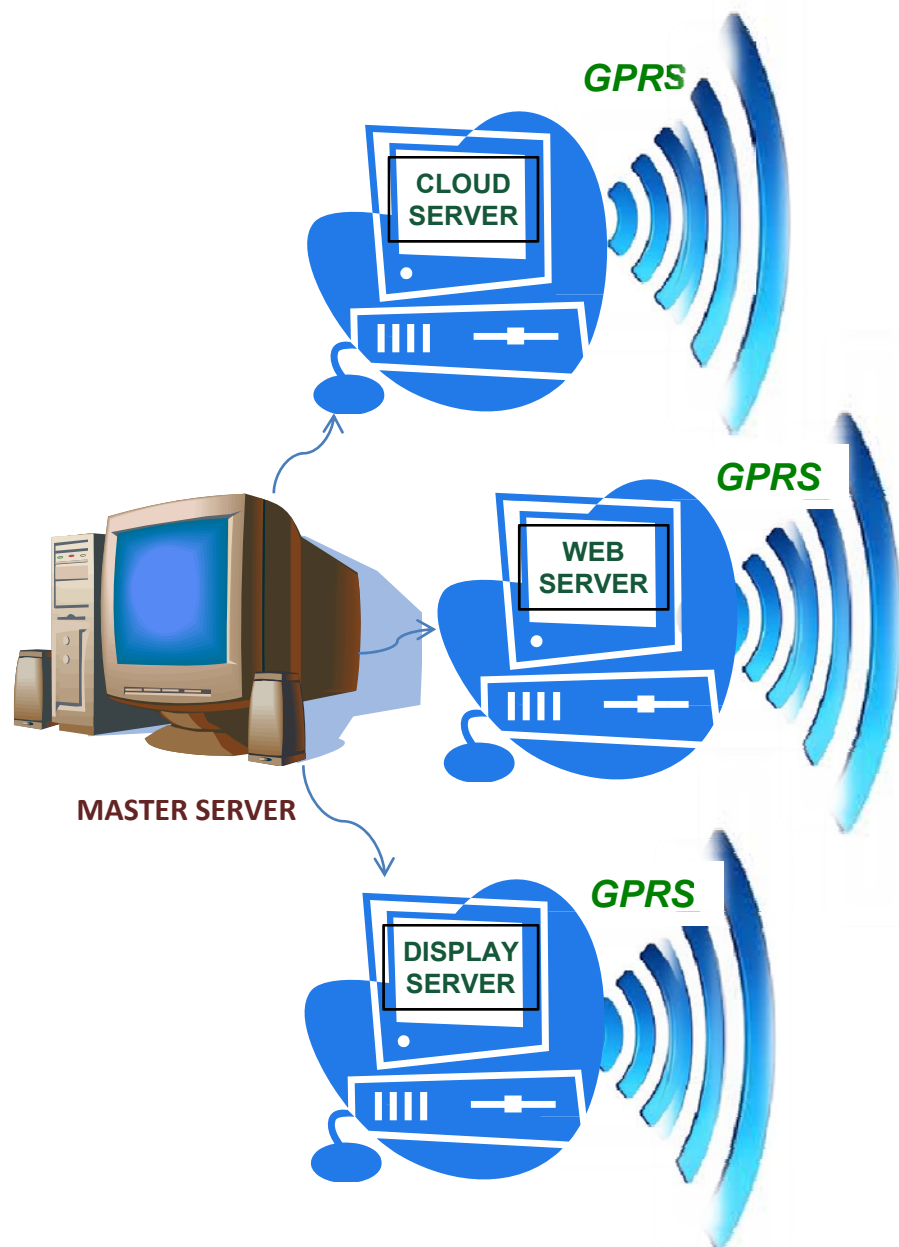
Multilingual & Voice enabled SAFAR Mobile App

SAFAR-FORECASTING MODEL FRAMEWORK
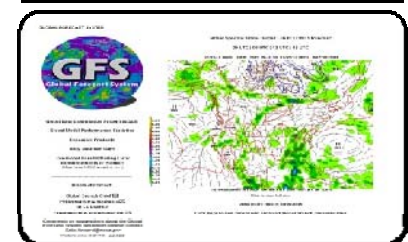

Real Time AQMS and AWS Network Data

Real Time Satellite Data -Assimilation
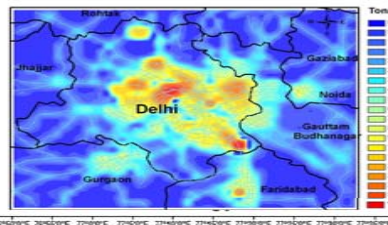
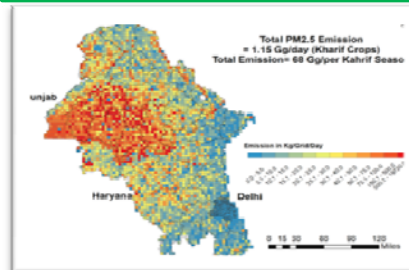**Forecasted -MACC-Chemical IC & BC**

Forecasted -NCMRWF-GFS-Met IC&BC

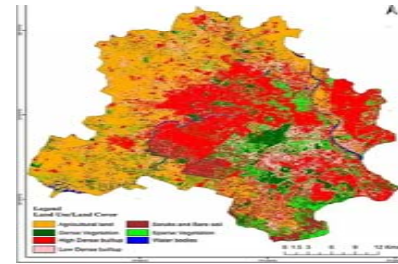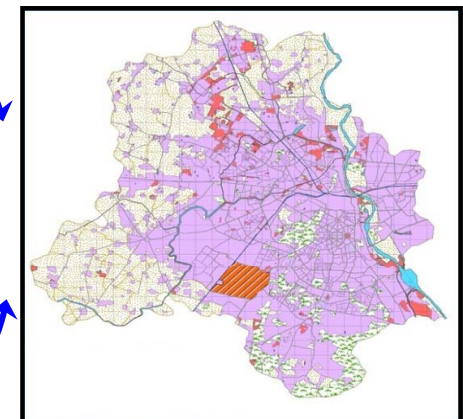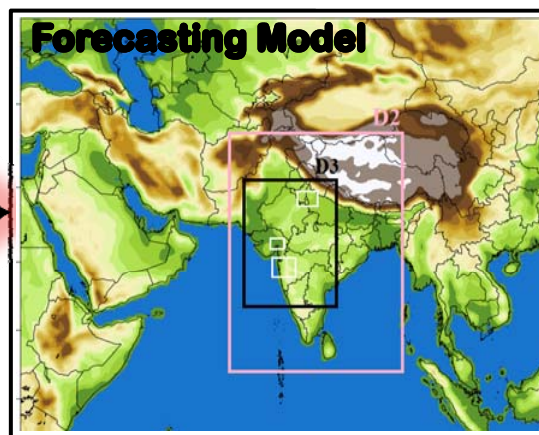**High Resolution Emission Scenario –Regional-2018**

Stubble Bio-Mass Burning Emission Products-SAFAR..

Land use and Land cover Products: IRS-Bhuvan:

72h -Air Quality Warning Products

Forecasting Model

Possible airsheds within India defined by possible dominant source

Airsheds

- Coal
- Dust
- Open fires
- Residential Biomass
- Urban Transport
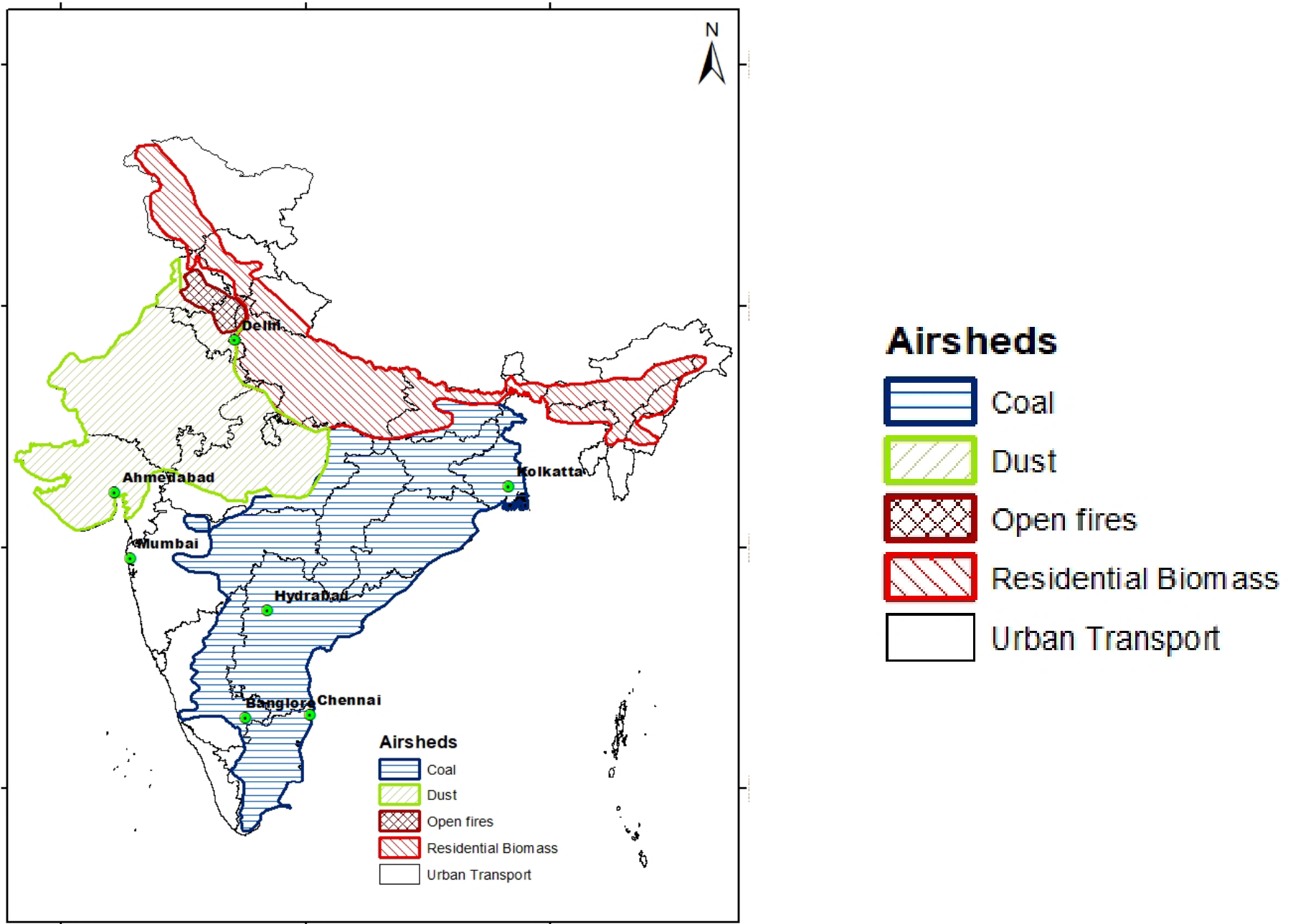
SOUTH INDIA

MAPAN- Bangalore Station 2016 - PM2.5

Good 48%
Satisfactory 41%
Moderate 10%
Poor 1%
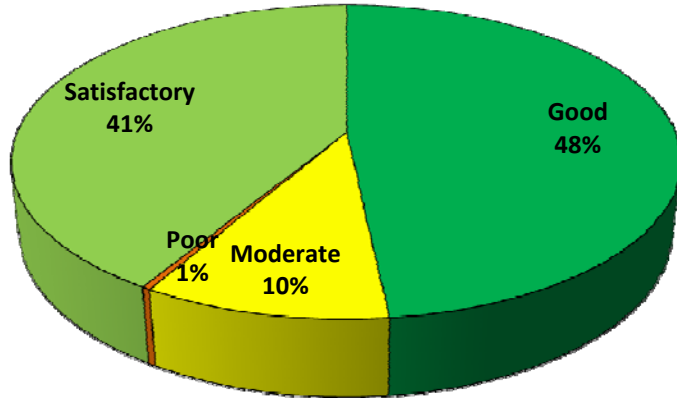
MAPAN- Chennai Station 2016 - PM2.5

Good 61%
Satisfactory 29%
Very Poor 0%
Poor 0%
Moderate 10%
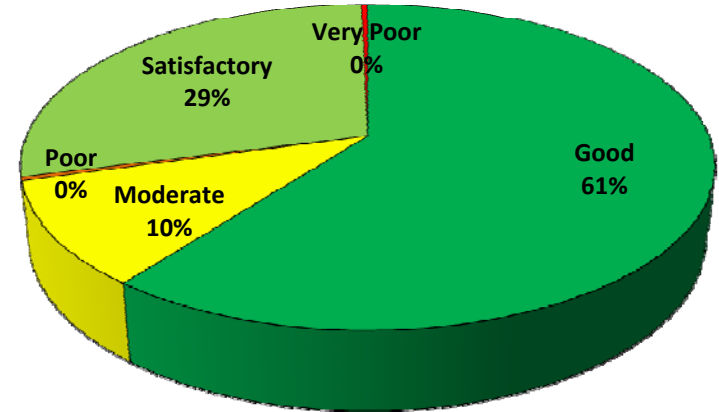
MAPAN-Vishakapatnam Station 2016 - PM2.5

Good 52%
Satisfactory 34%
Very Poor 1%
Poor 2%
Moderate 11%
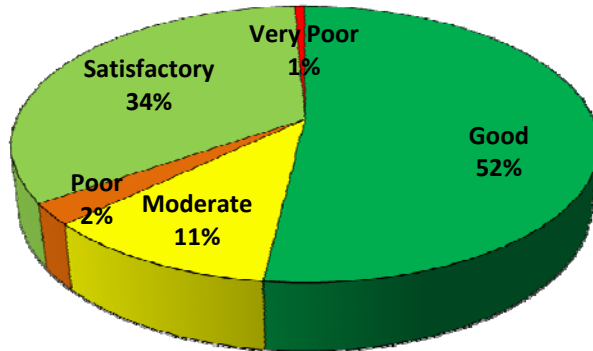
MAPAN-Trivendrum Station 2016 - PM2.5

Good 52%
Satisfactory 37%
Poor 1%
Moderate 10%
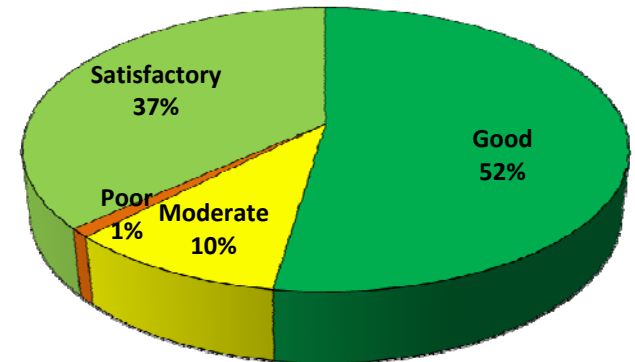
MAPAN- Hyderabad Station 2016 - PM2.5

Good 51%
Satisfactory 29%
Severe 8%
Very Poor 1%
Poor 1%
Moderate 10%
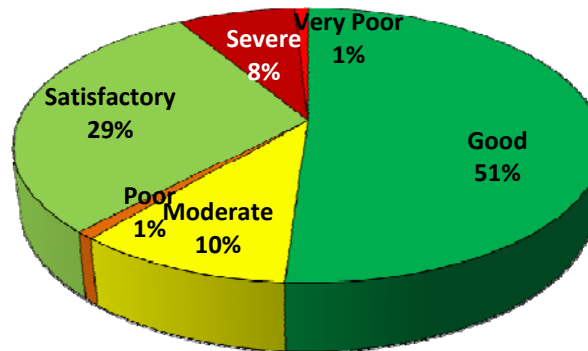
EAST INDIA

MAPAN- Aizwal Station 2016 - PM2.5

- Very Poor 1%
- Satisfactory 30%
- Poor 1%
- Moderate 4%
- Good 64%
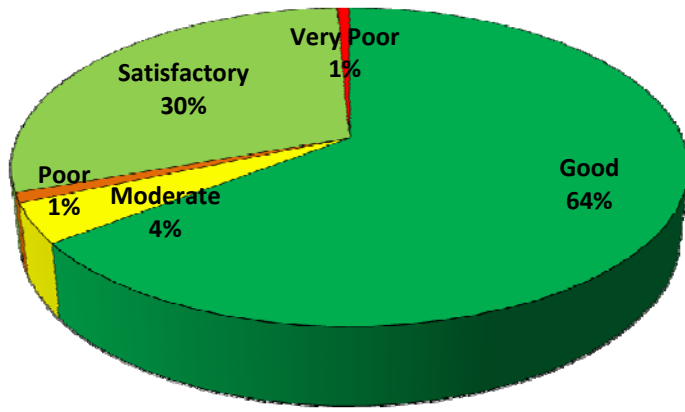
MAPAN- Gwahati Station 2016 - PM2.5

- Very Poor 1%
- Satisfactory 31%
- Poor 2%
- Moderate 20%
- Good 46%
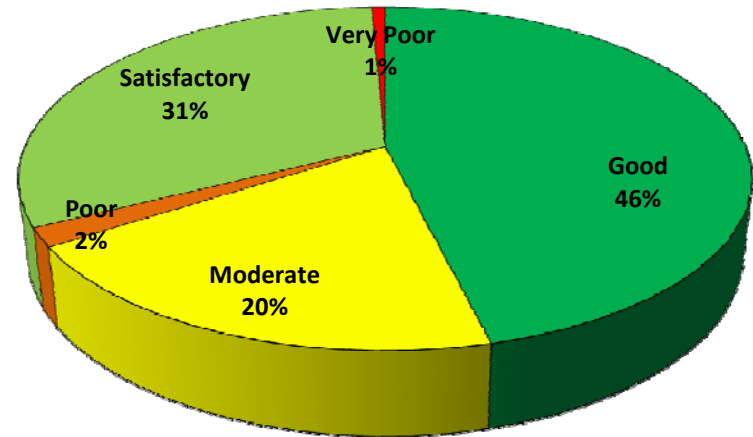
MAPAN-Tezpur Station 2016 - PM2.5

- Very Poor 3%
- Satisfactory 30%
- Poor 3%
- Moderate 5%
- Good 59%
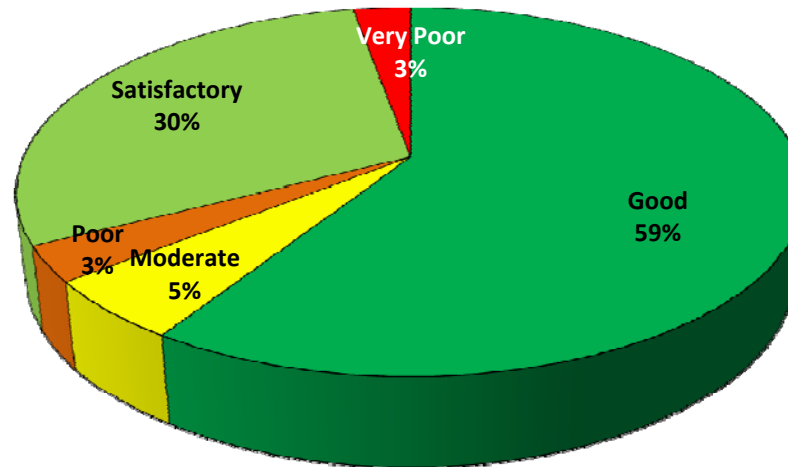
NORTH-WEST INDIA

MAPAN- Srinagar Station 2016 - PM2.5

- Severe 18%
- Very Poor 13%
- Good 11%
- Moderate 13%
- Poor 8%
- Satisfactory 37%
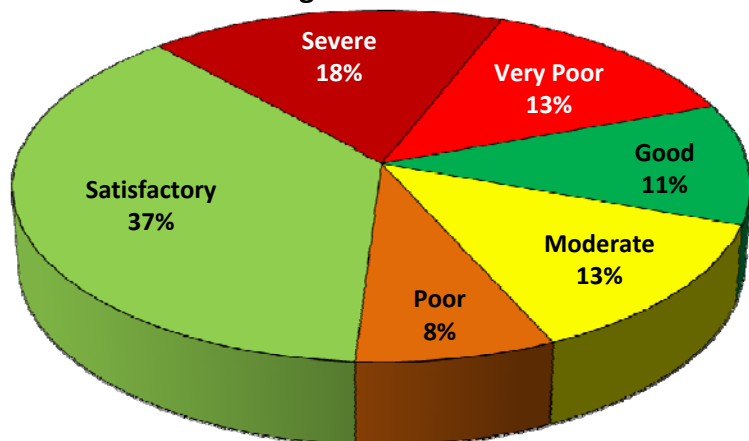
MAPAN-Patiala Station 2016 - PM2.5

- Good 5%
- Moderate 22%
- Very Poor 31%
- Severe 3%
- Poor 21%
- Satisfactory 18%
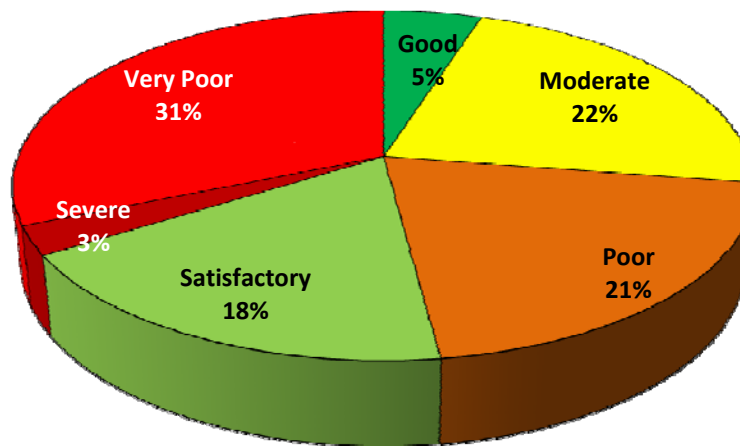
MAPAN-Udaipur Station 2016 - PM2.5

- Very Poor 0%
- Good 42%
- Satisfactory 45%
- Poor 2%
- Moderate 11%
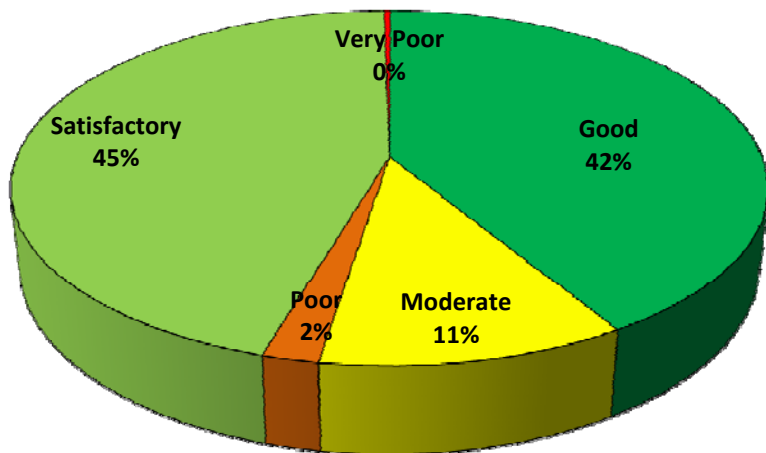
MAPAN- Jabalpur Station 2016 - PM2.5

- Satisfactory 44%
- Good 46%
- Moderate 10%
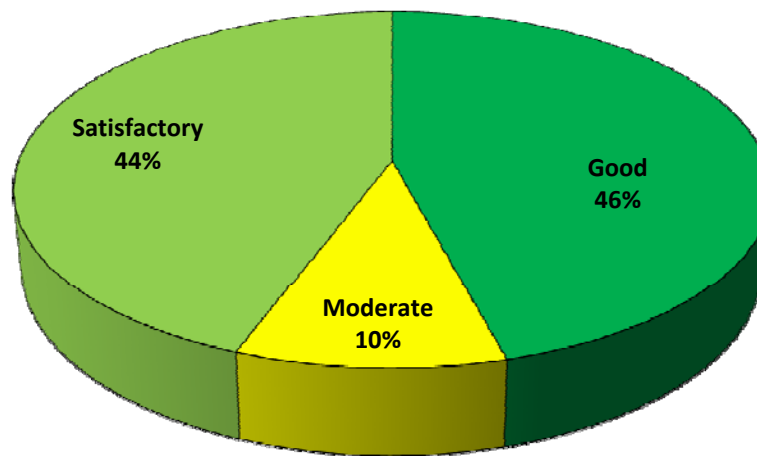
DELHI: ANNUAL PM2.5 TRENDS (2012-2018)

PM2.5 -TREND (ANNUAL AVG.) FOR DELHI: 2012 -2018

DELHI ANNUAL (2012-18)

AQI TRENDS OF PM2.5 (Yearly)

Line chart showing AQI trends of PM2.5 (Yearly) for Delhi from 2012 to 2018. Y-axis: NUMBER OF DAYS (%) from 0 to 40. X-axis: YEAR (2012–2018). Legend: GOOD, SATISFACTORY, MODERATE, POOR, VERY POOR, SEVERE.
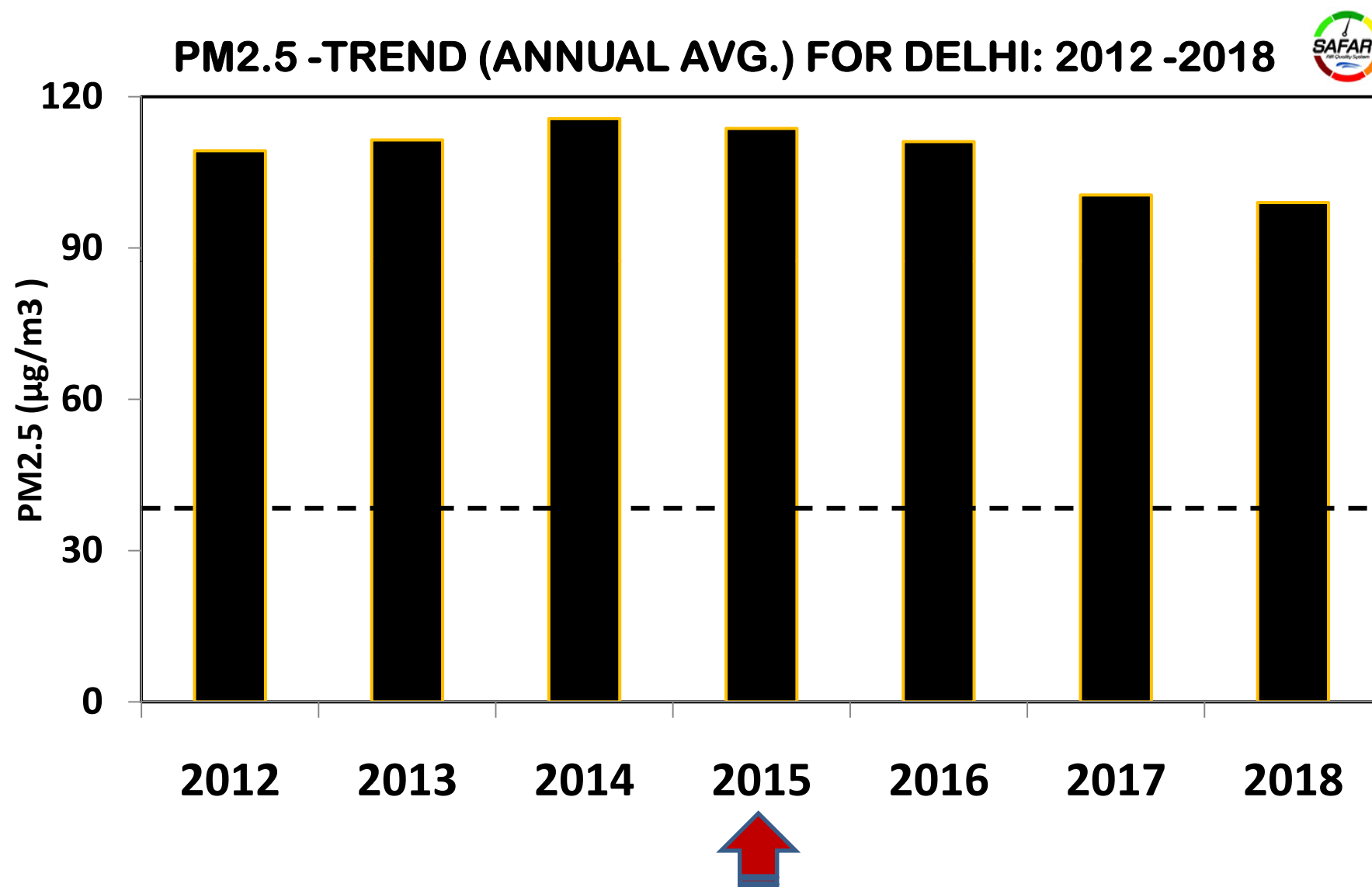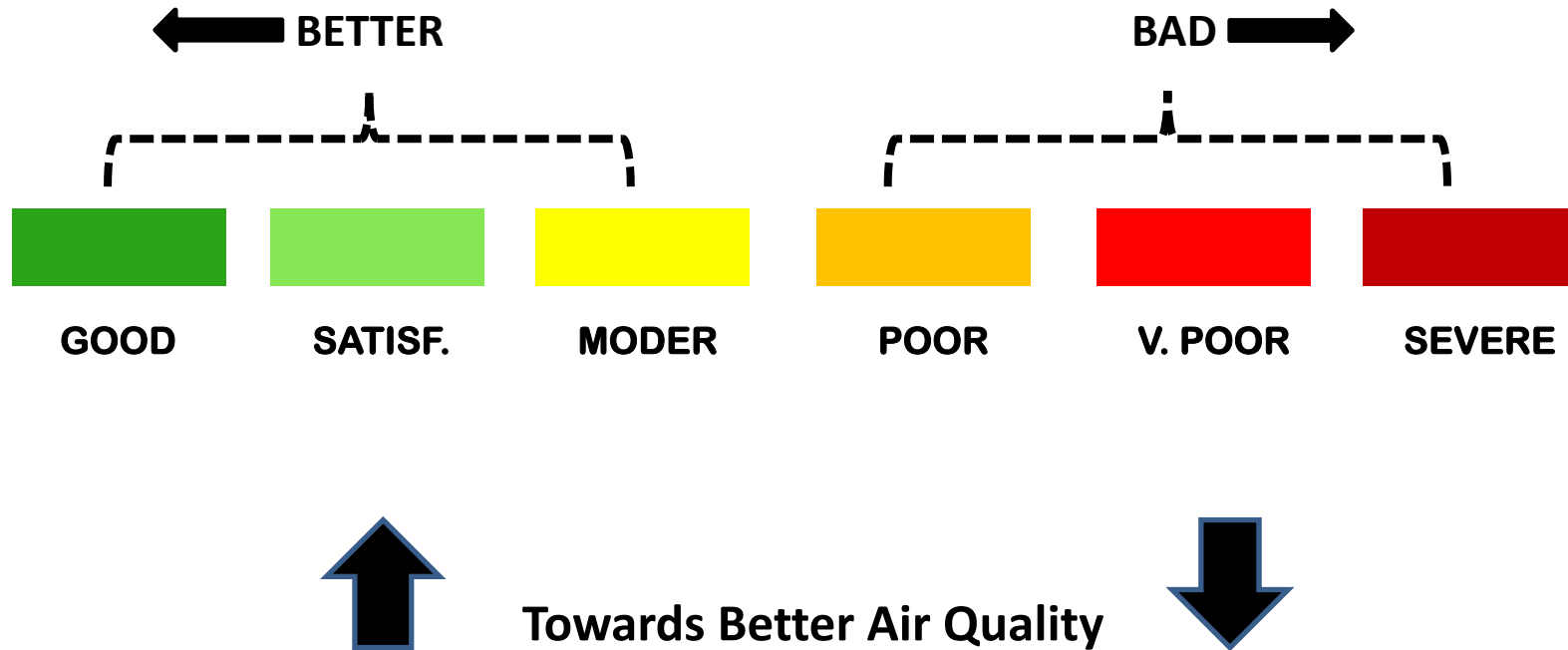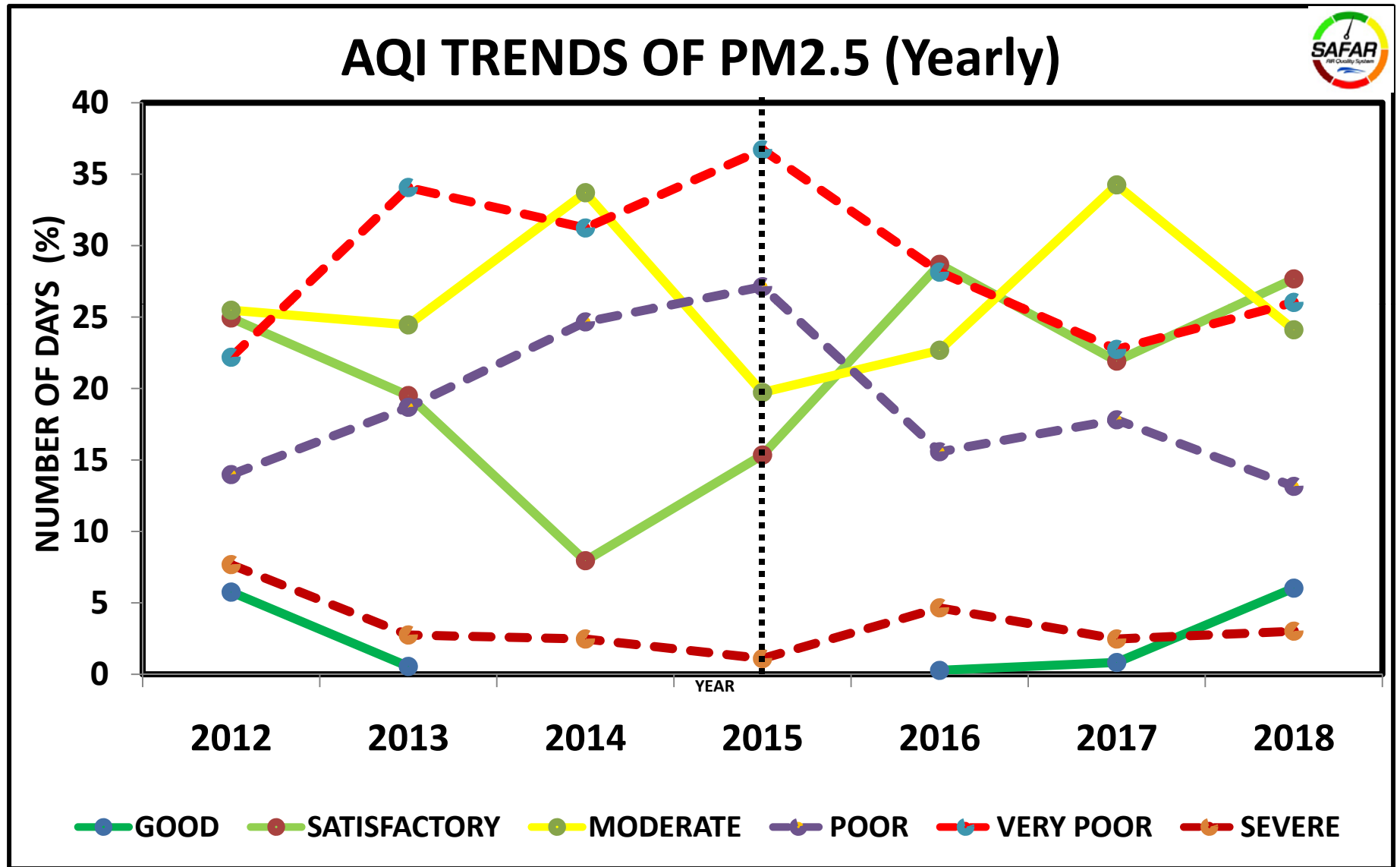
DELHI MONSOON (2012-18)

AQI TRENDS OF PM2.5 (JJAS)

Legend: GOOD, SATISFACTORY, MODERATE, POOR, VERY POOR, SEVERE
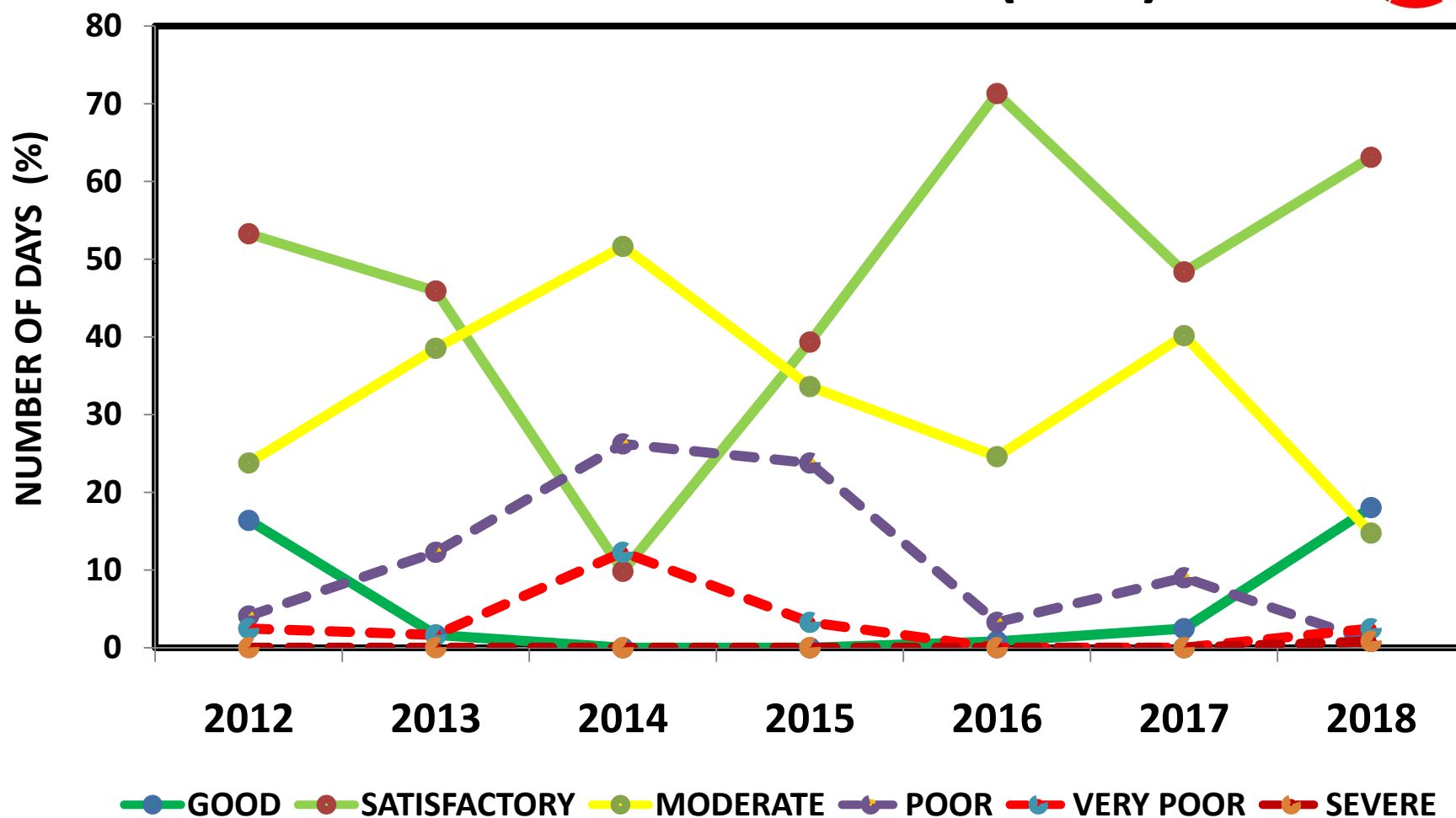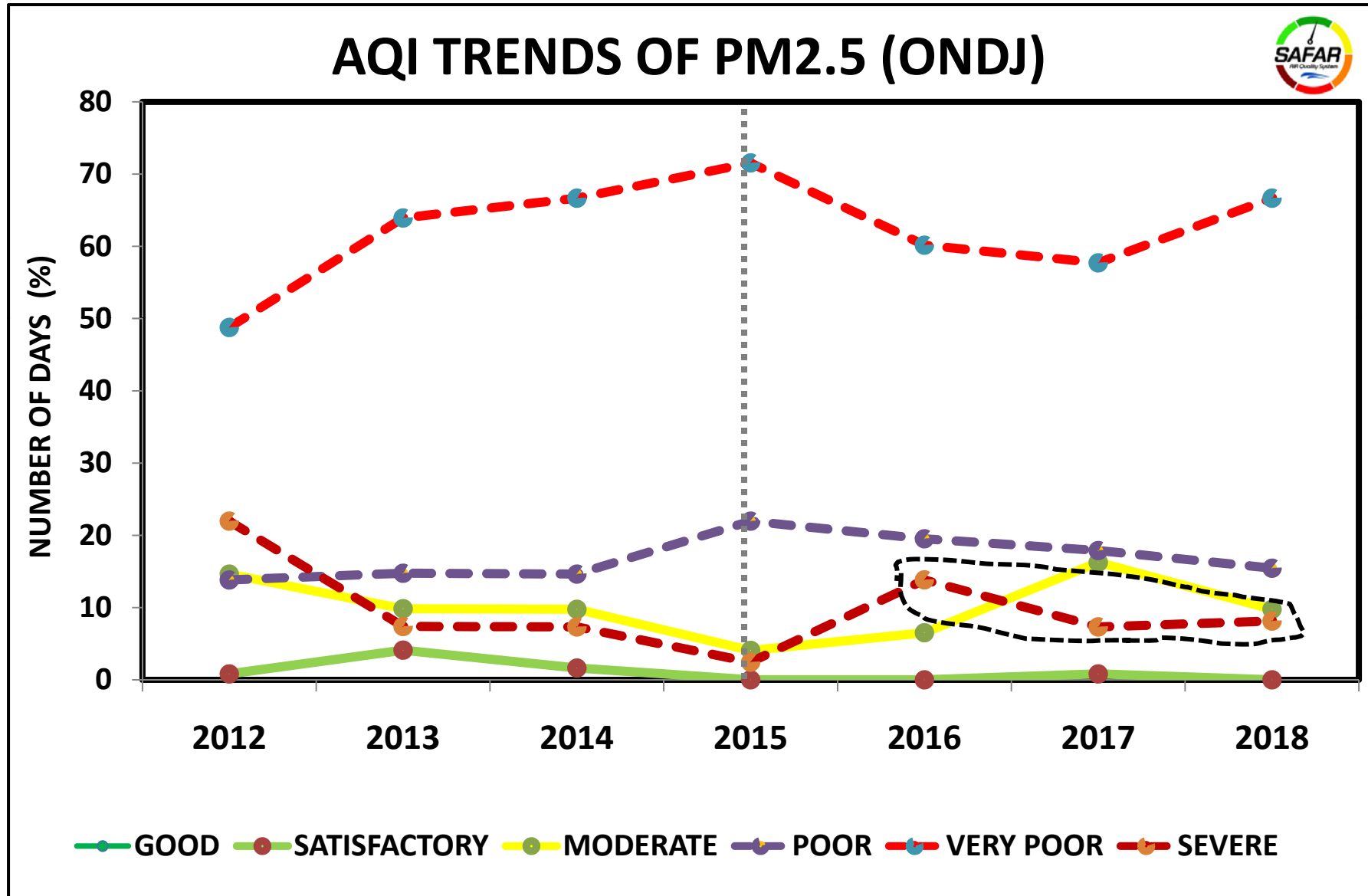
DELHI SUMMER (2012-18)

Emission Control Meter?

AQI TRENDS OF PM2.5 (FMAM)

GOOD · SATISFACTORY · MODERATE · POOR · VERY POOR · SEVERE
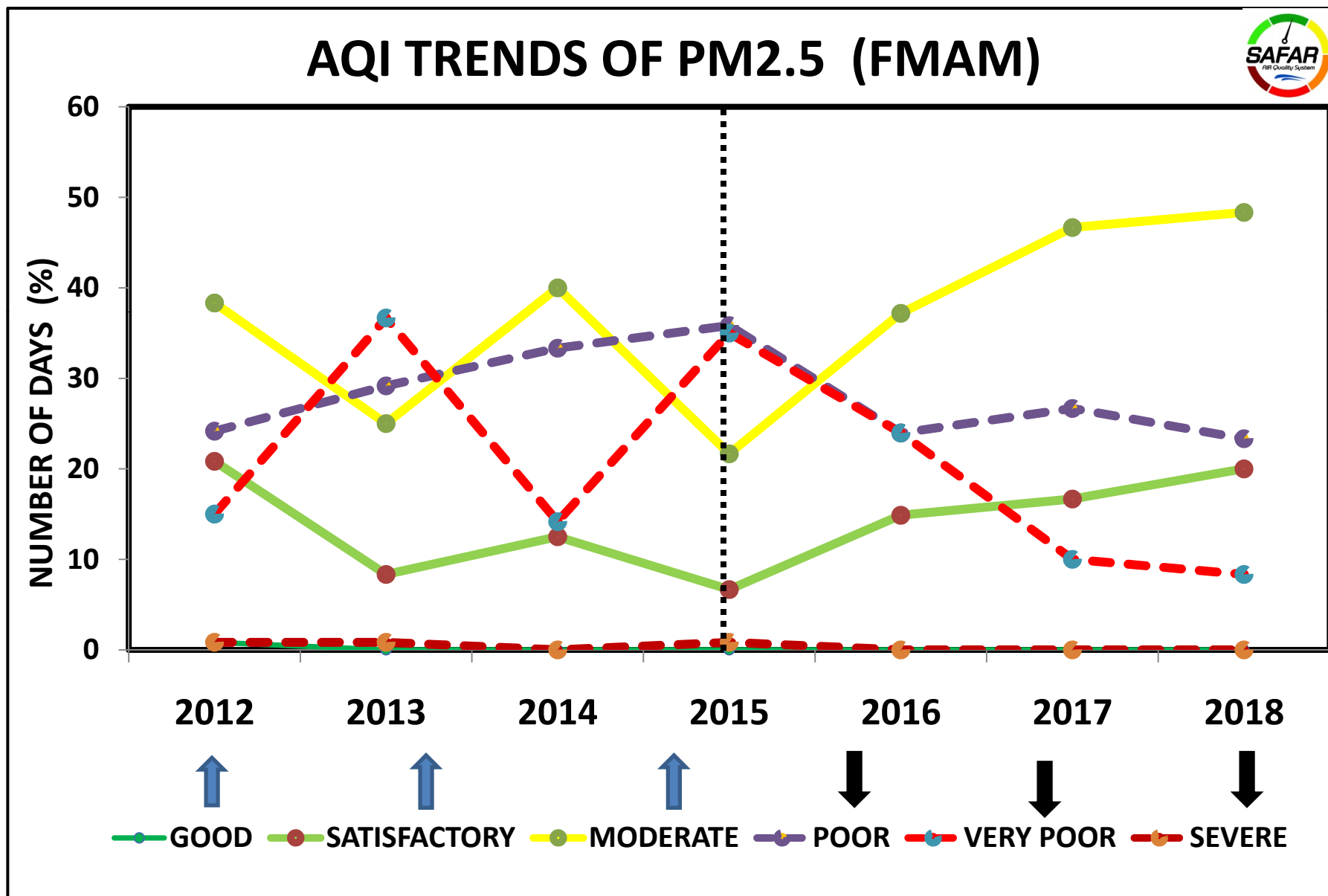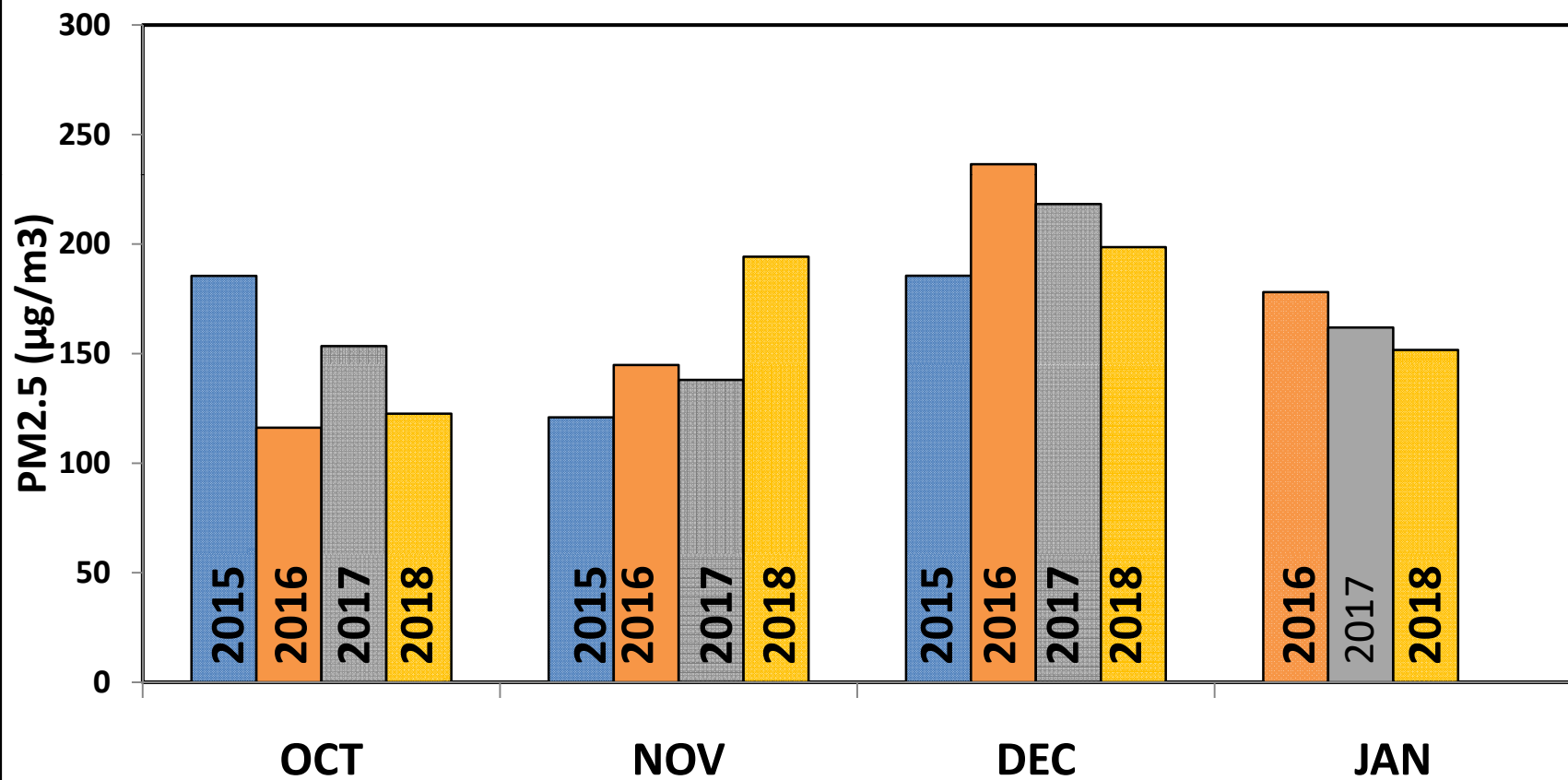
THE BIG SMOG!!
AN UNUSUAL HAPPENING

DELHI 2016 2017 2018 → **WORST AIR QUALITY CRISIS EVENT OF ALL TIME** → **UNUSUAL ENVT. EMRGENCY?** → **BUT SIGN OF AIR QUALITY IMPROVMENT** → **IS THERE ANY OTHER FACTOR?**
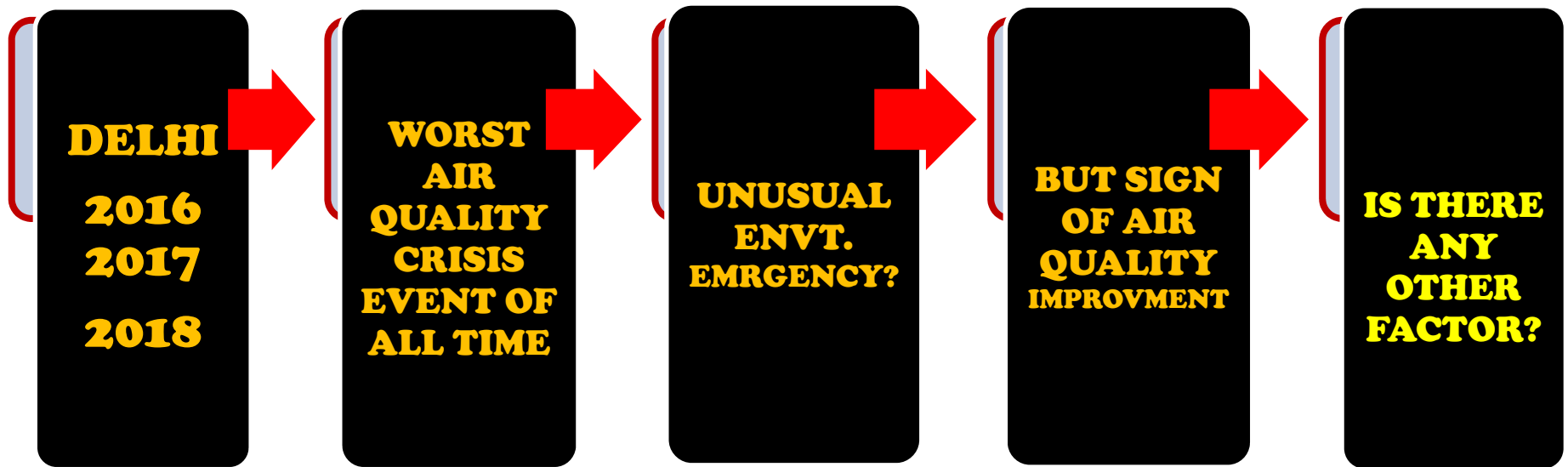
Understanding Severity of Pollution

SBI

Discrete → High Pollution -Alert

10 Oct.   21 Oct.   4 Nov.   11 Nov.   17 Nov. 7 Dec **(7 Days in 3 months)**

Continuous... → Emergency -DSS

November, 7-13 (7 Days in a row)
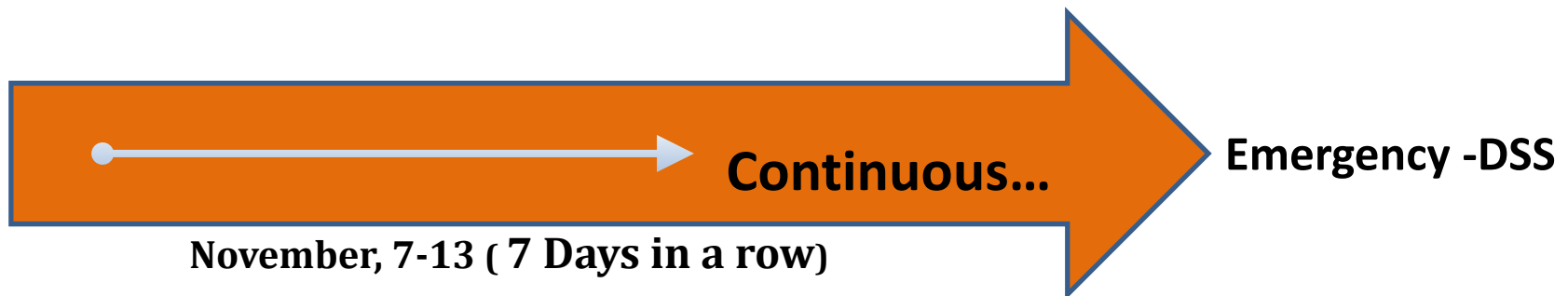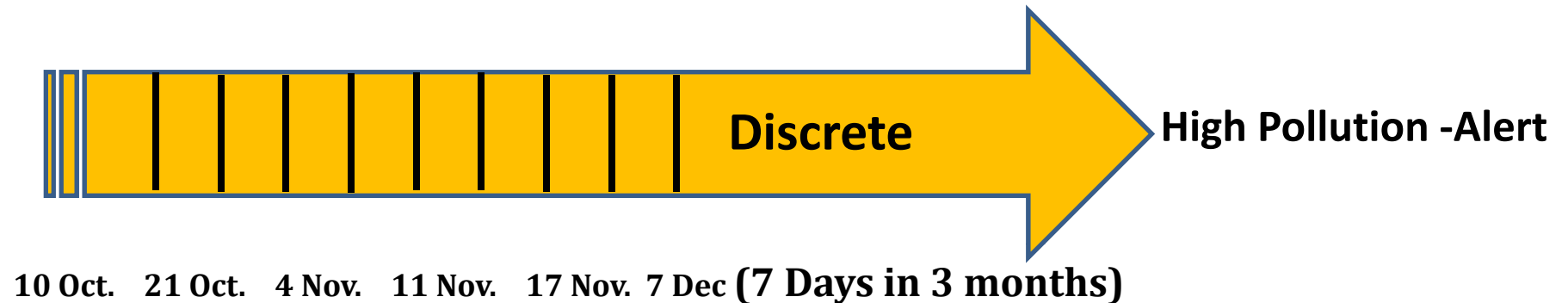
2016 (25th October – 7th November) -DELHI

BUILT-UP OF DEADLY 'PM2.5'
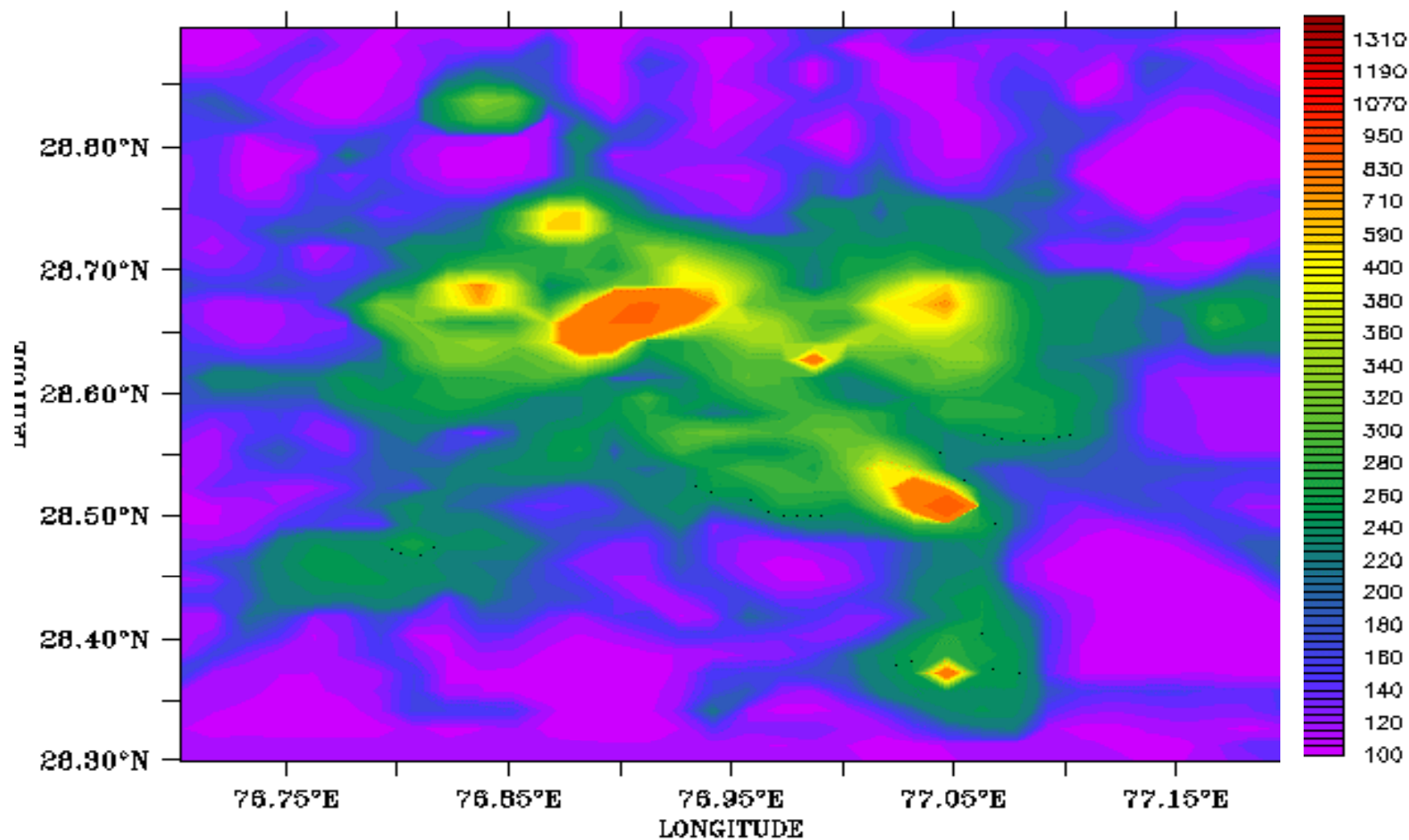
ANTI-CYCLONIC CIRCULATION AND CALM WIND VANTILATION

Mean wind speeds (m/s) (November 1-6) at about 1 km height (925mb) (NCEP/NCAR-Reanalysis)
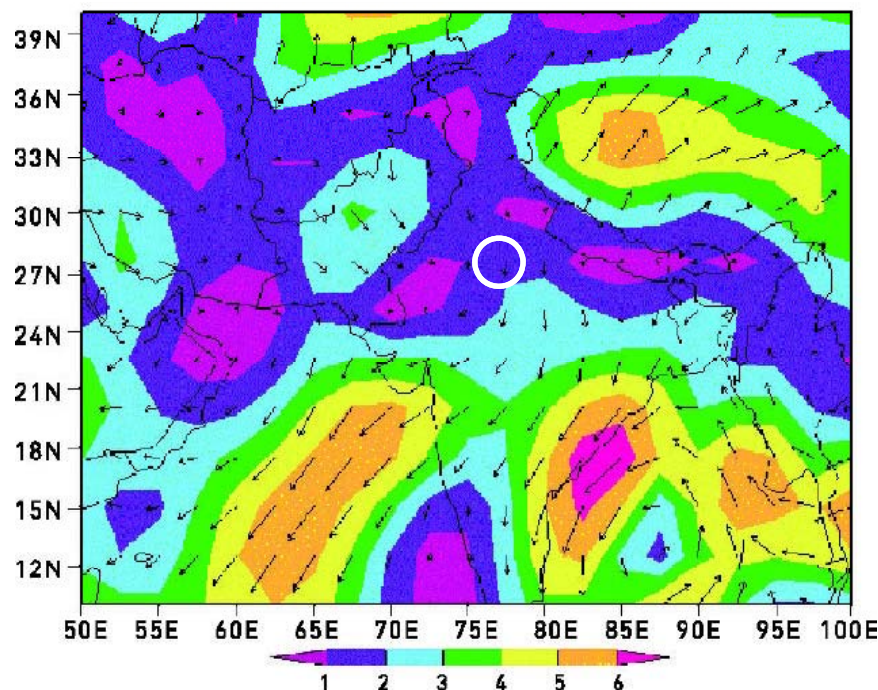
Because of the anti-cyclone was so low, surface winds were very weak and could not advect any local pollutants outside with near zero ventilation coefficient.

ANTI-CYCLON SO LOW

Normal Scenario:

Ac-circulation is art of winter circulations and forms at ~4km or more

Unusual (Oct' last week –Nov' 6):

- High pressure system formed at 1 km and very deep ➡ Impacted Lower atmosphere
- Air circulation coming down created a kind of subsidence ➡ Atmosphere became very stable and prevented local convection

Week after 7th November:

- With local heating, convection took place and air started to go-up and mix-up.

2017 (7th November – 14th November) -DELHI

BUILT-UP OF DEADLY 'PM2.5'

Date : 7-11-2017
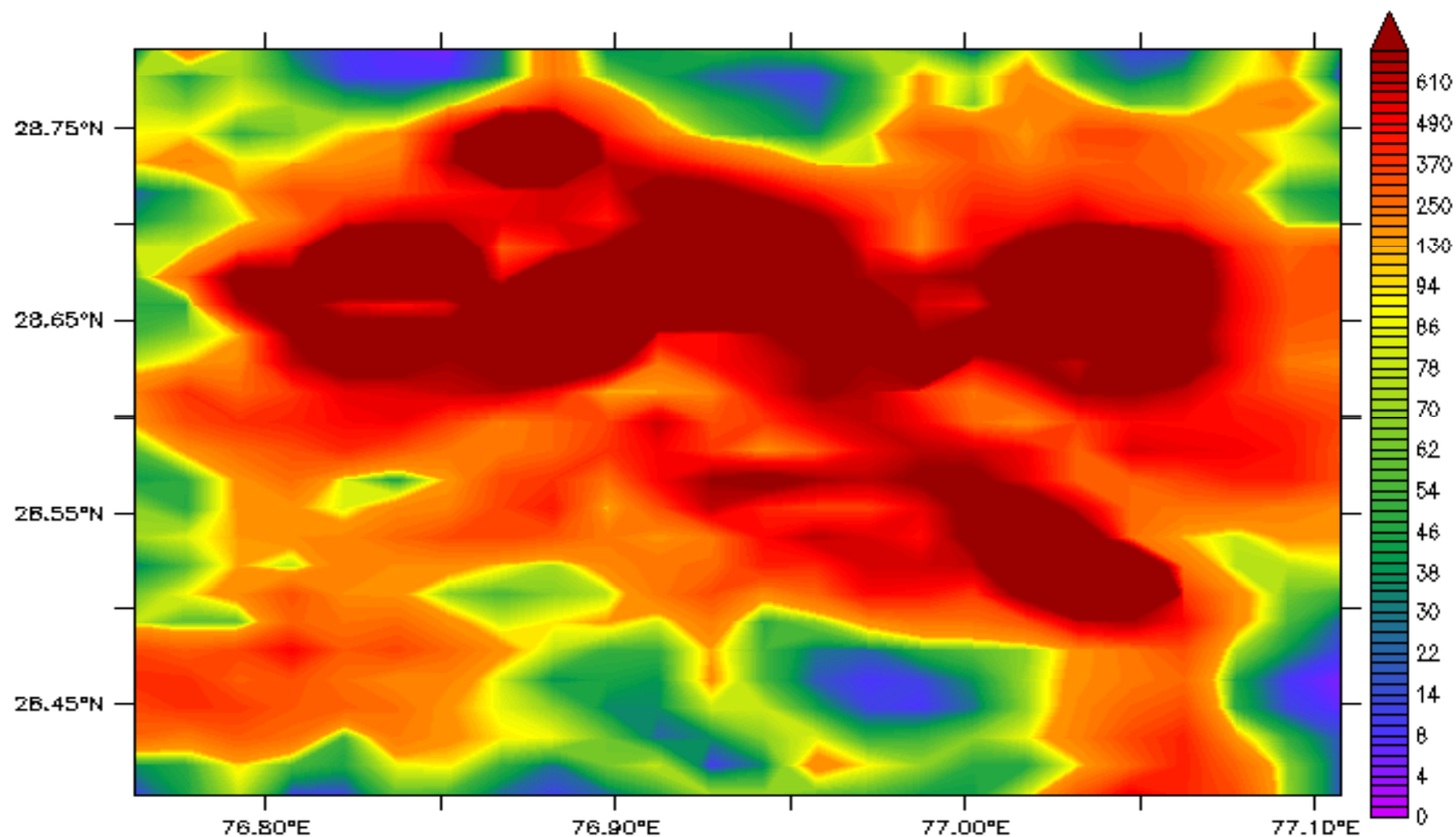
DELHI EMERGENCY EVENT -2017
LONG DISTANCE UPPER AIR TRASPORT
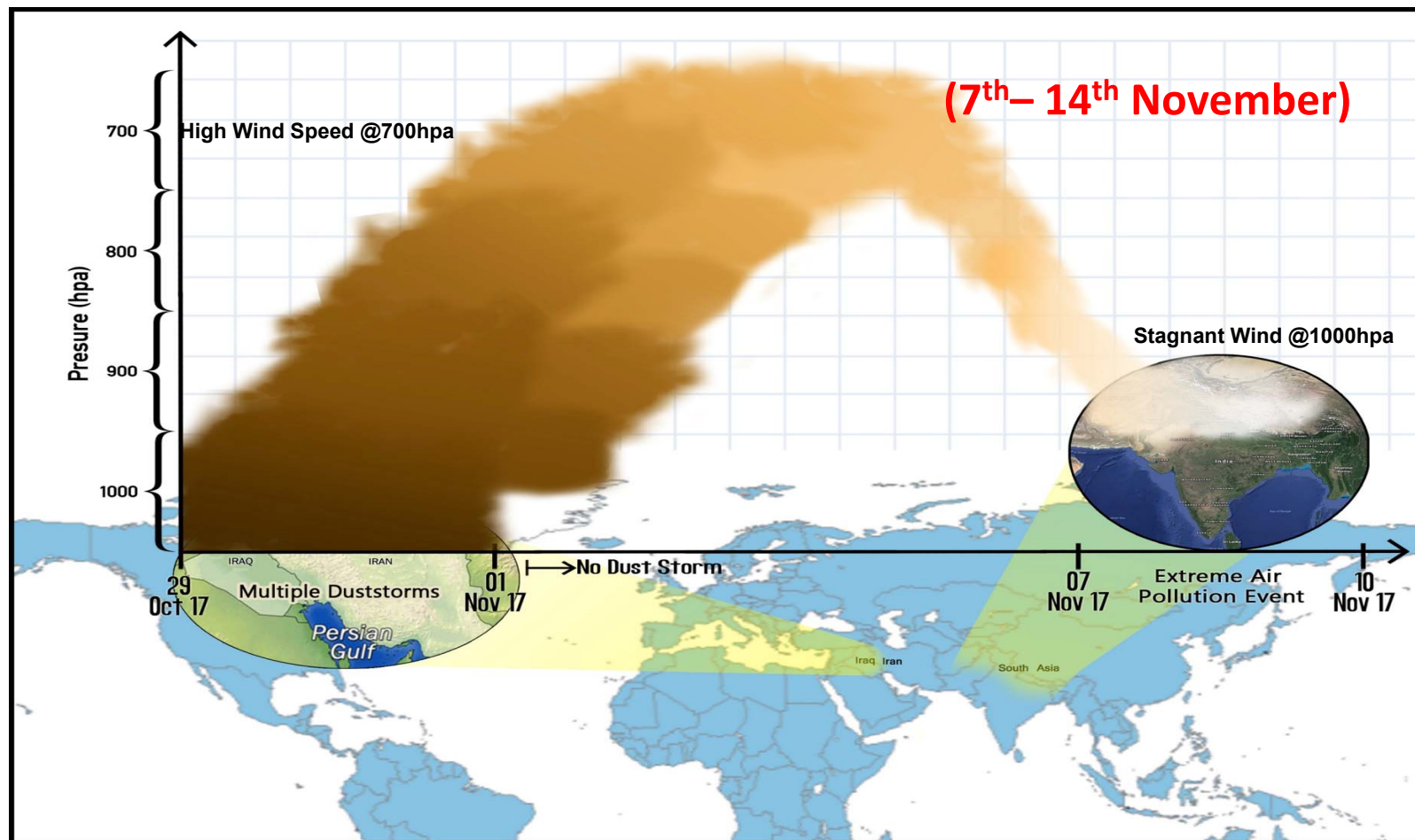
Relative share of different sources in PM2.5 during peak day of AQE-2017	
Dust Storm	40%
Stubble Burning	25%
Local Sources	35%

Development of Dynamic Emission Inventory of Stubble Bio-Mass and SAFAR Sensitivity Runs to calculate % share during Kharif Season of Oct-Nov' 2018

Spatial Hot Spots of Gridded PM2.5 Emission from Crop Residue Burning Over Punjab in one single Winter Day (2018) (Date:16-11-2018)

Total PM2.5 Emission
= 0.71 Gg/day (Kharif Crops)
Total Emission= 42.82 Gg/per Kahrif Season

Emission in Kg/Grid/Day

0.0 - 5.0 | 5.1 - 10.0 | 10.1 - 15.0 | 15.1 - 20.0 | 20.1 - 25.0 | 25.1 - 30.0 | 30.1 - 40.0 | 40.1 - 50.0 | 50.1 - 75.0 | 75.1 - 150.0 | 150.1 - 500.0 | 500.1 - 19720.0

0 10 20 40 60 80 Miles

Punjab

Spatial Location of Crop-Residue Burning Area During Khariff Season (2018)

Total Geographical Area:~50360Sq km
Total Cultivated Area: ~42000 Sq km
Crop-Residue Burning Area: ~8660 Sqkm

Punjab

Legend
Residue Burning Area
Punjab

0 15 30 60 Miles

Spatial Hot Spots of Gridded PM2.5 Emission from Crop Residue Burning Over Punjab-Haryana in one single Winter Day (2018) (Date:16-11-2018)

Total PM2.5 Emission
= 1.15 Gg/day (Kharif Crops)
Total Emission= 68 Gg/per Kahrif Season

Punjab

Emission in Kg/Grid/Day

0.0 - 5.0 | 5.1 - 10.0 | 10.1 - 15.0 | 15.1 - 20.0 | 20.1 - 25.0 | 25.1 - 30.0 | 30.1 - 40.0 | 40.1 - 50.0 | 50.1 - 75.0 | 75.1 - 150.0 | 150.1 - 500.0 | 500.1 - 19720.0

Haryana   Delhi

0 15 30 60 90 120 Miles
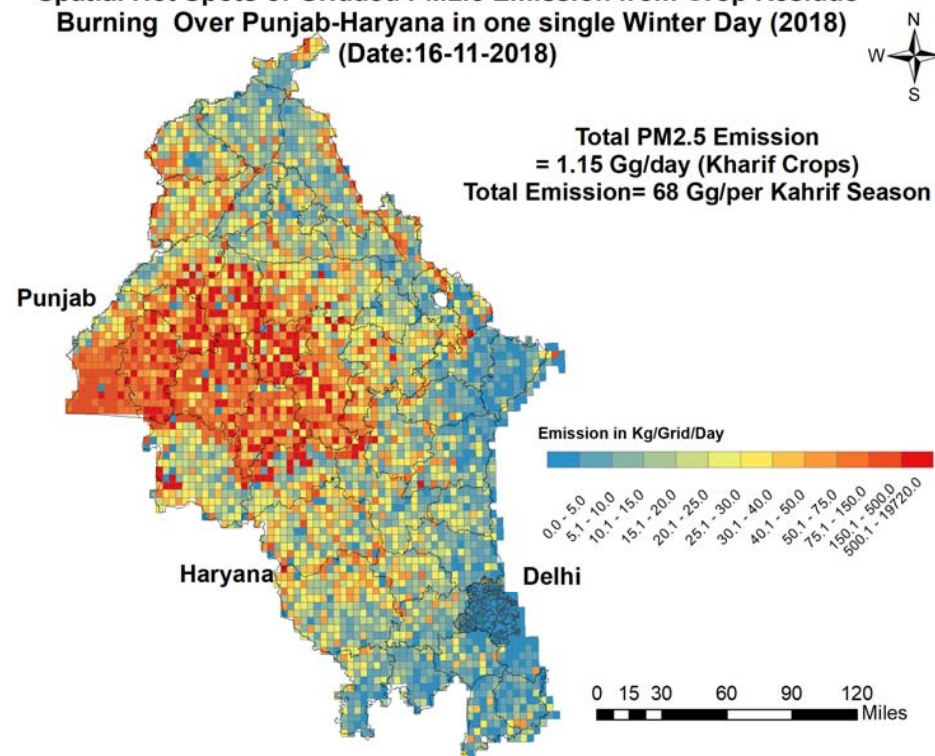
A combination of INSAT-3D and MODIS fire counts with Real field incidences data, we identify the actual stubble burn areas only and filter out false signals.

SAFAR
Air Quality System
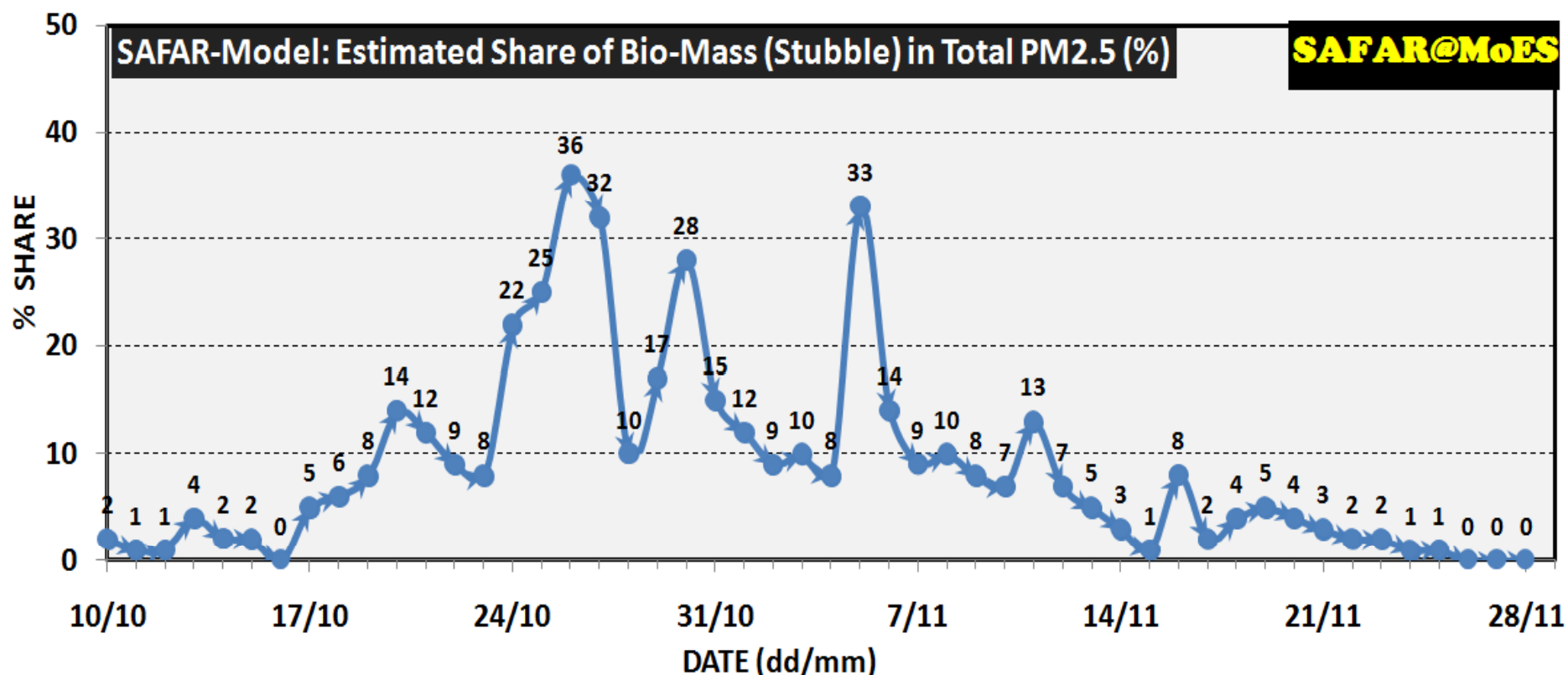
Take Away: Stubble burning almost remain continue with varying counts, there are maximum fire counts on some days but Delhi air quality **may not get affected** as it is based on sensitive combination of WS, WD, transport height at Stubble site and local weather conditions.

PM2.5 CHEMICAL SPECIATION (DELHI) TO UNDERSTAND TOXICITY (First Result in SAFAR)

METALS

EXPERIMENT

PM2.5 Sampling: Low volume sampler with Quartz /Teflon filters
Time period: (1) Daily two six hr samples in winter (Jan-Feb 2018) at 4 locations; (2) 18-24 hr in summer (May 2018) at 24 Locations
Methodology: Atomic Absorption spectrometer (elemental detection)

Monitoring stations over Delhi region during Summer Campaign
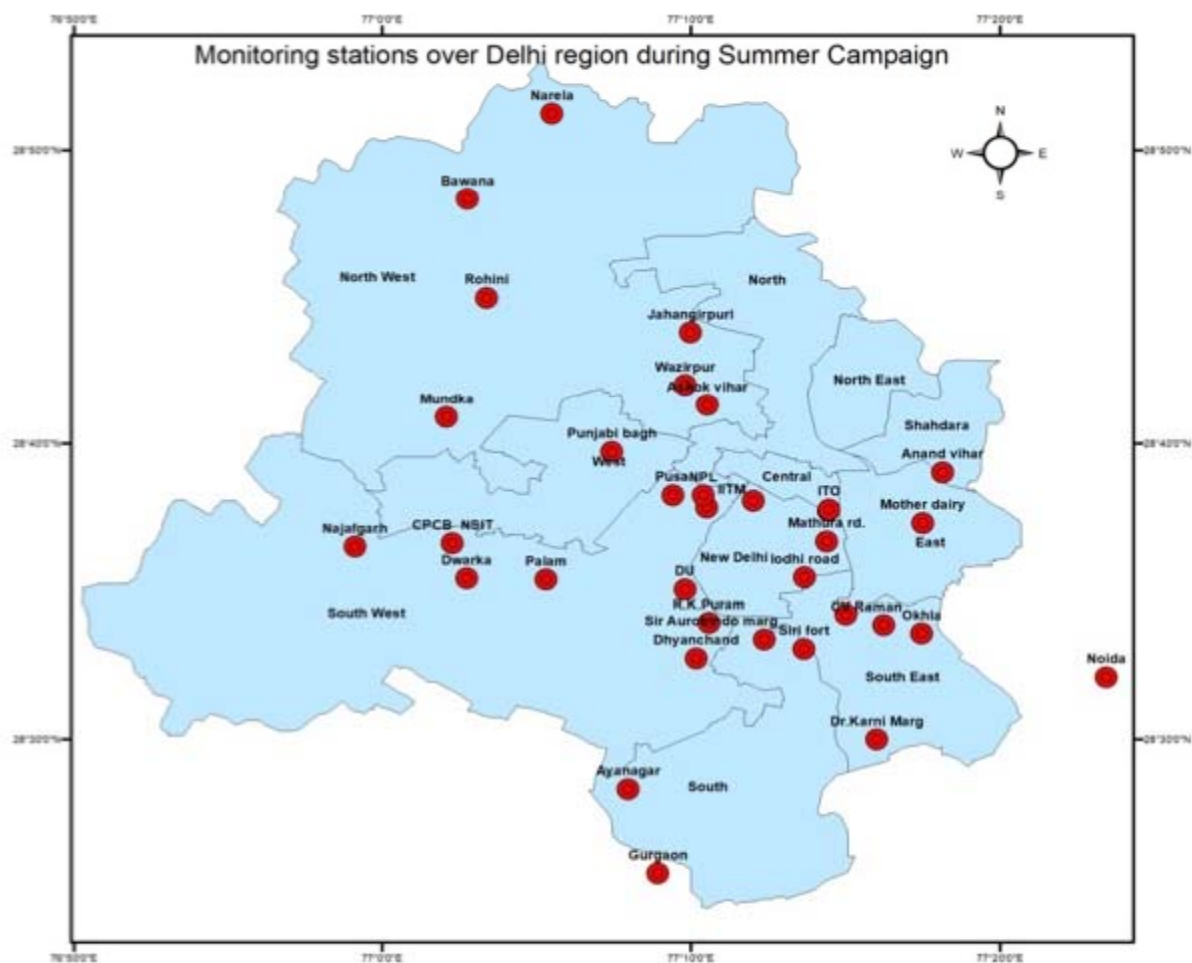
Metal: WINTER (Delhi)
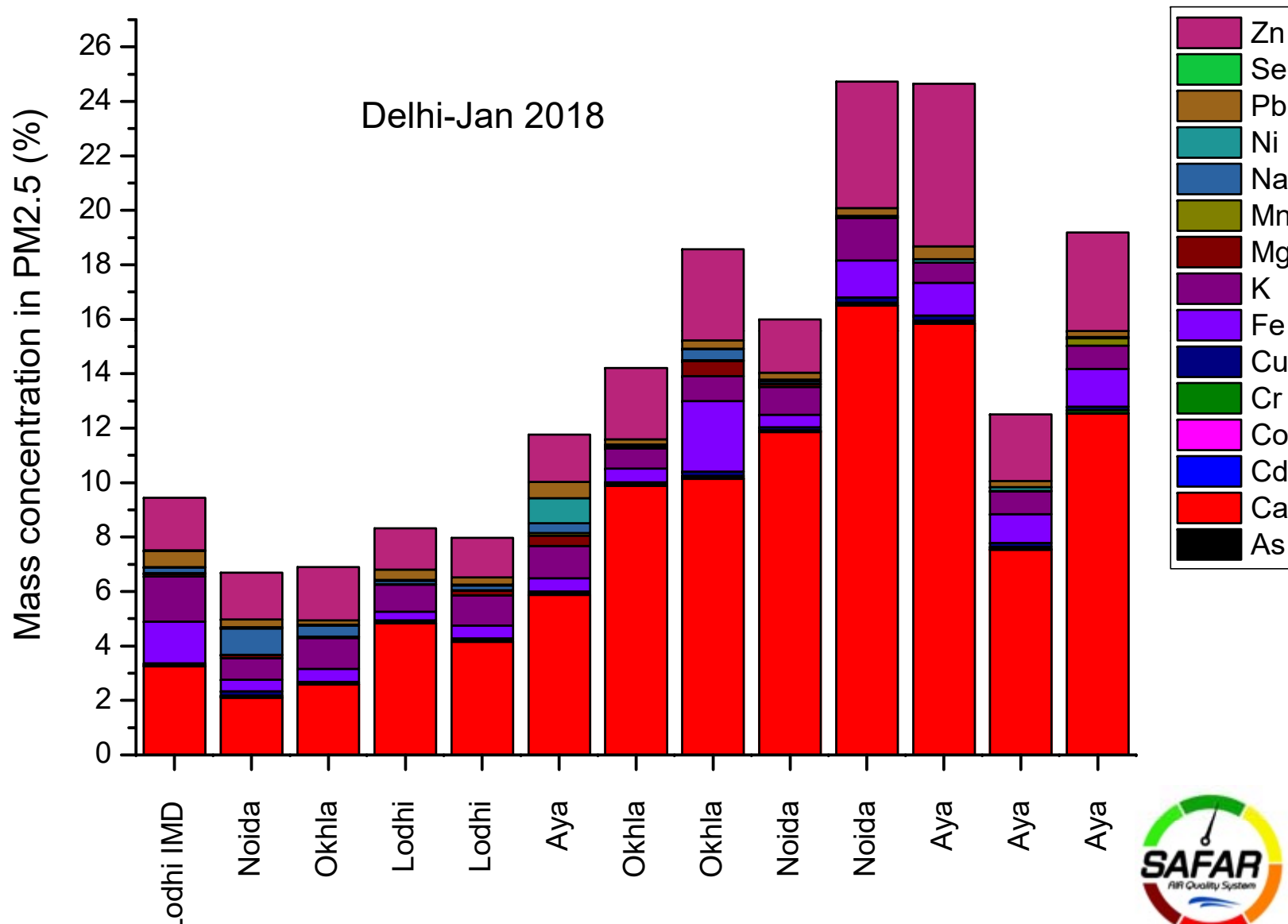
Annual mean concentration (2017)
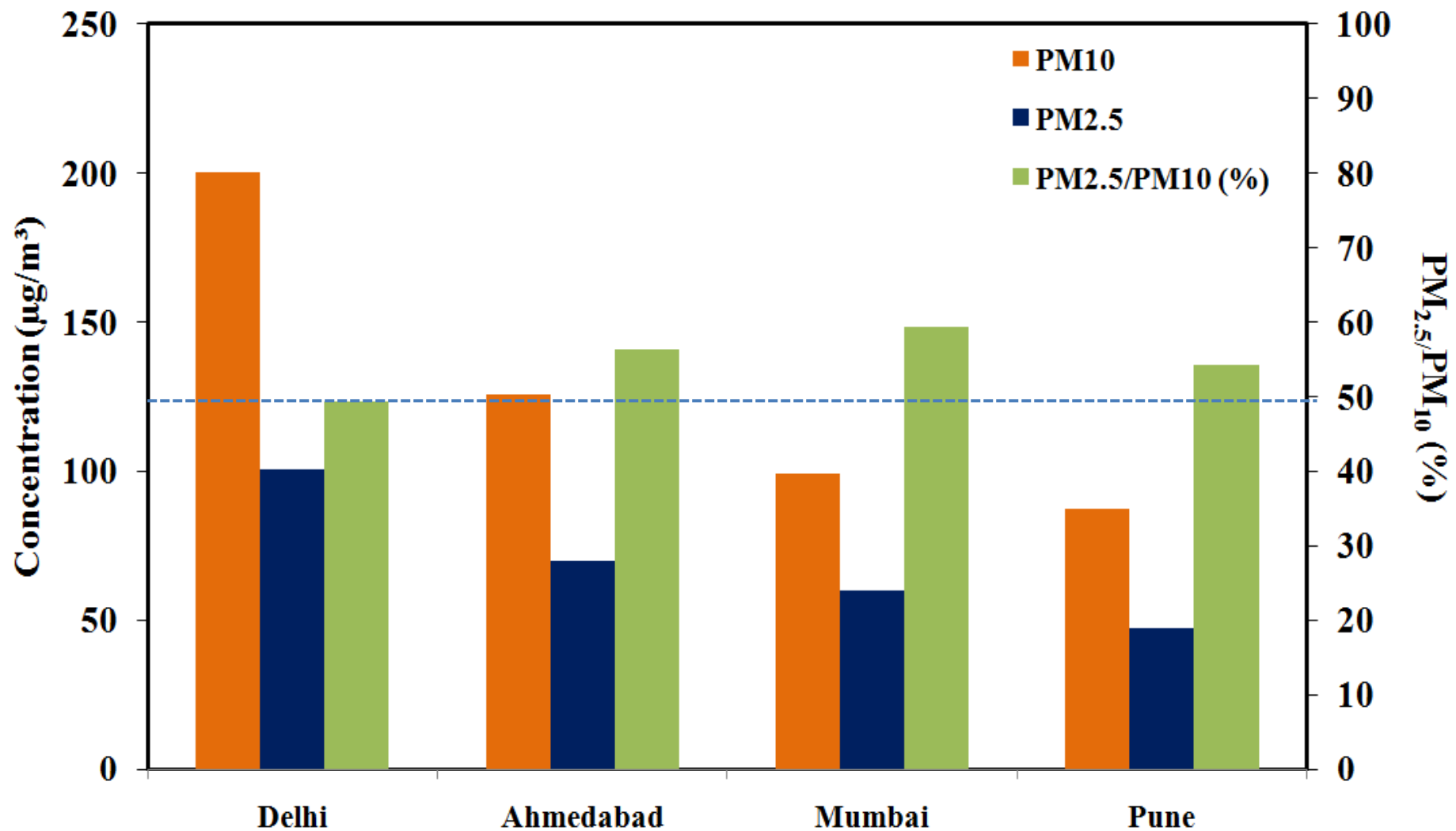
Composition of particle plays a critical role in Adverse Health Effect

$PM2.5 = 120 \mu g/m^3$ $=$ $PM2.5 = 150 \mu g/m^3$

Domain- 4 (1.67km)

Domain- 4 (1.67 km)

Mumbai, at times, more toxic than Delhi

Mumbai: BC composition is more in PM2.5 as compared to Delhi

WORKING TOWARDS TRUE HEALTH INDICATOR FOR SOCIETY
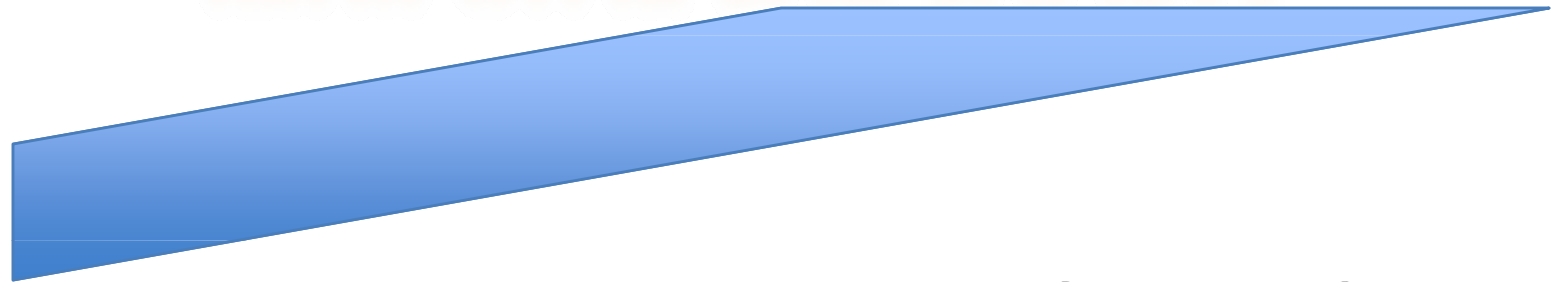
AQ-HEALTH INDEX (AQHI)
F (SIZE, VOLUME, TOXIN)

=

LEVEL OF POLLUTION
+ CHEMICAL CHARACTERIZATION

IMPACTS:
DALYs attributable to air pollution in India in 2017

DALYs-2017: AIR POLLUTION v/s TABACCO

Legend:
- Lower respiratory infections
- Chronic obstructive pulmonary disease
- Ischaemic heart disease
- Stroke
- Diabetes mellitus
- Lung cancer
- Cataract

Air pollution values: 821, 817, 667, 210, 194, 49, 43
Tobacco use values: 194, 574, 587, 190, 95, 62, 10

Y-axis: DALY rate per 100 000 population
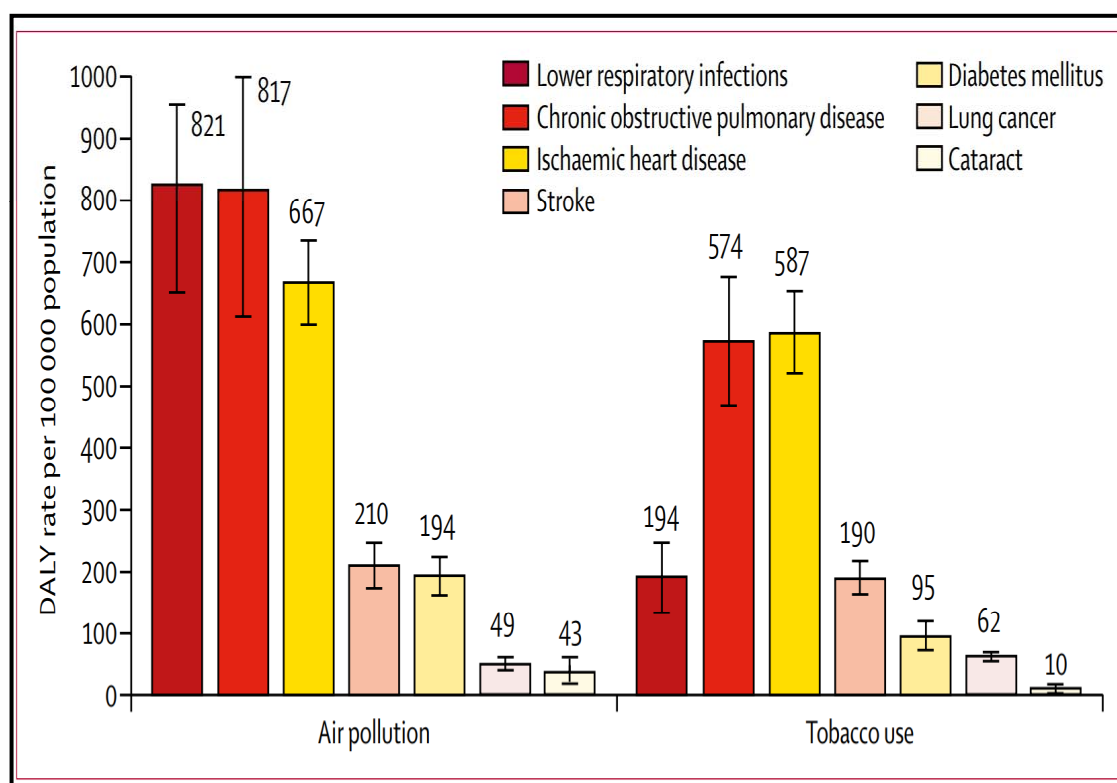
DALYs attributable to air pollution in India in 2017	
lower respiratory infections	29·3%
Chronic obstructive pulmonary disease	29·2%
Ischaemic heart disease	23·8%
Stroke	7·5%
Diabetes	6·9%
Lung cancer	1.8%
Cataract	1.5%

Balakrishnan, K., et al. (**Gufran Beig**, one of authors), *The Lancet*, Dec 2018. **(Impact Factor = 53)**

SAFAR
Air Quality System

HIGH RESOLUTION (0.4 X 0.4 km²) EMISSION INVENTORY of 8 POLLUTANTS FOR DELHI + FRINGE AREAS-2018

➢ **NUMBER OF POLLUTANTS = 8**
PM_{10}, $PM_{2.5}$, NOx, CO, SO_2, BC, OC, VOCs

➢ **Number of Volunteer: 140**

➢ **Number of hours of effort by Volunteers: ~39,500+ Hours**

➢ **Source Sectors covered: 26**
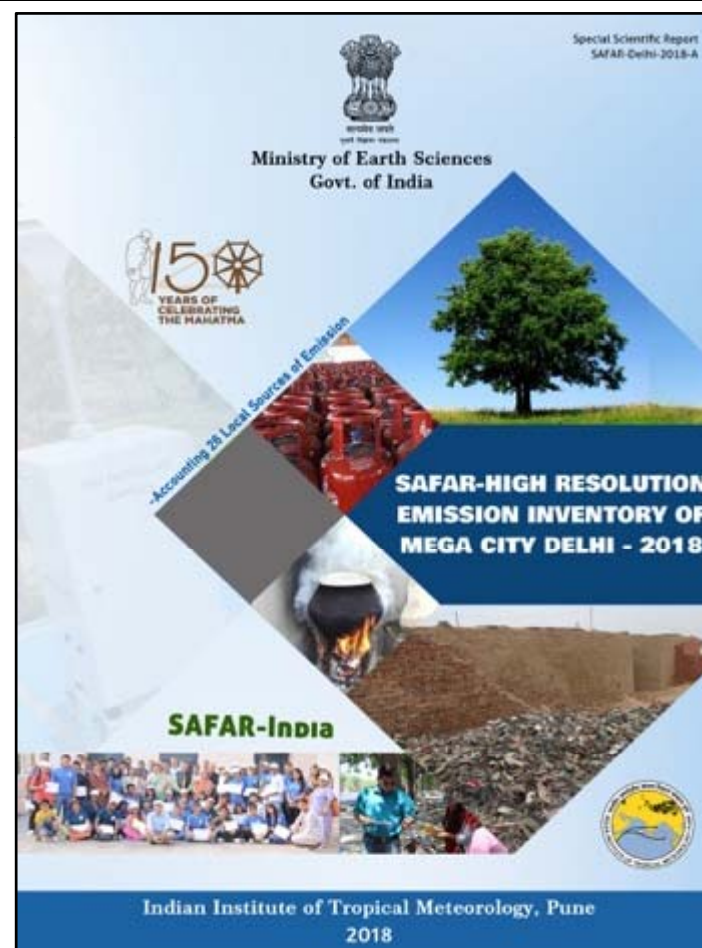
RELATIVE SOURCE SHARE AND GROWTH FROM 2010 TO 2018

SOURCE SECTORS	2018 Relative Share (70x65 km²) (%)	2010 Relative Share (70x65 km²) (%)	Growth /Decline in 2018 wrt 2010 (%)
Transport	39.1	32.1	+40 (Increase)
Industry	22.3	17.3	+48 (Increase)
Power	3.1	3.0	+16 (Increase)
Residential	5.7	18.5	-64 (Decline)
Suspended Dust	18.1	27.8	-26 (Decline)
Rest Others	11.7	1.3	Additional New

TOTAL (All Sectors) GROWTH in 2018 wrt 2010 (8 years) = +15%

8 Tons of Biomass (Tudi) + 5 tons of Rubber is being used as fuel to generate **1 lakh Bricks semi-ZIGZAG** technology as compared to 10 tons coal for producing same number of bricks.

New Initiatives: SAFAR-Modelling strategy for predicting air quality PAN-India

- **Set-up of Dust Model (WRF-Chem) with different Dust Schemes for large scale dust storm and transport to predict extreme events.**

- **Improvement of existing SAFAR-forecasting system for better predictability, particularly for air pollution emergencies (New emissions, assimilated satellite-ground data, stubble emission, boundary layer scheme) -CITY**

- **A moderate resolution air quality forecasting set-up for Indian Domain with 25x25 km^2 resolution and 2 nested domain set-up (National High resolution Emissions, MAPAN-Network) -INDIA**

- Develop the **coupled local-urban-regional modelling system** (street level modelling) for predicting high resolution concentrations of $PM_{2.5}$, PM_{10}, NO_2 with source attribution **–ADMS –STREET** (APHH)

SAHAS

Safar Air Health Alert System

"SAHAS engineers awareness drive by educating Public, Medicos and Executives paving path to develop mitigation strategies for NEW India"

साहस

स्वास्थ्य, वायु गुणवत्ता और मौसम
के लिए पुर्व चेतावनी प्रणाली

2. Public Awareness And Community Outreach

- AMC website updated with AQI and AIR Plan
- Information, education and communication (IEC) materials developed
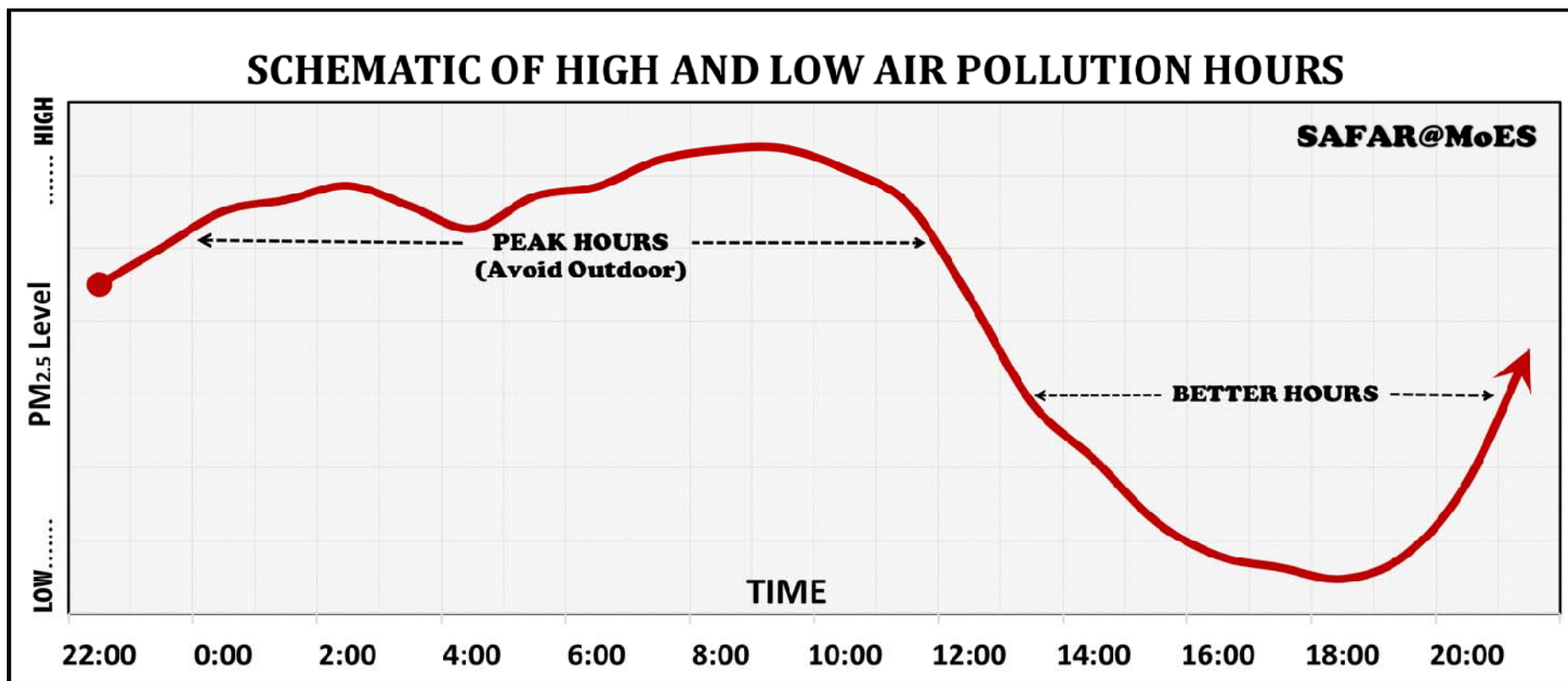- Media engaged on AQI and AIR plan

3. Focused Activities For Vulnerable Groups: School Flags Program

- Launched in June 2017
- SAFAR AQI data being communicated to schools daily – emails, WhatsApp
- IEC materials distributed to schools – more IECs to be designed
- Over 90 schools participating already

SCHOOL FLAG PROGRAM AWARENESS FOR STUDENTS

GOOD — AQI 0-100 : Great day for outdoor activity!

MODERATE — AQI 101-200 : Good day for outdoor activity!

POOR — AQI 201-300 : Okay to do outdoor activity, but not for longer periods

VERY POOR — AQI 301-400 : Avoid outdoor activity as much as possible

SEVERE — AQI 400-500 : It is best to stay indoors !

Things you can do

- Spread the word - tell your family members to be vigilant of the SAFAR Ahmedabad Air Quality Index (AQI)
- Encourage your friends and family to not burn trash or fire wood
- Ask drivers of buses and cars you travel in to turn off engines when they are not moving at traffic signals
- Watch for Symptoms - Coughing or shortness of breathe are signs to take it easier. Air pollution can make asthma symptoms worse and trigger attacks

INDIAN INSTITUTE OF PUBLIC HEALTH GANDHINAGAR

NRDC

Good

Moderate

Poor

Very Poor

Severe

SCHEMATIC OF HIGH AND LOW AIR POLLUTION HOURS

When the sun sets, additional heating and mixing stops, dooming everything in the lower atmosphere to stay there through the night. On the Diwali day, this means ~8pm mixing will stops. If there is firework, smoke will suddenly get trapped forcing overnight levels of particles and smoke in the air to make significantly higher than they would be naturally, and are stuck that way until sunrise or breeze mixes it away. Highest polluted hours in the night of 7-8 Nov will be "11PM to 4AM" –SAFAR-Advisory

Five Key SAHAS Components

Increase your Handprint !

Decrease your Footprint!

Thank You!!