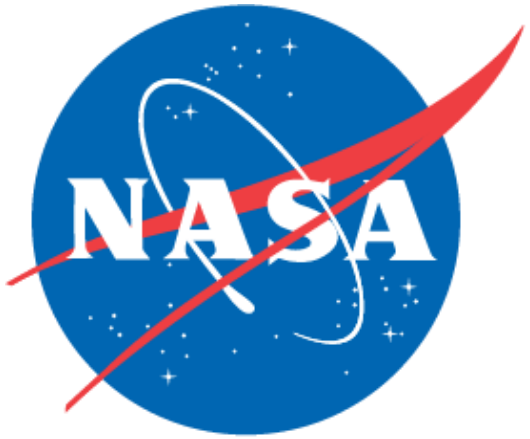


HEALTH & AIR QUALITY

EARTH SCIENCE
APPLIED SCIENCES

Enhancing air quality decision-making activity in Indian megacities through assimilation of NASA Earth observations and development of a decision support system

Rajesh Kumar

23 April 2024

E-mail: rkumar@ucar.edu

Project Partners/Collaborators

EARTH SCIENCE
APPLIED SCIENCES

Role	Name	Affiliation	Organization Type
Co-I	John Schreck	NSF NCAR	FFRDC
Co-I	Gabriele Pfister	NSF NCAR	FFRDC
Co-I	David Edwards	NSF NCAR	FFRDC
Co-I	Scott Meech	NSF NCAR	FFRDC
Collaborator	Sachin Ghude	IITM	Government organization
Collaborator	Vijay Soni	IMD	Government organization
Collaborator	Helen Worden	NSF NCAR	FFRDC
Collaborator	Alexander Baklanov	WMO	United Nations
Collaborator	Prafull Yadav	IITM	Government organization
Collaborator	Gaurav Govardhan	IITM	Government organization
Collaborator	Rajmal Jat	IITM	Government organization

NSF NCAR: National Science Foundation (NSF) National Center for Atmospheric Research (NCAR);
IITM: Indian Institute of Tropical Meteorology
IMD: India Meteorological Department; WMO: World Meteorological Organization

E-mail: rkumar@ucar.edu

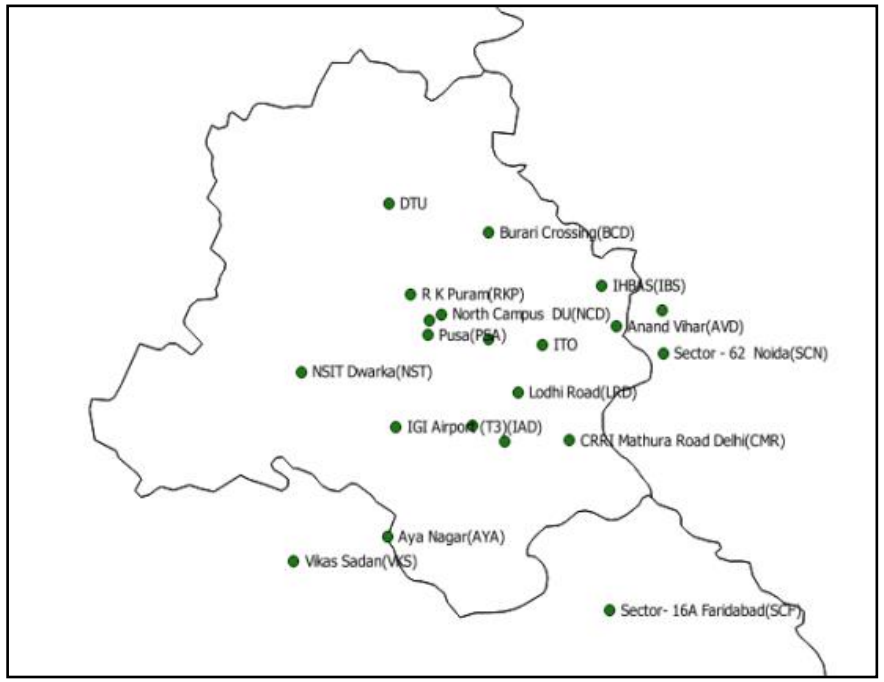
Air Pollution has become a severe issue in New Delhi

- Indian medical association declared a public health emergency and called conditions equivalent to smoking 50 cigarettes a day.
- Delhi Chief Minister called the city a “Gas-chamber”!
- Maximum $PM_{2.5}$ concentration on 08 Nov 2017 reached 1500 $\mu g/m^3$. WHO air quality guideline for 24-h average is 15 $\mu g/m^3$.
- A person on an average loses ~6.5 years of their life due to exposure to air pollution in Delhi.

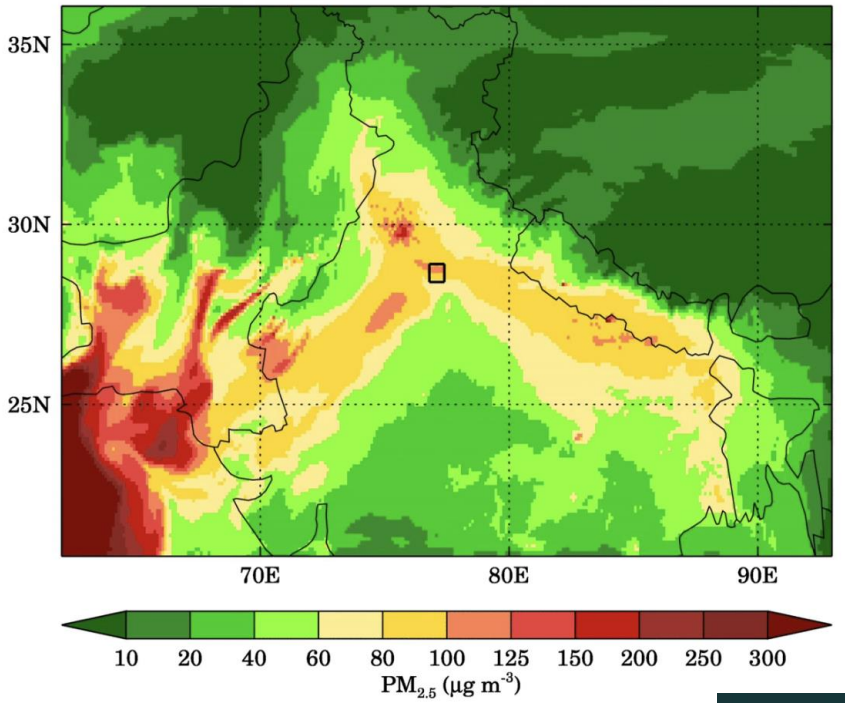
E-mail: rkumar@ucar.edu

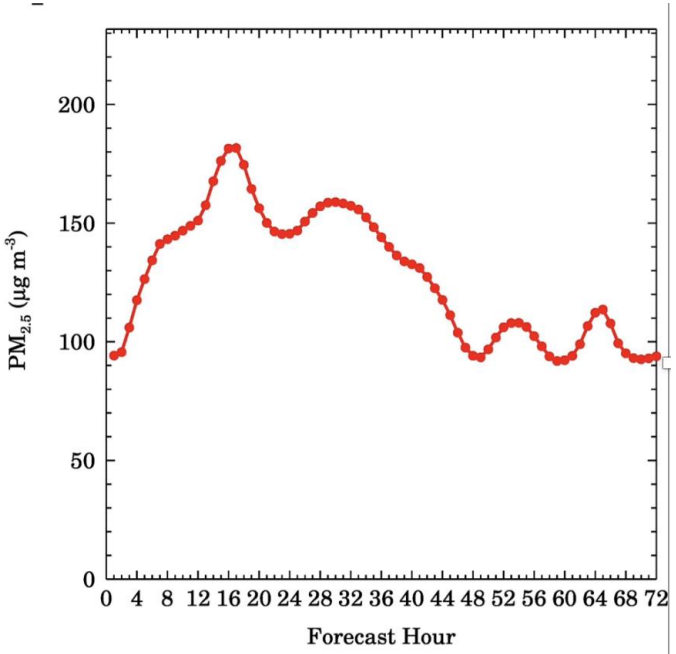
Government (Ministry of Earth Sciences), India Initiatives

Air Quality Monitoring Network (Delhi-NCR)



Air Quality Forecasts





Information Dissemination:

Digital boards

SMS

Mobile Apps

Websites

E-mail: rkumar@ucar.edu

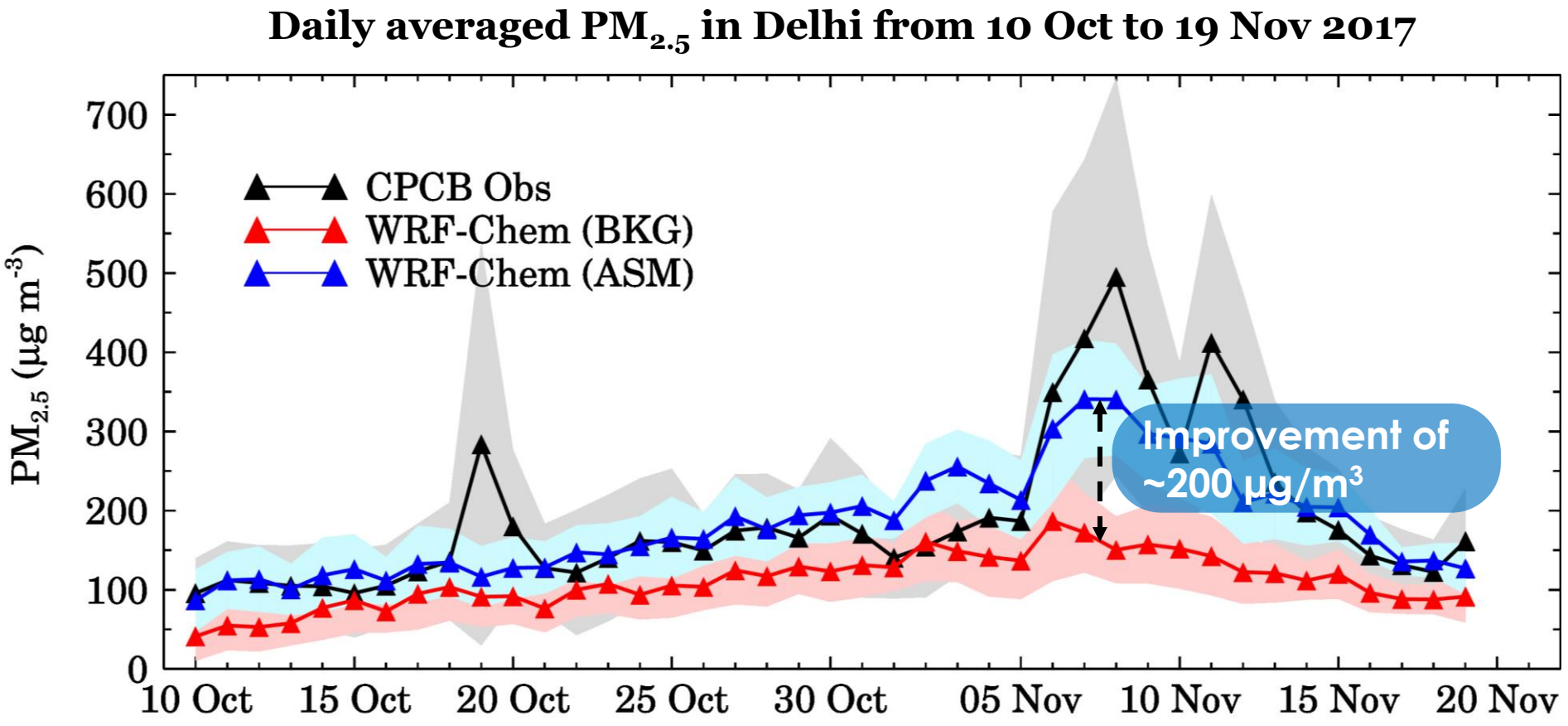
Earth Observations, Models, and/or Technologies

Satellite Sensor/Model/Tech.	Product Used	Temporal Coverage and Latency required	Comments
MODIS Terra	NRT Level 2 AOD	Daily, latency: 3-hours	Currently assimilated
MODIS Aqua	NRT Level 2 AOD	Daily, latency: 3-hours	Currently assimilated
VIIRS	NRT Level 2 AOD	Daily, latency: 6-hours	Assimilation tested
TROPOMI	NRT Level 2 CO	Daily, latency: 3-hours	To be assimilated
Surface observations	PM2.5 and PM10	Hourly; latency: 1-hour	NRT evaluation and assimilation in 400 m domain
WRF-Chem	Air quality simulations	Daily, 72-h forecasts	Operational air quality forecasting model

Delayed availability of VIIRS AOD retrievals can delay the forecasts!

E-mail: rkumar@ucar.edu

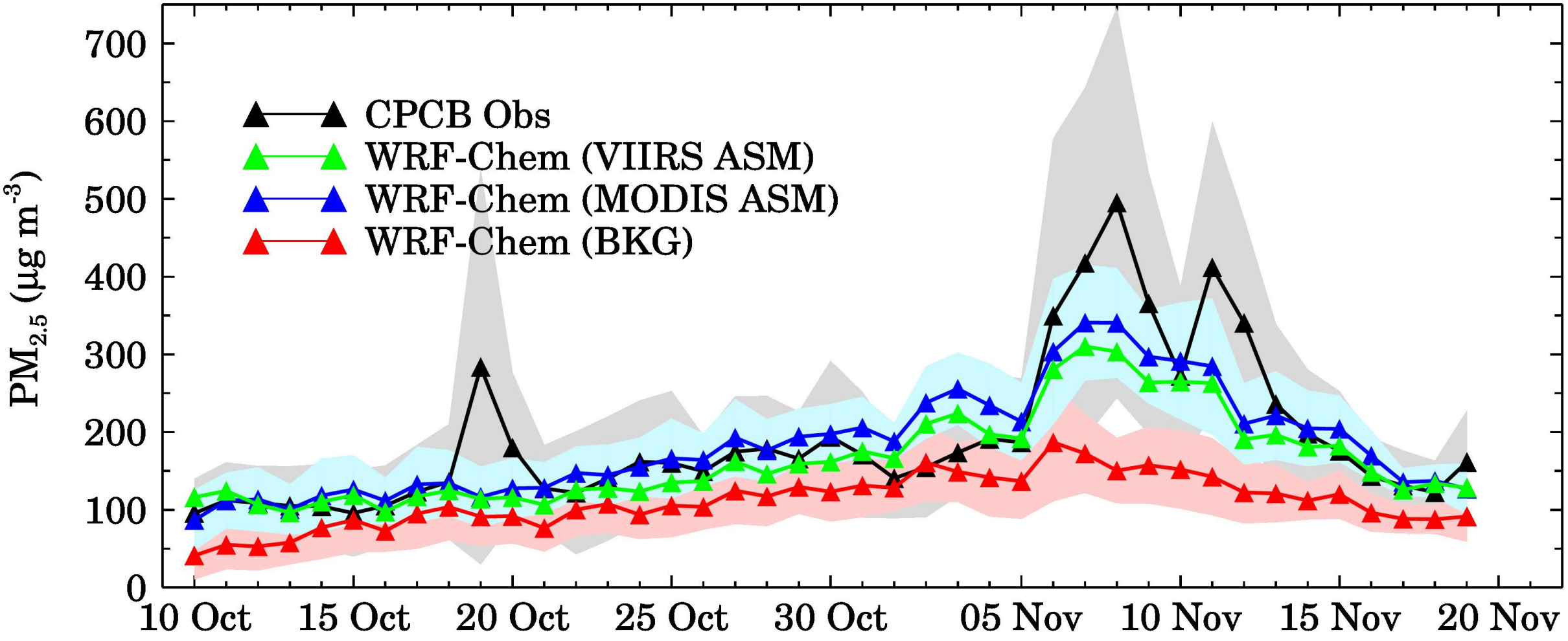
Improvements in daily average $PM_{2.5}$ Forecasts



Mean bias reduction over the entire period: 86% [Kumar et al., 2020]

E-mail: rkumar@ucar.edu

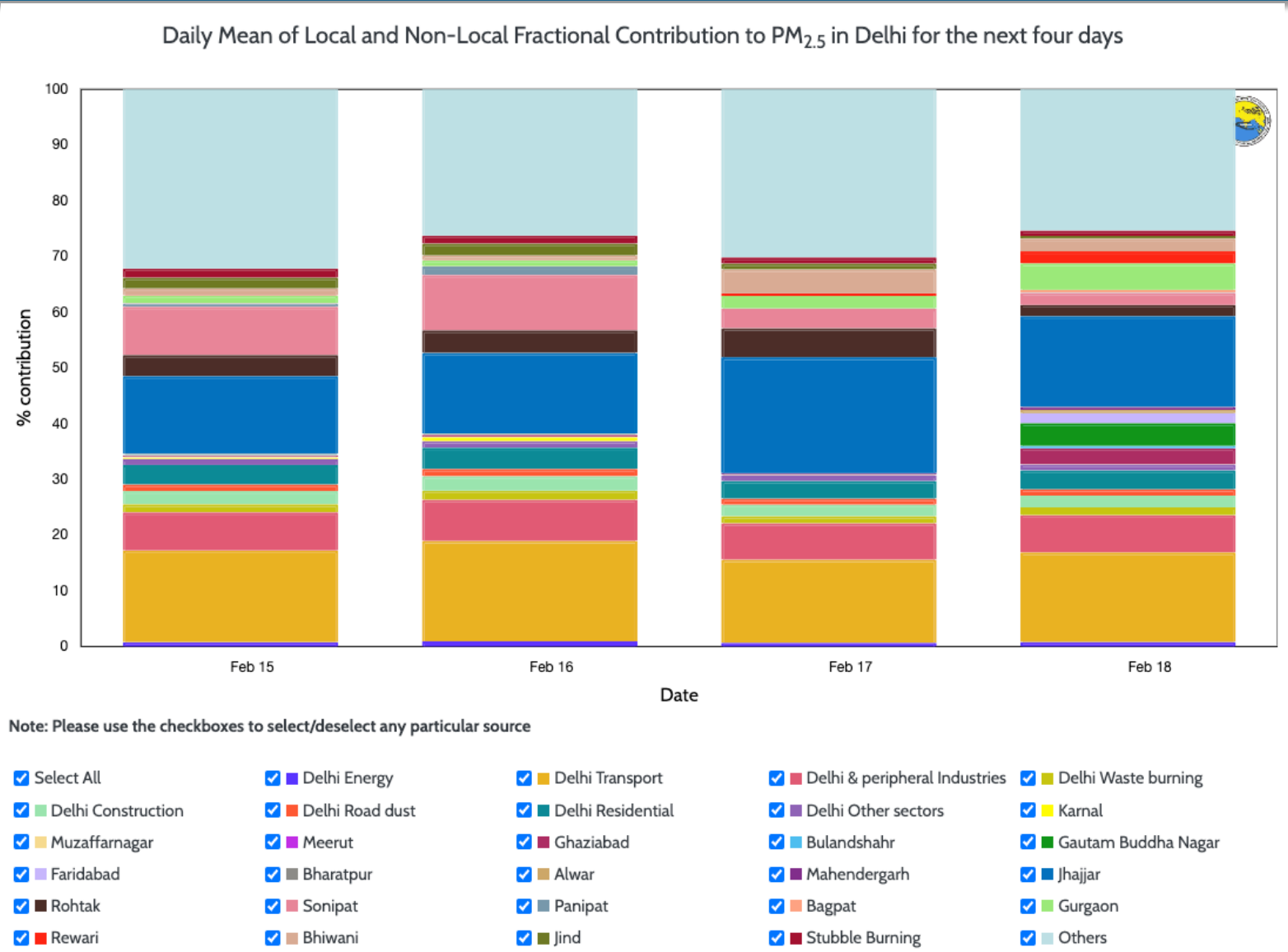
Impact of assimilating VIIRS AOD retrievals



Assimilating VIIRS AOD provides nearly the same benefit as MODIS AOD assimilation.

E-mail: rkumar@ucar.edu

Prediction of source attribution information (15-18 Feb 2024)

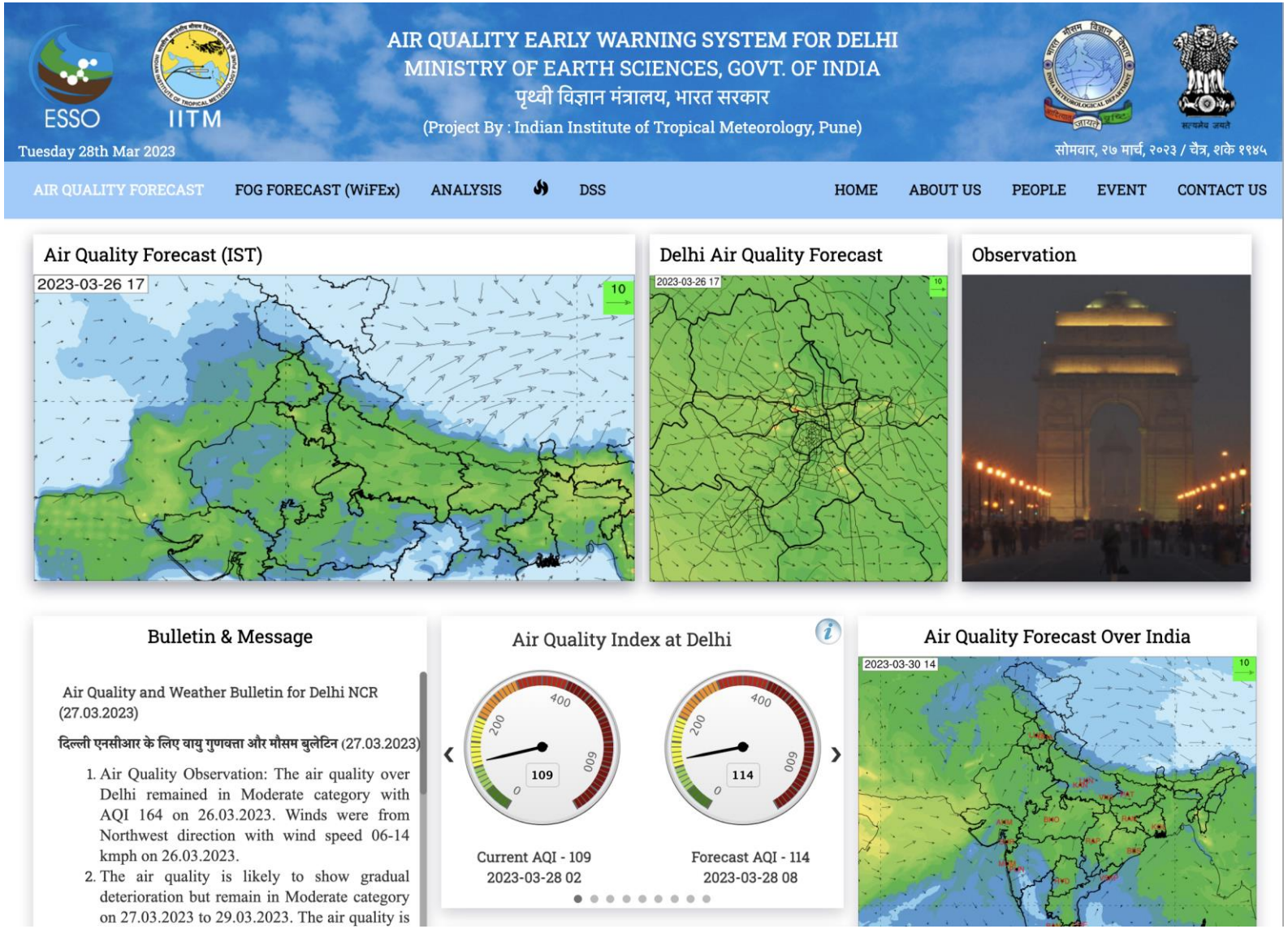


Predicting source attribution information was the identified decision-making at the beginning of this project.

[Govardhan et al., GMD, 2024]

E-mail: rkumar@ucar.edu

Information Dissemination (https://ews.tropmet.res.in/)



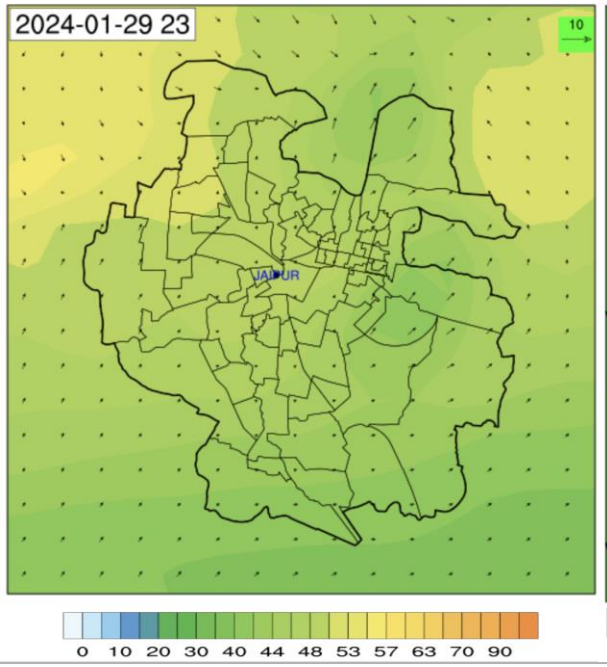
- A new website has been developed to disseminate these air quality information (both observations and forecasts) to the public.
- This website has been launched by the Ministry of Earth Sciences.
- The website also provides information about fog forecasts.

E-mail: rkumar@ucar.edu

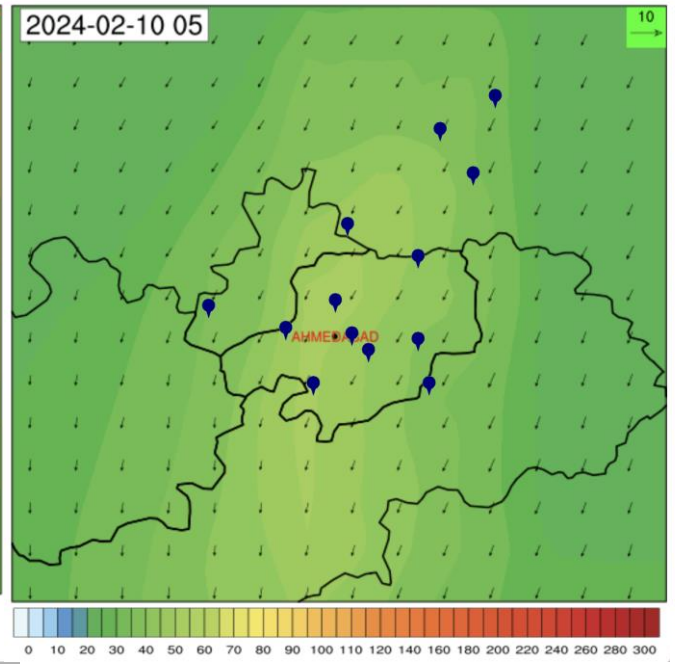
AQEWS for Mumbai, Jaipur, Pune, and Ahmedabad

- In addition to Delhi air quality forecasts, we have started providing air quality forecasts at 2 km resolution for Mumbai, Jaipur, Pune, and Ahmedabad.
- High-resolution (2 km) emission inventories developed by our end-user organization (IITM) are integrated into these forecasts. A 72-h forecast is being generated every day.

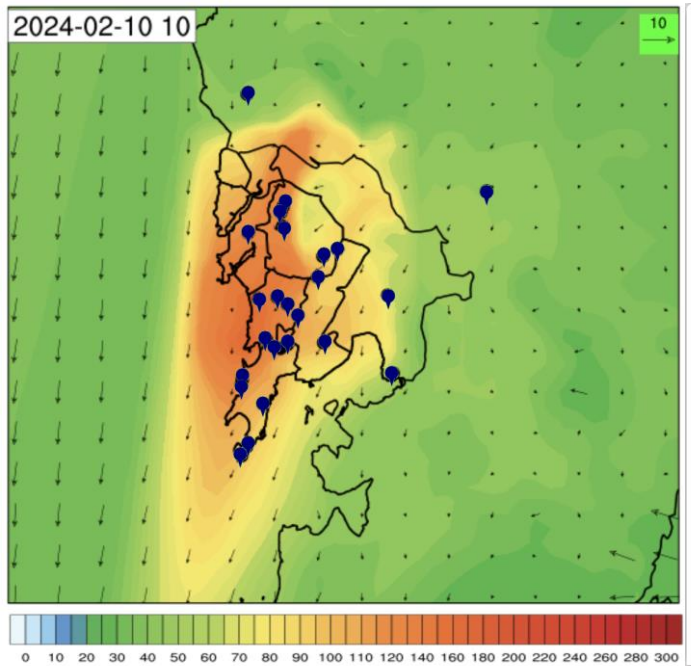
PM2.5 forecast (Jaipur)



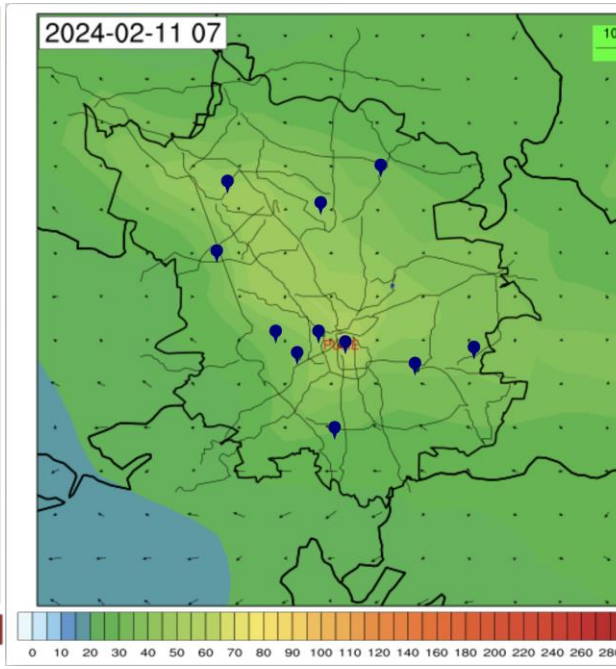
PM2.5 forecast (Ahmedabad)



PM2.5 forecast (Mumbai)



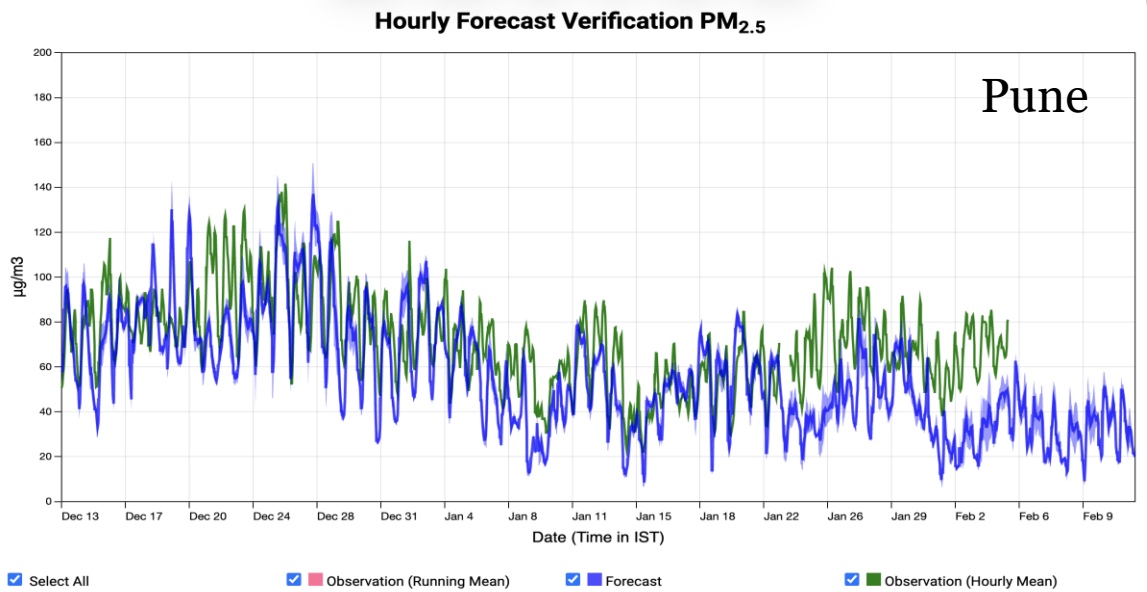
PM2.5 forecast (Pune)

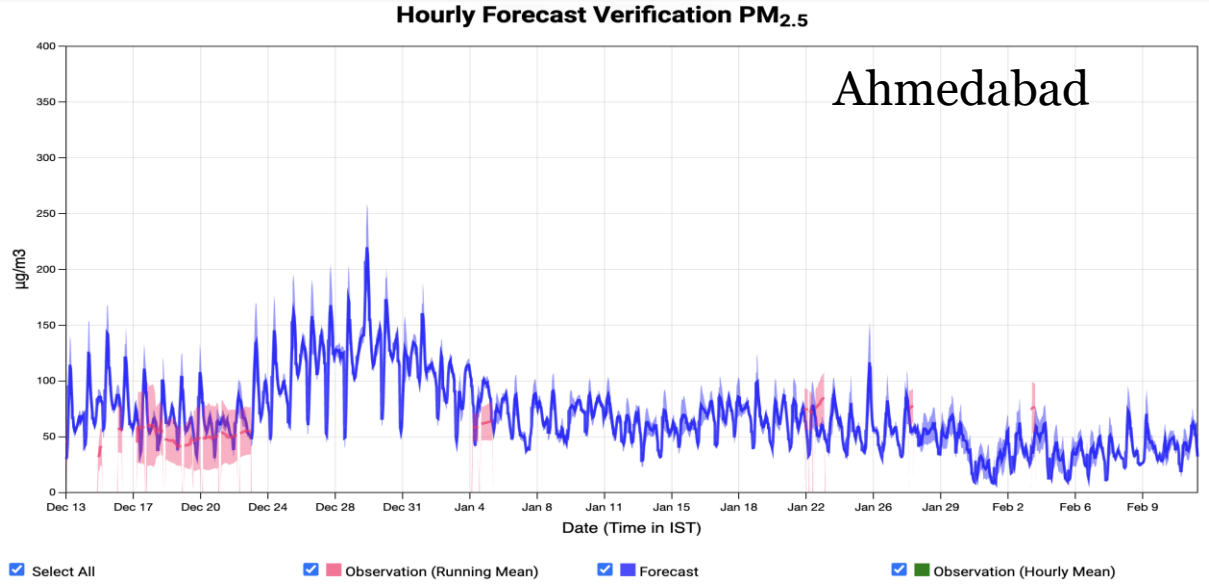


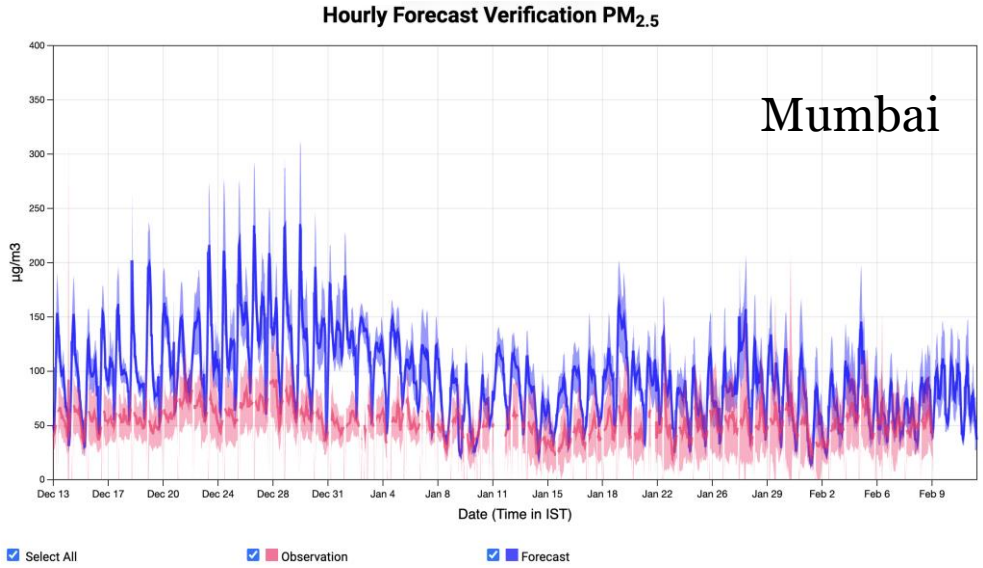
Pins show the location of observation sites in each city. An observation network is being implemented in Jaipur.

E-mail: rkumar@ucar.edu

NRT evaluation in other cities







E-mail: rkumar@ucar.edu

Project End-users & Stakeholders

List organization names and organization types

Organization Name	Organization Type	Decision Making Activity
IITM	Government	Produces operational air quality forecasts for use by the IMD to generate air quality bulletins
IMD	Government	Generates air quality bulletins including information about potential emission mitigation scenarios
Commission for Air Quality Management	Policy-making	Uses the information from air quality forecasts to determine when to activate and enforce temporary emissions control measures

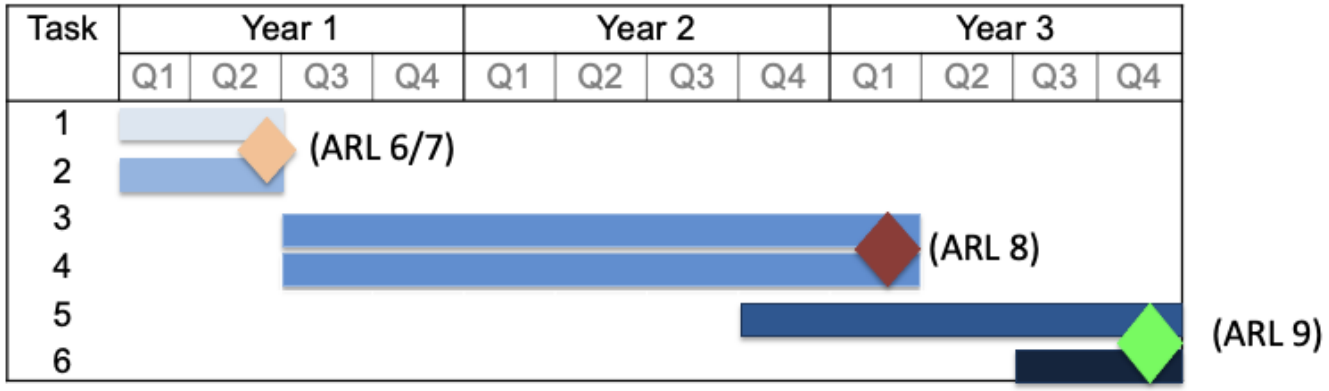
Stakeholder engagement

- I meet with IITM team every week.
- Sachin Ghude (IITM) visited NSF NCAR from 14 Feb – 10 Mar 2023 to work on our project activities.
- Prafull Yadav (IITM) will be visiting from 01 May – 01 July 2024 to transition VIIRS assimilation capability to IITM.

E-mail: rkumar@ucar.edu

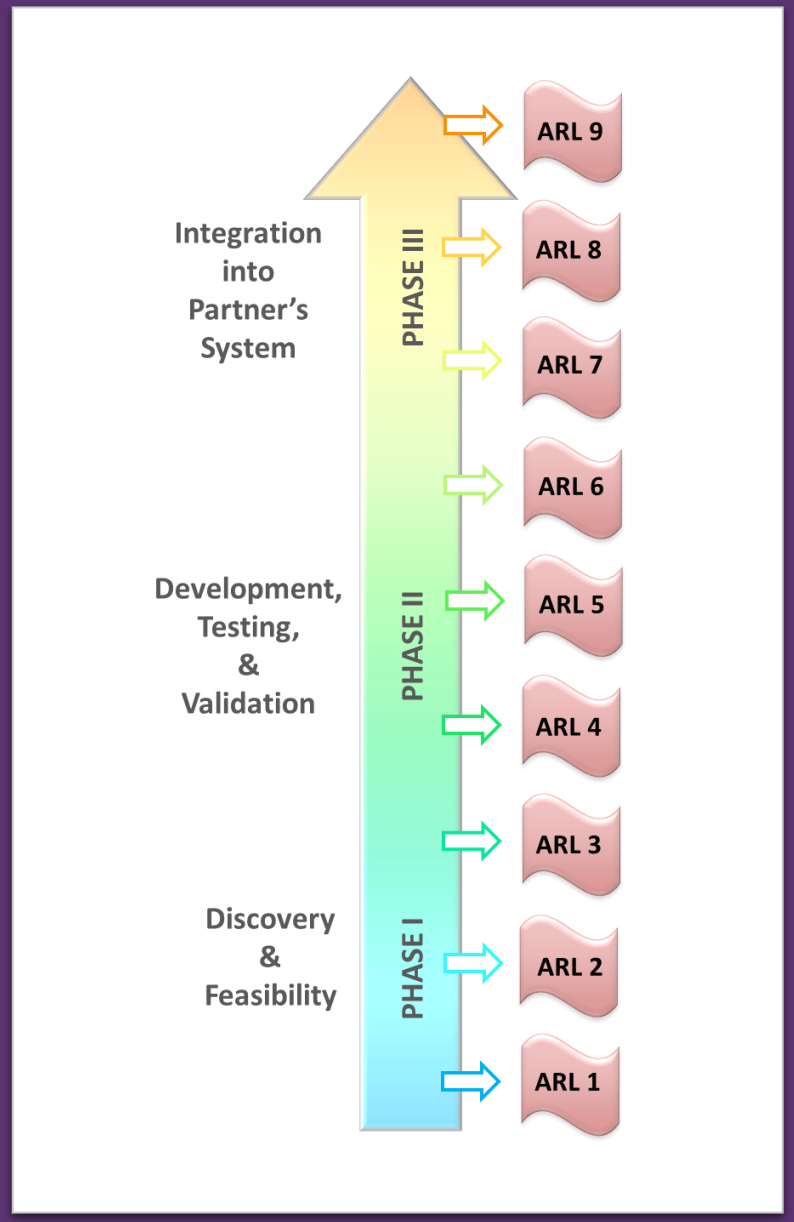
Schedule & Milestones

Task #	Description	Status
1	Set-up air quality forecasting system	Completed
2	Set-up Chemical data assimilation system	Completed
3	Developing machine learning based decision support system	Ongoing (60%)
4	Developing AQWES for urban areas of India	Completed
5	Integrating new capabilities in the information dissemination system	Ongoing (50%)
6	Transition to operations of the new air quality forecasting capabilities	Ongoing (50%)



E-mail: rkumar@ucar.edu

ARL Performance



- Start-of-Project ARL = 6 *(01 Aug 2022)*
  - Delhi AQEWS has already been running in the end user's operational environment and MODIS AOD is currently being assimilation in the Delhi AQEWS.
- Goal ARL = 9
- Current ARL = 7.8 *(20 Apr 2024)*
  - Assimilation of MODIS AOD implemented in the redesigned operational system with monthly varying background error covariances. (ARL 9).
  - A physics-based decision support system has been implemented operationally and provided important tested in end-user's operational environment. (ARL9)
  - VIIRS AOD assimilation framework is ready now and is under testing for implementation in operations (ARL 7).
  - High-resolution emission inventories are completed and prototype operational forecasts started for Mumbai, Pune, Ahmedabad, and Jaipur. (ARL 8). With full automation in winter 2024, we will achieve ARL 9.
  - A machine-learning based decision support system is also under development (6).

E-mail: rkumar@ucar.edu

Current ARL-Supporting Evidence

11 GRAP orders issued this season: https://caqm.nic.in/index1.aspx?lsid=4168&lev=2&lid=4171&langid=1

Order dated 27.02.2024 - Revocation of Actions under stage-I, Poor Air Quality of GRAP	7312KB
Order dated 19.02.2024 - Revocation of Actions under Stage-II Very Poor Air Quality of GRAP and intensifying actions under Stage-I of revised GRAP in Delhi - NCR	7014KB
Order dt. 18.01.2024 - Revocation of Actions under Stage-III (Severe Air Quality) of revised GRAP in Delhi-NCR - Steps to be taken	7032KB
Order dated 14.01.2024 - Implementation of Actions under Stage-III (Severe Air Quality) of revised GRAP in Delhi-NCR- Steps to be taken	240KB
Order dt 01.01.2024 - Revocation of Actions under Stage-III Severe Air Quality of revised GRAP in Delhi - NCR	19660KB
Order dated 22.12.2023 - Implementation of Actions under Stage-III Severe Air Quality of revised GRAP in Delhi-NCR	21990KB
Order dated 28.11.2023 - Revocation of Actions under stage-III (Severe Air Quality) of revised Graded Response Action plan in Delhi-NCR	18736KB
Order dated 18.11.2023 - Revocation of Actions under Stage-IV (Severe Plus Air Quality) of revised Graded Response Action Plan in Delhi-NCR	226KB
Order dated 05.11.2023 - Implementation of Actions under Stage-IV (Severe Plus Air Quality) of revised GRAP in Delhi-NCR- Steps to be taken	7238KB
Order dated 02.11.2023 - Implementation of Actions under Stage-III (Severe Air Quality) of revised GRAP in Delhi-NCR- Steps to be taken	22576KB
Order dated 21.10.2023 - Implementation of Actions under Stage-II (Very Poor Air Quality) of revised GRAP in Delhi-NCR- steps to be taken	224KB

E-mail: rkumar@ucar.edu

Current ARL evidence: GRAP Order coverage in media

EDITION IN DELHI 31°C

THE TIMES OF INDIA

City Delhi Mumbai Bengaluru Hyderabad Kolkata Chennai Agra Agartala Ahmedabad Ajmer ...

CIVIC ISSUES DELHI MCD ELECTIONS CRIME POLITICS SCHOOL AND COLLEGES CITIZEN REPORTER VIDEOS PHOTOS WEATHE

NEWS / CITY NEWS / DELHI NEWS / GRAP 3 Restrictions Reimposed As Air Quality Dete...

TRENDING Pune Bitcoin Scam Bihar Lok Sabha Election Voting Hubballi Campus MCA student D

THIS STORY IS FROM JANUARY 14, 2024

GRAP 3 restrictions reimposed as air quality deteriorates in Delhi-NCR

TOI City Desk / TIMESOFINDIA.COM / Updated: Jan 14, 2024, 12:11 IST

SHARE AA FOLLOW US

Image used for representational purpose only

NEW DELHI: The Commission for Air Quality Management (CAQM) on Sunday reimposed restrictions under Stage-III of GRAP in the entire NCR with immediate effect amid worsening air quality.

14 Jan 2024

EDITION IN DELHI 31°C

THE TIMES OF INDIA

City Delhi Mumbai Bengaluru Hyderabad Kolkata Chennai Agra Agartala Ahmedabad Ajmer ...

CIVIC ISSUES DELHI MCD ELECTIONS CRIME POLITICS SCHOOL AND COLLEGES CITIZEN REPORTER VIDEOS PHOTOS WEATHE

NEWS / CITY NEWS / DELHI NEWS / GRAP's Grip Loosened As Air Quality Shows Improv...

TRENDING Hubballi Campus MCA student Death CM Conrad K Sangma DK Shivakumar

THIS STORY IS FROM JANUARY 19, 2024

GRAP's grip loosened as air quality shows improvement in Delhi-NCR

TNN / Updated: Jan 19, 2024, 06:47 IST

SHARE AA FOLLOW US

19 Jan 2024

The Commission for Air Quality Management in NCR and adjoining areas revoked all GRAP Stage III measures, including restrictions on construction, demolition, ... Read More

E-mail: rkumar@ucar.edu

Accomplishments

- Operationalization of 72-h air quality forecasts for four new cities of India namely Pune, Mumbai, Ahmedabad, and Jaipur.
- Use of 72-h air quality forecasts in Delhi by the Commission for Air Quality Management.
- Four Peer-reviewed paper and three conference presentations describing activities of this project.

E-mail: rkumar@ucar.edu

Peer-reviewed Publications

Govardhan, G., Ghude, S. D., R. Kumar, Sharma, S., Gunwani, P., Jena, C., Yadav, P., Ingle, S., Debnath, S., Pawar, P., Acharja, P., Jat, R., Kalita, G., Ambulkar, R., Kulkarni, S., Kaginalkar, A., Soni, V. K., Nanjundiah, R. S., and Rajeevan, M.: Decision Support System version 1.0 (DSS v1.0) for air quality management in Delhi, India, Geosci. Model Dev., 17, 2617–2640, https://doi.org/10.5194/gmd-17-2617-2024, 2024.

Kalita, G., Prafull P. Yadav; Rajmal Jat; Gaurav Govardhan; Rupal Ambulkar; Rajesh Kumar; Preeti Gunwani; Sreyashi Debnath; Pratul Sharma; Santosh Kulkarni; Akshara Kaginalkar; Sachin D Ghude, Forecasting of an unusual dust event over Western India by the Air Quality Early Warning System, Atmos. Environ., 311, 120013, https://doi.org/10.1016/j.atmosenv.2023.120013, 2023.

Jat, R., Jena, C., Sachin D. Ghude, Rachana Kulkarni, Sreyashi Debnath, R. Kumar, Vijay Kumar Soni, Prodip Acharja, Santosh H Kulkarni, Manoj Khare, Akshara J. Kaginalkar, Dilip M. Chate, Kaushar Ali, Ravi S. Nanjundiah, and Madhavan Rajeevan, Evaluating the sensitivity of fine particulate matter (PM2.5) simulations to chemical mechanism in Delhi, Atmos. Environ., 323, 120410, https://doi.org/10.1016/j.atmosenv.2024.120410, 2024.

Sachin D Ghude, Gaurav Govardhan, R. Kumar, Prafull P. Yadav, Rajmal Jat, Sreyashi Debnath, Gyatri Kalita, Chinmay Jena, Shubhangi Ingle, Preeti Gunwani, Pooja Pawar, Rupal Ambulkar, Sumit Kumar, Santosh Kulkarni, Akshay Kulkarni, Manoj Khare, Akshara Kaginalkar, Vijay Soni, Narendra Nigam, Kamaljit Ray, S D Attri, Ravi Nanjundiah, M Rajeevan, Air Quality Warning and Integrated decision Support system for Emissions (AIRWISE): Enhancing Air Quality management in Megacities, under review, Bulletin of the American Meteorological Society, submitted: April 2024.

E-mail: rkumar@ucar.edu

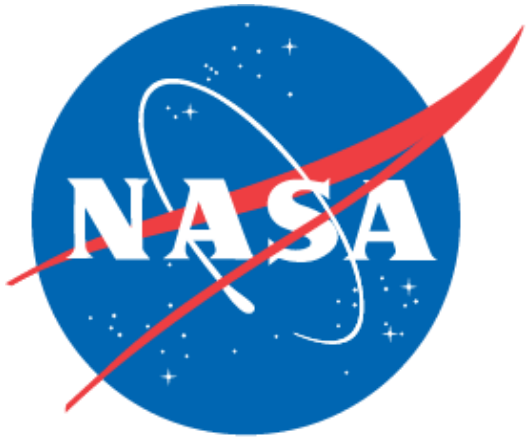
Conference Presentations

Kumar, R., S. D. Ghude, G. Govardhan, C. Jena, V. K. Soni, P. Yadav, and S. Debnath, Enhancing Air Quality Decision-Making Activity in Indian Megacities through Assimilation of NASA Earth Observations, AMS 103rd Annual Meeting, 8-12 Jan 2023, Denver and online.

Maryam Golbazi, John Schreck, Scott Meech, Rajmal Jat, Prafull Yadav, Gaurav Govardhan, R. Kumar, Sachin D Ghude, Stefano Alessandrini and William Y Y Cheng, Enhancing the Development of an Air Quality Early Warning System for Indian Megacities through High-Resolution Forecasting and Machine Learning Techniques, AGU Fall Meeting, 11-15 Dec 2023, San Francisco, USA.

R. Kumar, M. Golbazi, J. Schreck, S. D. Ghude, G. Kalita, P. Yadav, R. Jat, G. Govardhan, C. Jena, V. K. Soni, and S. Debnath, Using NASA Earth Observations to Improve Air Quality Decision-Making Activity in Indian Subcontinent, AMS 104th Annual Meeting, 28 Jan - 1 Feb 2024, Baltimore, MD and online.

E-mail: rkumar@ucar.edu



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Thanks for your attention!

E-mail: rkumar@ucar.edu