Air Sensors International Conference

*Pushing Ahead: Application and Communication in Science*

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# Supplementing Air Pollution Data using Low-Cost Sensor Network – CSTEP Studies

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CSTEP Center for Study of Science, Technology & Policy

# Center for Study of Science, Technology & Policy

**MISSION:**
*To enrich policymaking with innovative approaches, using science and technology for a sustainable, secure, and inclusive society.*

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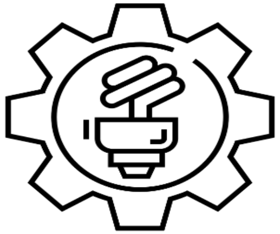
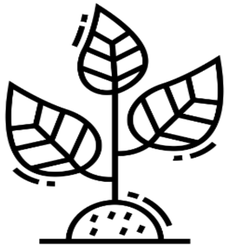
**Research Domains**



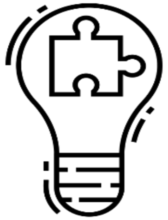
**Energy**



**Environment**

**Strategic Materials**

**Tech for Social Good**



**Computational Tools**

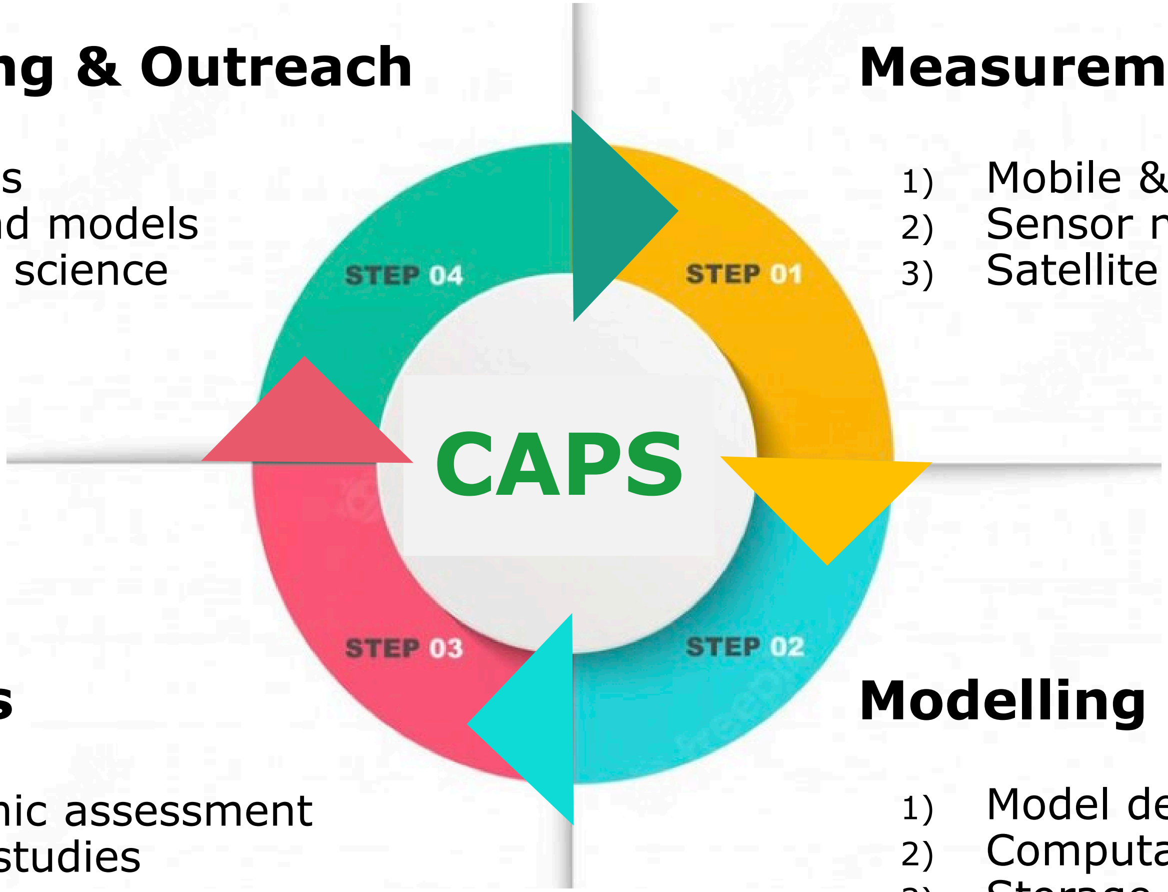
# Centre for Air Pollution Studies (CAPS)

### Capacity Building & Outreach

1) Scientific studies
2) Methodology and models
3) Communicating science

### Measurement & Monitoring

1) Mobile & Static measurements
2) Sensor network
3) Satellite measurements




### Policy Analyses

1) Techno-economic assessment
2) Health impact studies
3) Policy analysis

### Modelling & Analysis

1) Model development
2) Computational set-up
3) Storage facilities

# Monitoring scenario in India

Total number of cities in India: **~4,000**

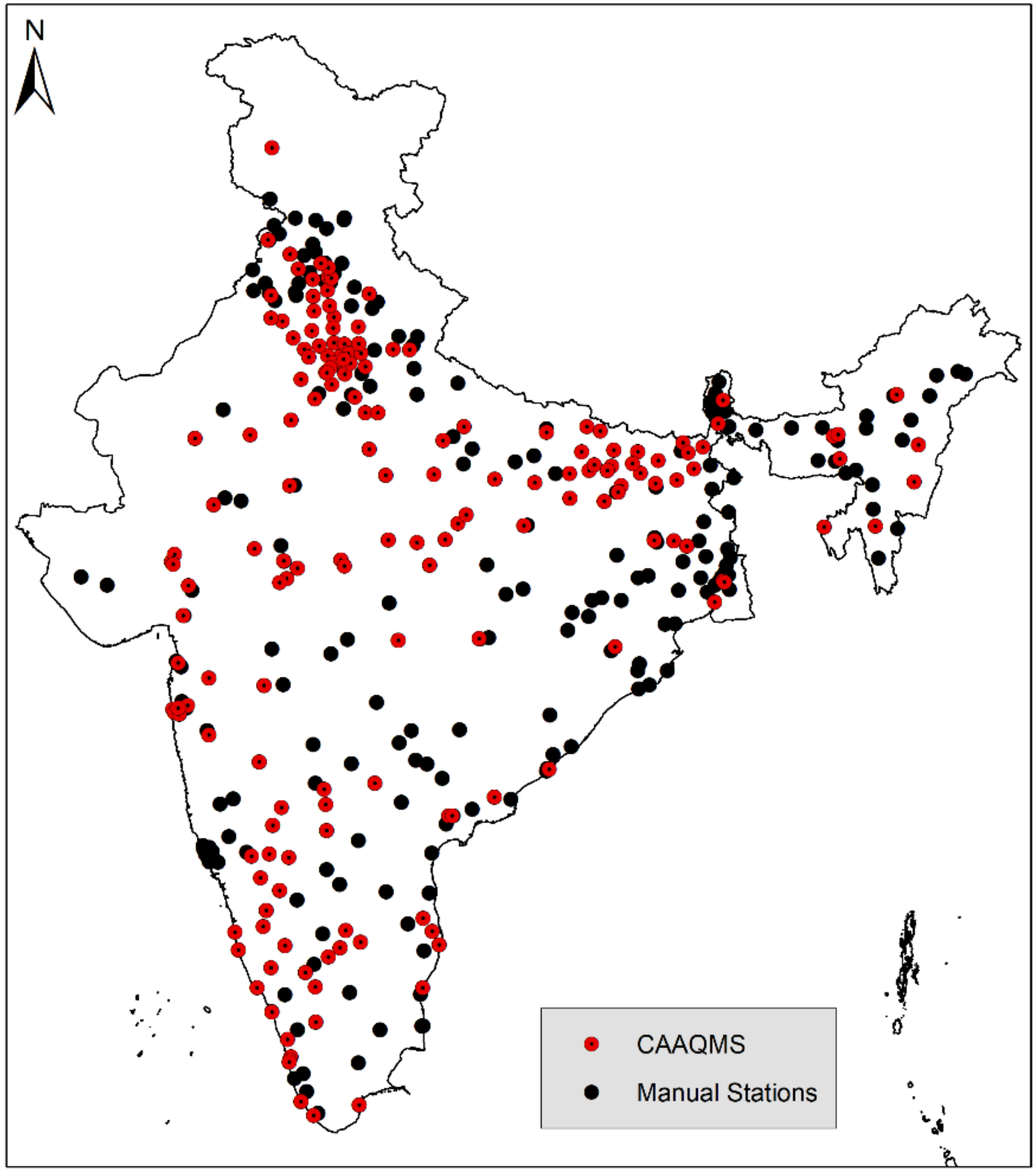
- 40 cities > 1m people
- 396 cities between 1L to 1m people
- 2500 cities between 1K to 1L people

CPCB Rule:

- <1L population: 4 continuous monitoring stations

Monitoring stations in India

- Manual stations: $PM_{10}$ (706) & $PM_{2.5}$ (263)
- Continuous stations: 349 covering 179 cities (31 states & UTs)
- More than 33% of real time monitors are concentrated in Delhi-National Capital

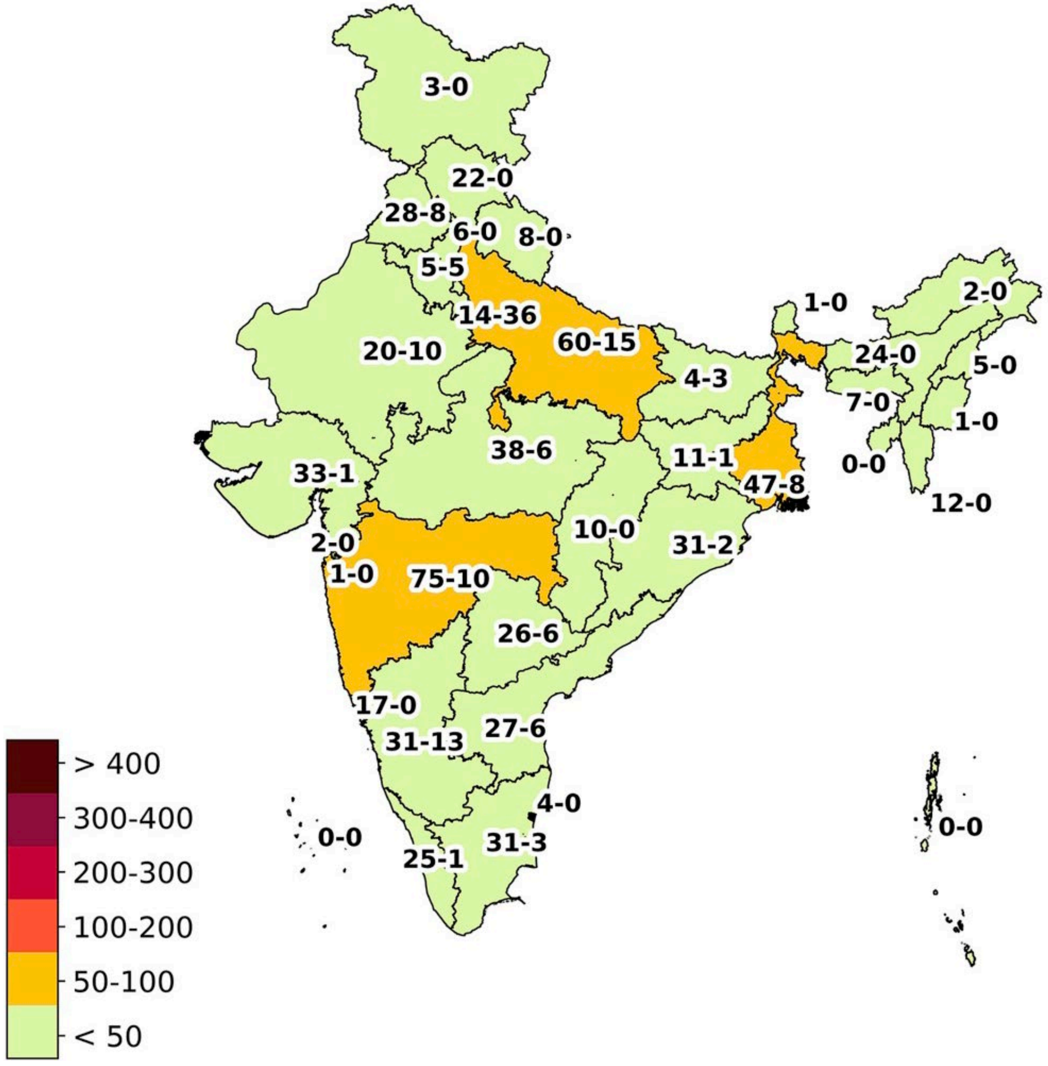



Monitoring stations status (Source: CPCB)

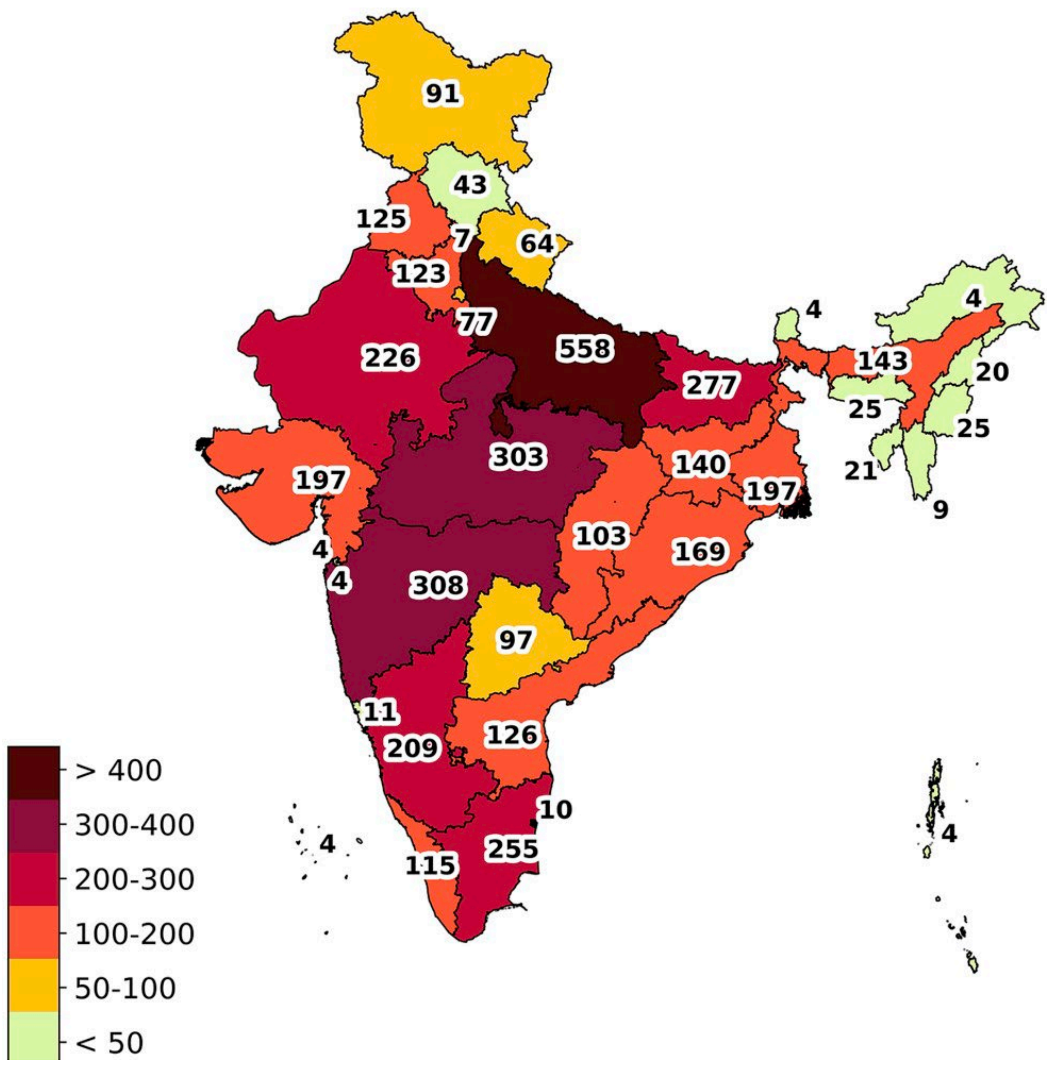
*Source: CPCB (2020)*

# Operating Vs Recommended Monitors

Number of operating (as of Nov 2018) in India (manual - continuous)




Number of recommended (PM) monitors



# Contd..

Monitor density (0.6 monitors/million persons) which falls behind that of most countries

Based on the CPCB monitoring targets (4 monitors per 100,000 persons), India falls short of the target by CPCB (Central Pollution Control Board, 2003).

A study estimated need for 4000 stations in India: 2800 in the urban areas and 1200 in the rural areas.

Currently India has a similar monitor density (0.2–0.6 monitors/million persons) to that of the relatively low PM2.5 exposure setting of Japan, but lags well behind of all the comparator countries.

India’s current inadequate air quality monitoring network if had to meet monitor density to that of China would require a substantial investment (capital + maintenance)

# Necessity of Low-Cost Sensors

Supplementing traditional air quality monitoring network with improved spatial resolution and greater coverage

Opportunities for improved understanding of spatial and temporal patterns in air quality

Potential to provide, at comparatively low cost, continuous measurements of air quality everywhere throughout an urban area

Understanding local hotspots and impacts of episodic sources, when government measurement data have been unavailable, or considered unreliable

Informing placement of additional monitors

Given the affordability, portability, and ease of installation, LCSs can help give air quality information in areas with no monitoring.

Bridging the data gaps

Local sources: waste burning

# Hybrid monitoring approach for India

A combination of monitoring approaches can inform a robust AQ management

**LCS** can be used as a supplement for on-ground measurement

**Remote sensing** based AQ information is critical especially in locations without any ground monitors

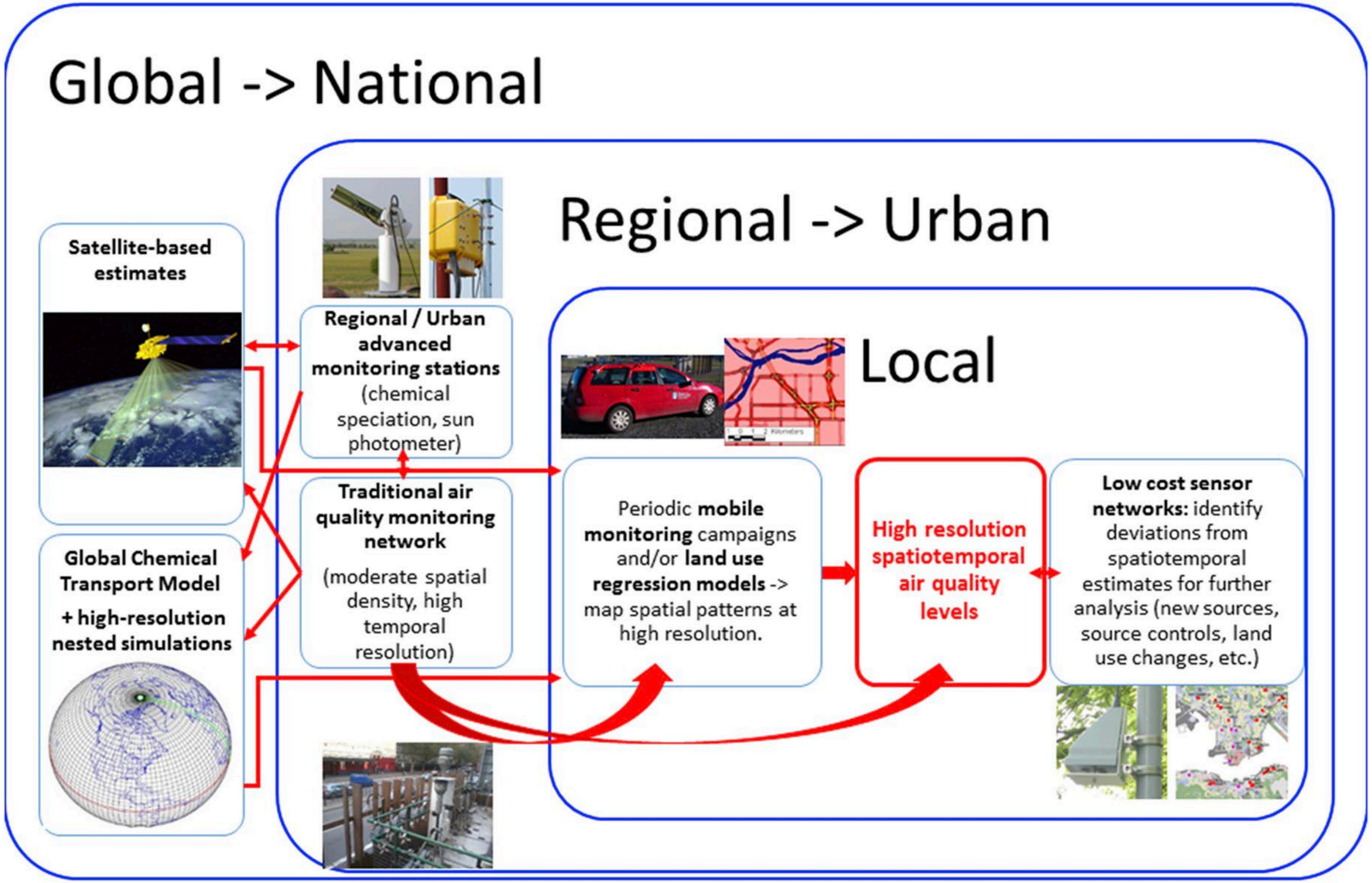
**Mobile measurements** to assess on-road exposure

**Reduced complexity models** can give hyper local data required for understanding the hotspots


Affordable sensor

CNG based mobile monitoring vehicle

# Hybrid measurements

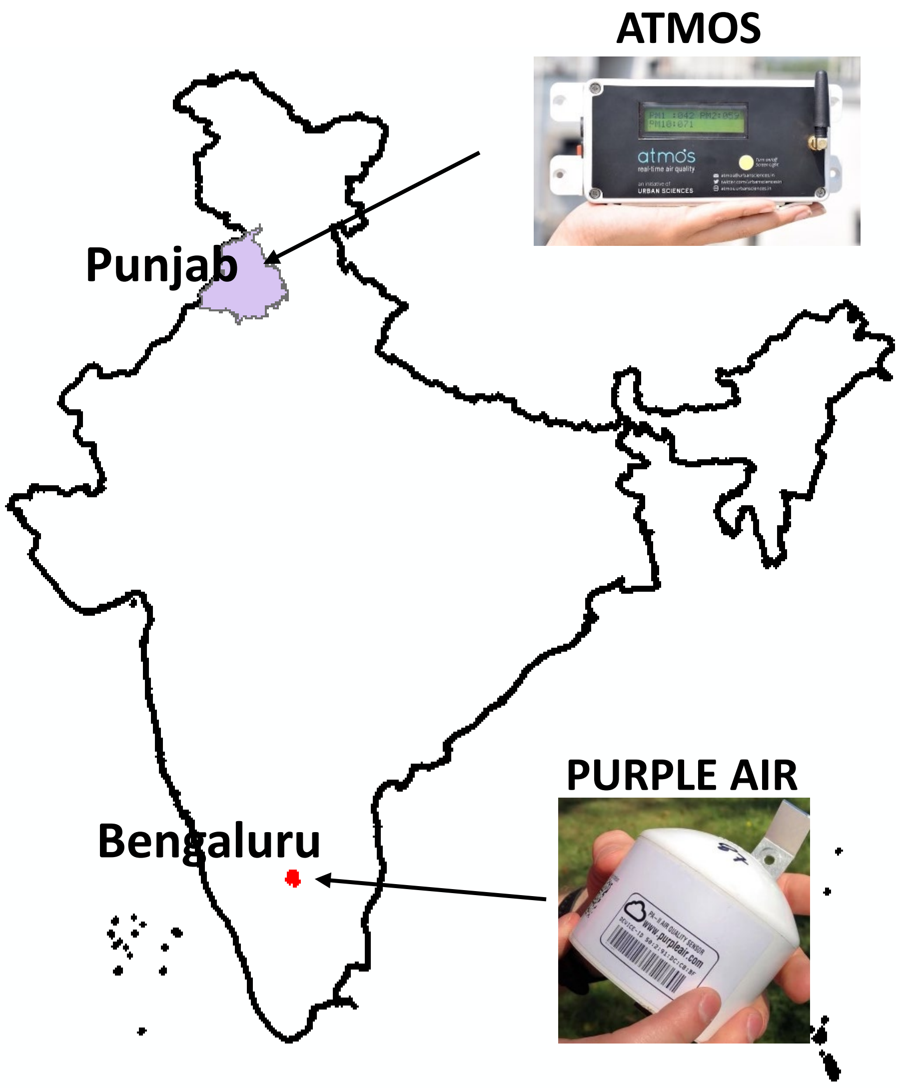



Source: Brauer et al 2021

# CSTEP's work using LCS

# LCS Network by CSTEP

- Network in Punjab state & Bengaluru city
- Punjab - 45 ATMOS sensors
- Bengaluru - 50 PURPLE AIR sensors
- Contrasting geographies – Punjab lies in the IGP & Bangalore has varying altitude and temperature variation



# Objectives

## Punjab study:

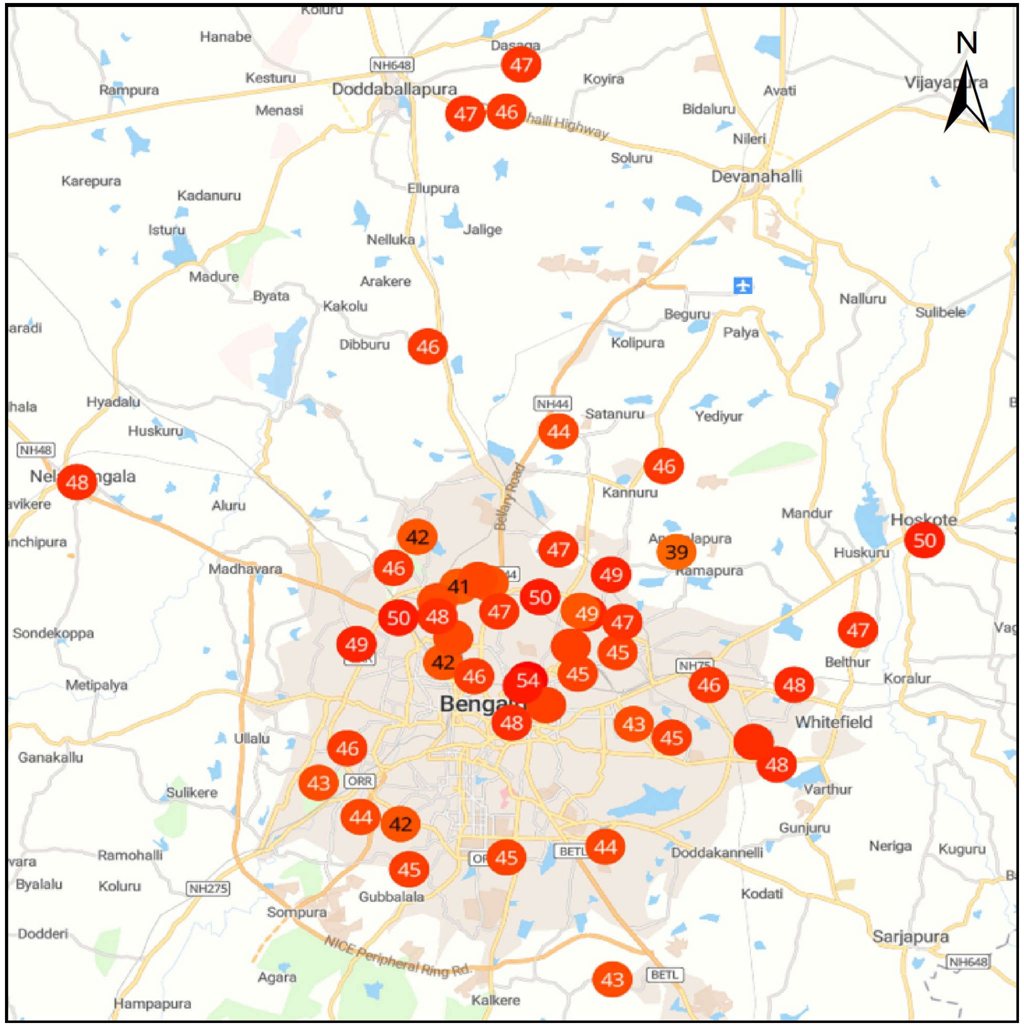
- Measure spread of pollutants by conducting both ambient and indoor measurements
- Exposure due to various sectors – Transportation, Industries and Stubble burning

## Bengaluru study:

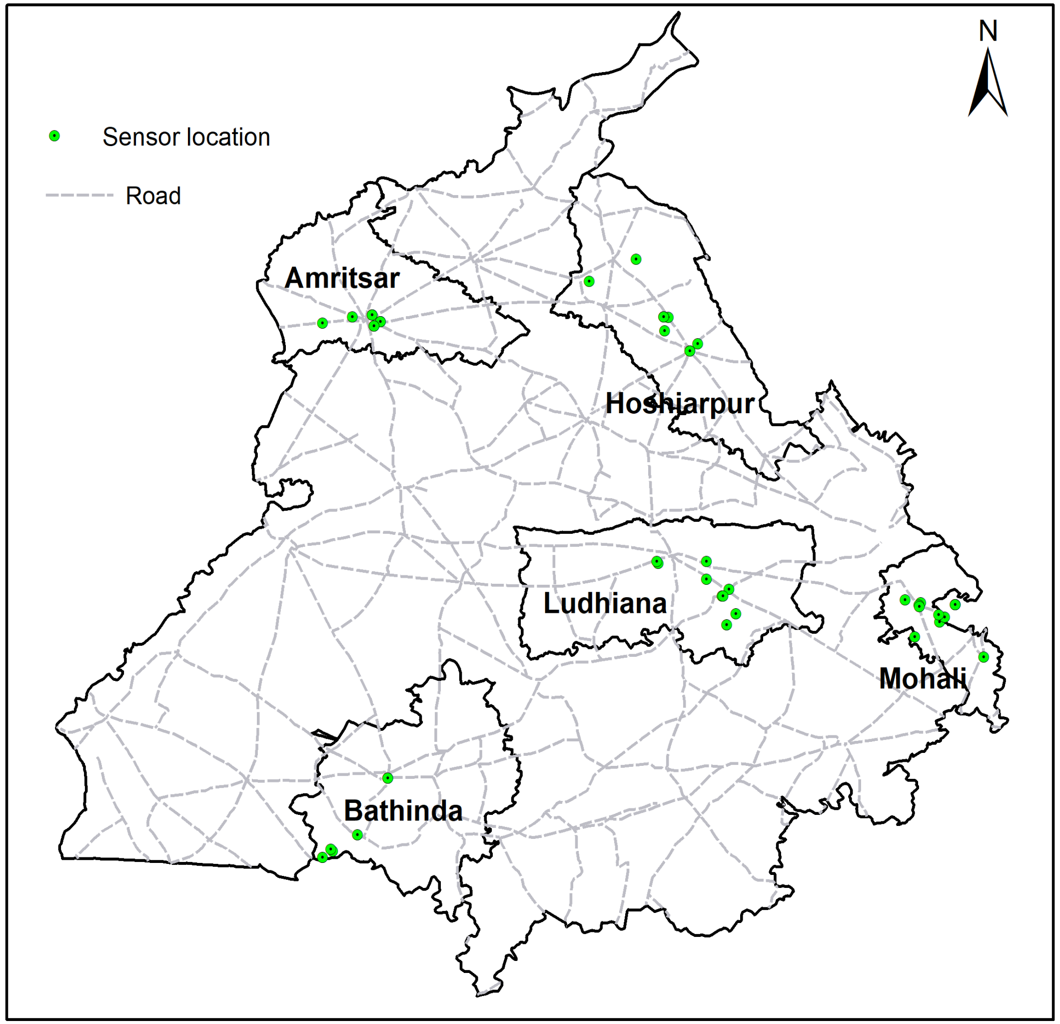
- Deploying dense network of low-cost sensors in the district
- Comparing various types of sensors
- High resolution (100 × 100 m) PM2.5 map using statistical models
- Urban and Sub-urban measurements

# Distribution of Sensors

## Bangalore City



## Punjab State



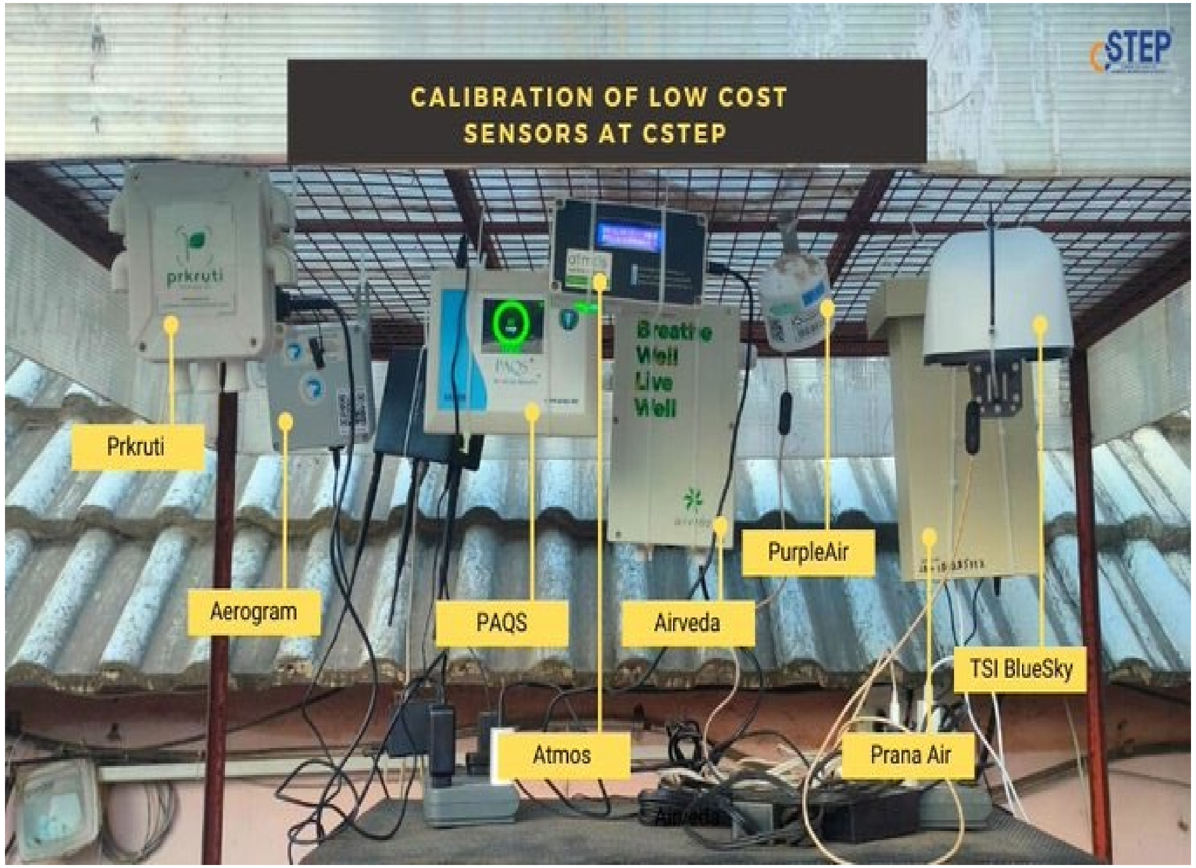
# Bangalore Study

First of its kind study in India - comparison of various sensor models carried out

The calibration of all the sensors was performed using BAM

The calibration was performed to check the precision and accuracy of the sensors against BAM and among themselves

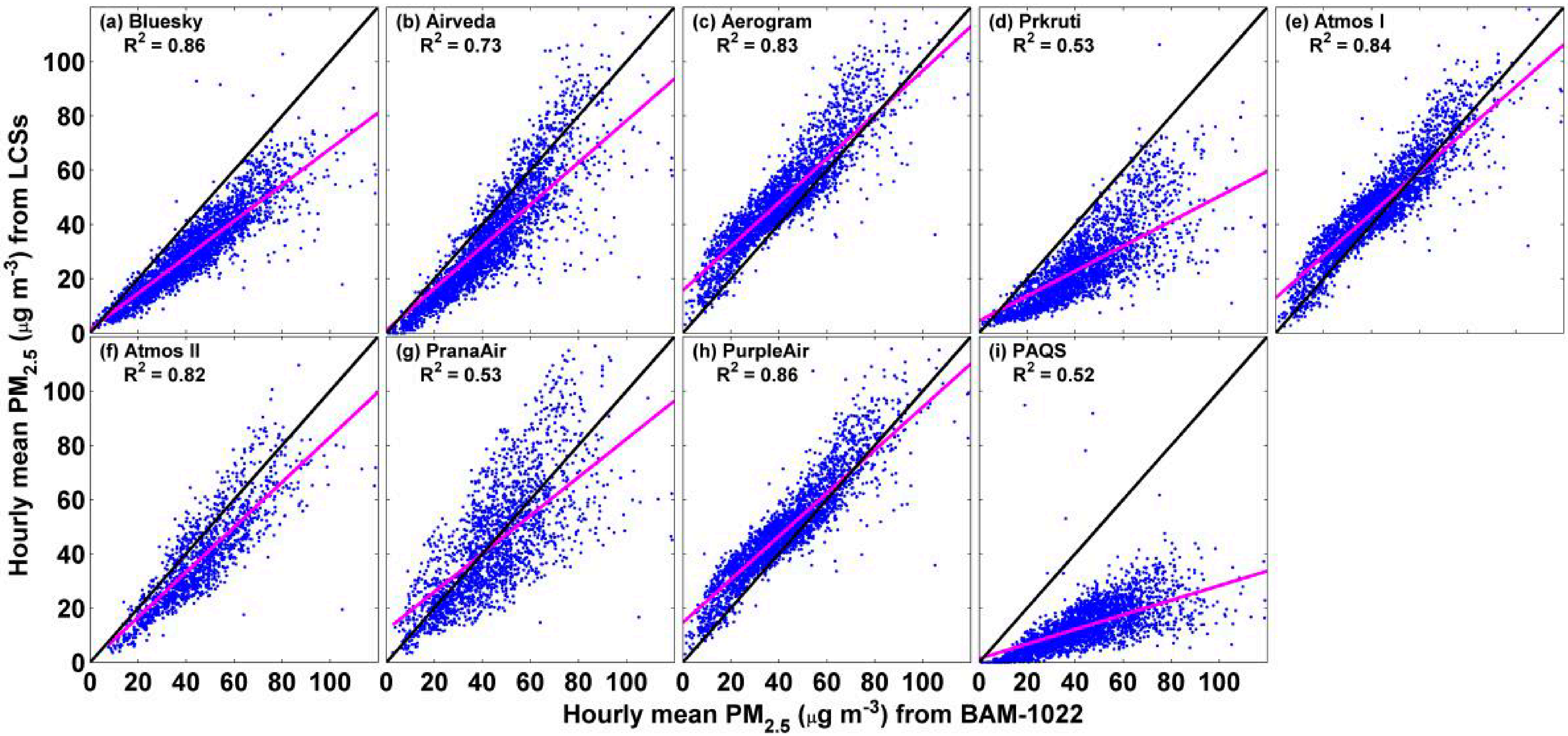
$PM_{2.5}$ from the sensors showed linearity in the data




*Collocated low-Cost Sensors in Bengaluru*

# BAM-1022 & LCSs Scatter Plots

**Black & pink lines denote the 1:1 & least square linear fit, respectively**



# Performance of different LCSs

- Nine different sensors were collocated with BAM & the performance of each sensor was evaluated
- Accuracy varied across all the sensors – most underestimated while few overestimated
- Compared to the reference grade instrument, the LCSs used in the study exhibited bias. Therefore, LCSs measurements need corrections

| Sensor | n | Slope | Intercept | $R^2$ | MAB ($\mu g\ m^{-3}$) | RMSE ($\mu g\ m^{-3}$) | NRMSE |
|---|---|---|---|---|---|---|---|
| BlueSky | 2880 | 0.66 | 1.39 | 0.86 | 13.6 | 16.9 | 0.38 |
| Airveda | 2891 | 0.77 | 1.07 | 0.73 | 10.7 | 15.3 | 0.35 |
| Aerogram | 2837 | 0.81 | 15.67 | 0.83 | 9.2 | 12.4 | 0.28 |
| Prkruti | 2582 | 0.46 | 4.51 | 0.53 | 18.6 | 24.5 | 0.58 |
| Atmos I | 2897 | 0.78 | 12.95 | 0.84 | 6.9 | 10.3 | 0.24 |
| Atmos II | 1387 | 0.83 | 0.06 | 0.82 | 10.0 | 12.5 | 0.27 |
| Prana Air | 2046 | 0.70 | 11.95 | 0.53 | 11.7 | 16.6 | 0.37 |
| PurpleAir (cf_atm) | 2836 | 0.80 | 14.65 | 0.86 | 7.9 | 10.9 | 0.25 |
| PAQS | 2880 | 0.27 | 1.39 | 0.52 | 30.8 | 35.9 | 0.82 |

*Performance metrics of LCS $PM_{2.5}$ (n represents number of paired data points)*

# Challenges and Way-forward

## Challenges

- Installation and implementation of the sensor monitors is huge challenge
- Need to develop suitable calibration model for various types of sensors

## Way-forward

- Bridging the gap due to reference grade monitors
- Understanding the local and regional challenges
- Understanding the rural/sub-urban impact

# Thank you

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