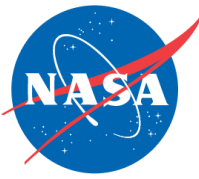


HEALTH & AIR QUALITY

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

Rajesh Kumar
29 March 2023



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Project Partners/Collaborators

Role	Name	Affiliation	Organization Type
Co-I	John Schreck	NCAR	FFRDC
Co-I	Gabriele Pfister	NCAR	FFRDC
Co-I	David Edwards	NCAR	FFRDC
Co-I	Carl Drews	NCAR	FFRDC
Co-I	Maryam Golbazi	NCAR	FFRDC
Co-I	Jessica Seddon	WRI	Non-profit organization
Collaborator	Sachin Ghude	IITM	Government organization
Collaborator	Vijay Soni	IMD	Government organization
Collaborator	Helen Worden	NCAR	FFRDC
Collaborator	Ajay Nagpure	Princeton University	University
Collaborator	Alexander Baklanov	WMO	United Nations
Collaborator	Prafull Yadav	IITM	Government organization

NCAR: National Center for Atmospheric Research; IITM: Indian Institute of Tropical Meteorology

IMD: India Meteorological Department; WRI: World Resource Institute; WMO: World Meteorological Organization

Delhi faces severe air pollution episodes every winter

Indian Express 01.04.2015

DEATH BY BREATH AN EXPRESS INVESTIGATION- PART TWO

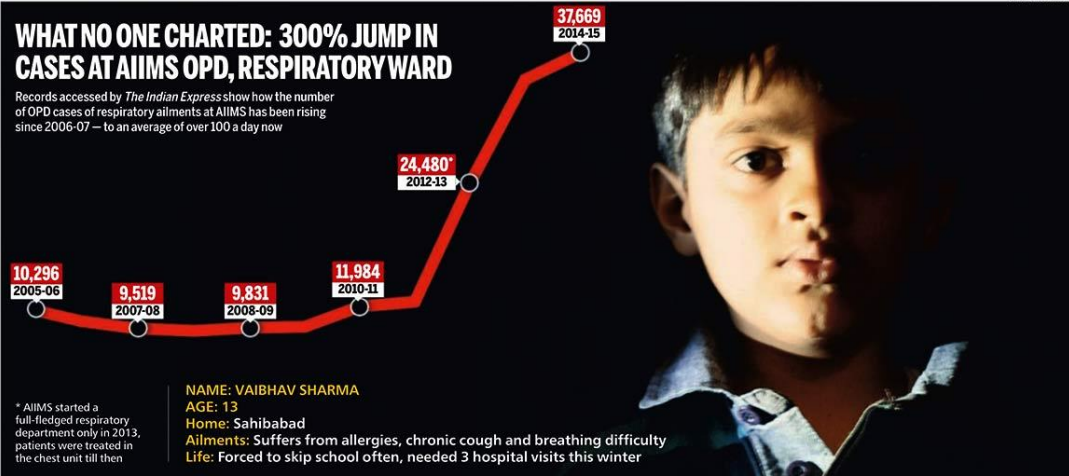
Leave Delhi

That's what doctors are prescribing to a record surge of patients with serious respiratory ailments triggered by the city's toxic air

PRAVEEN KHANNA

WHAT NO ONE CHARTED: 300% JUMP IN CASES AT AIIMS OPD, RESPIRATORY WARD

Records accessed by *The Indian Express* show how the number of OPD cases of respiratory ailments at AIIMS has been rising since 2006-07 — to an average of over 100 a day now



Sri Lanka cricketer Lakmal vomits on field, Delhi may lose winter tests



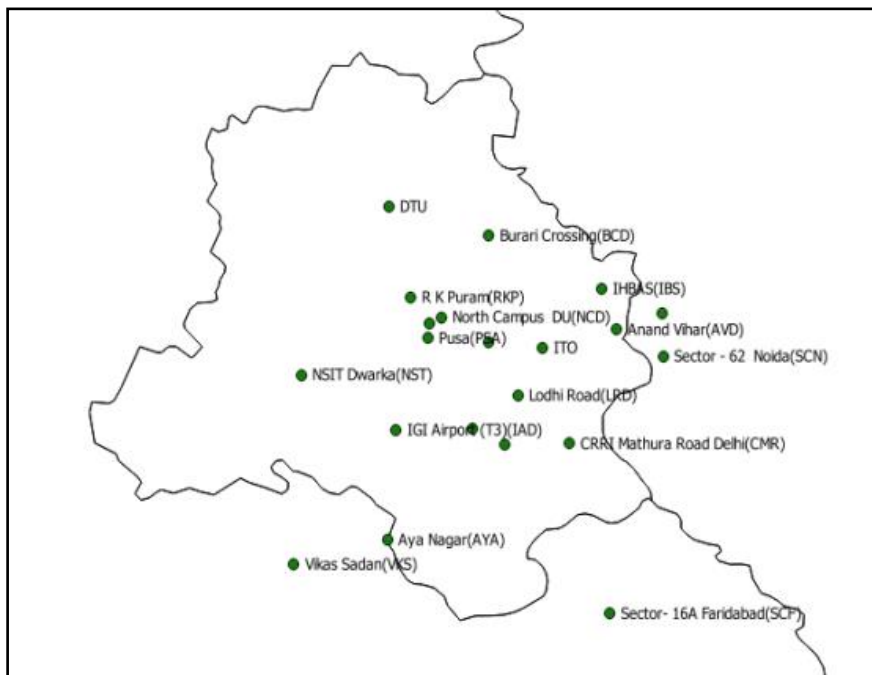
REUTERS

NEW DELHI:, DECEMBER 05, 2017 11:47 IST

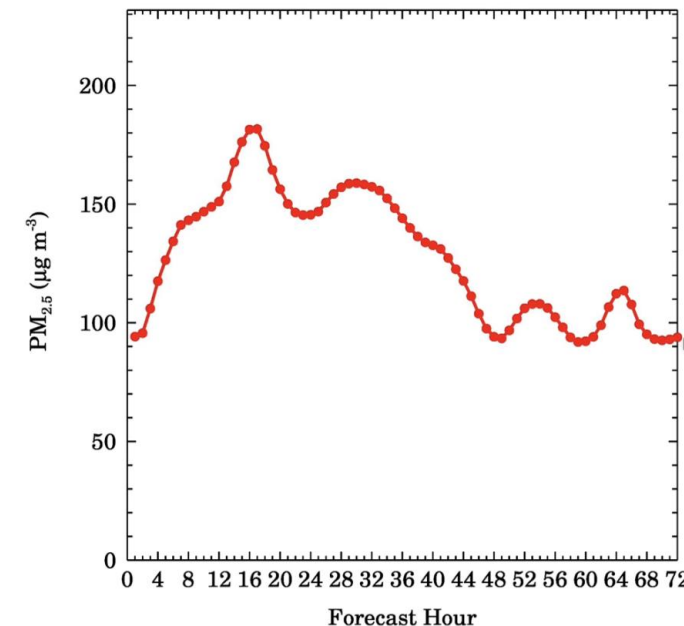
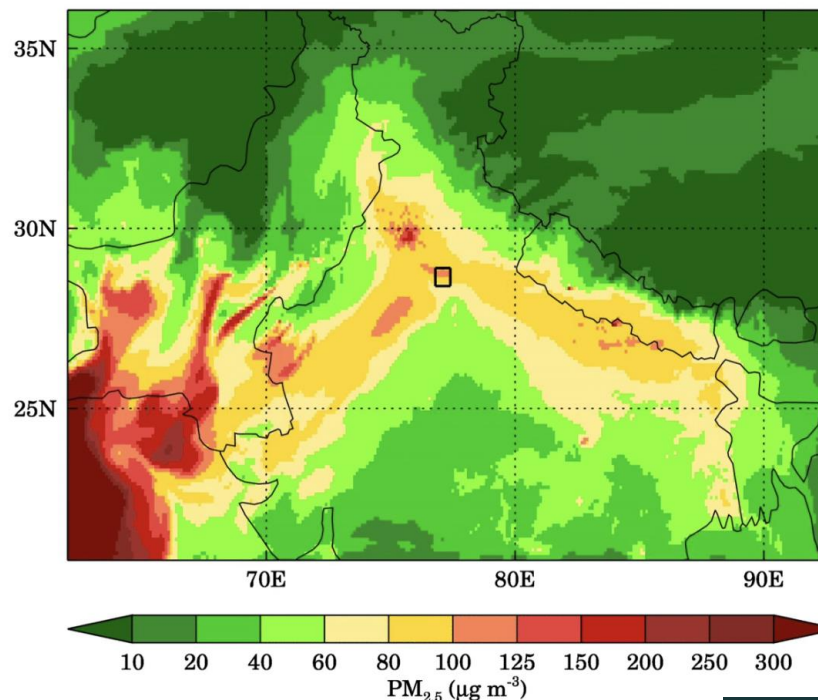
UPDATED: DECEMBER 05, 2017 19:13 IST

Government (Ministry of Earth Sciences), India Initiatives

Air Quality Monitoring Network (Delhi-NCR)

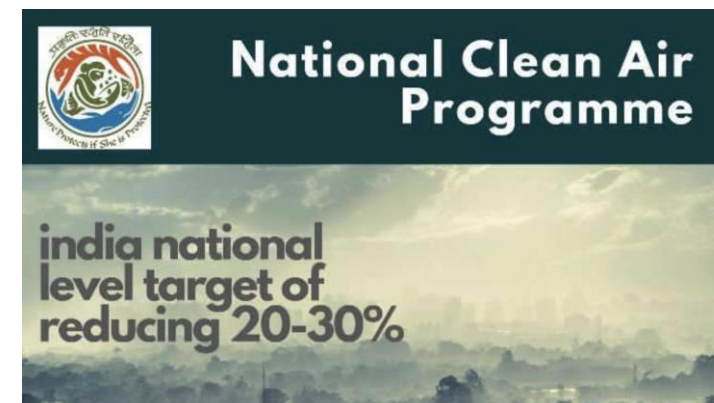


Air Quality Forecasts

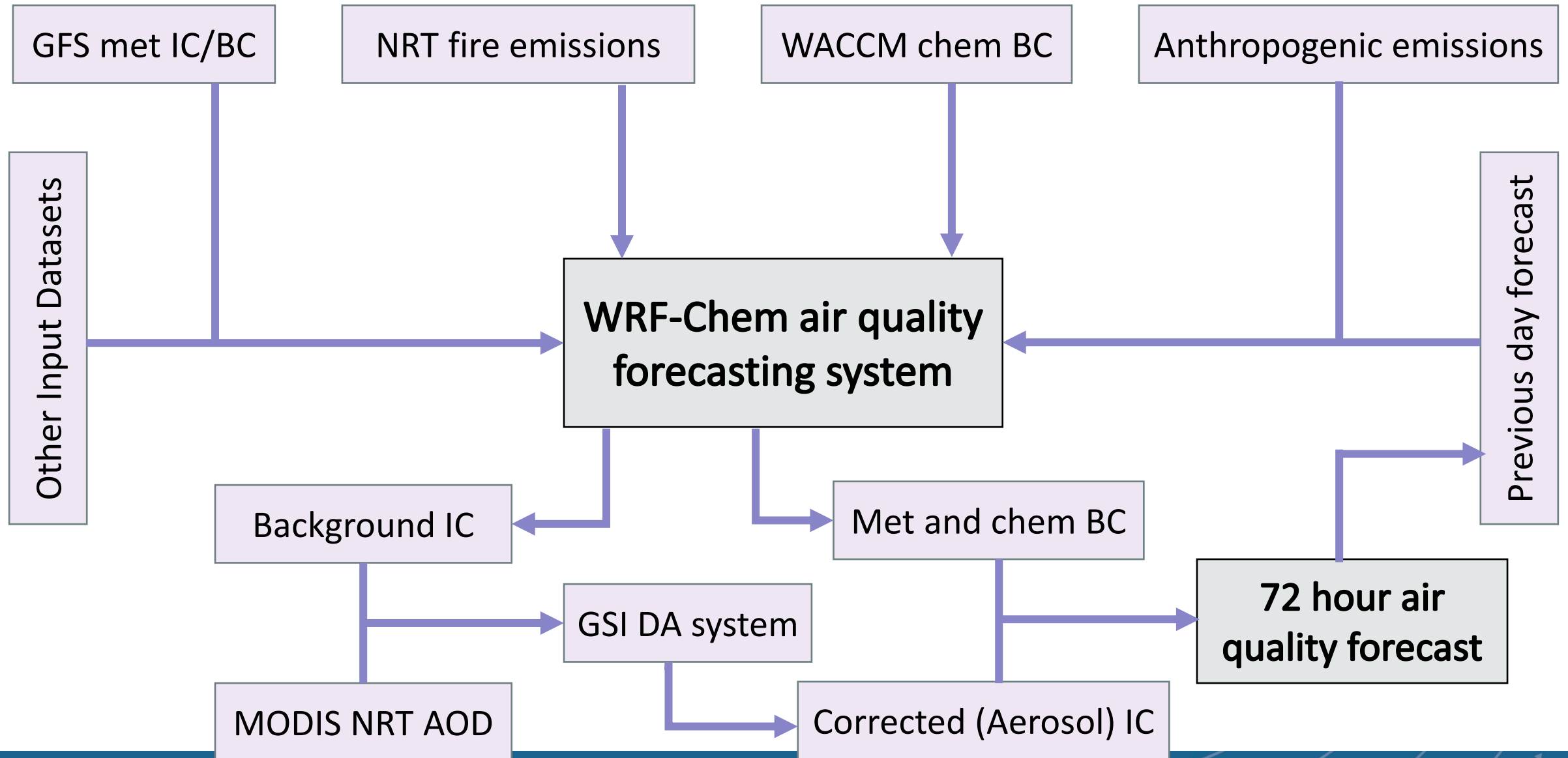


Information Dissemination:

- Digital boards
- SMS
- Mobile Apps
- Websites



Delhi Air Quality Forecasting System

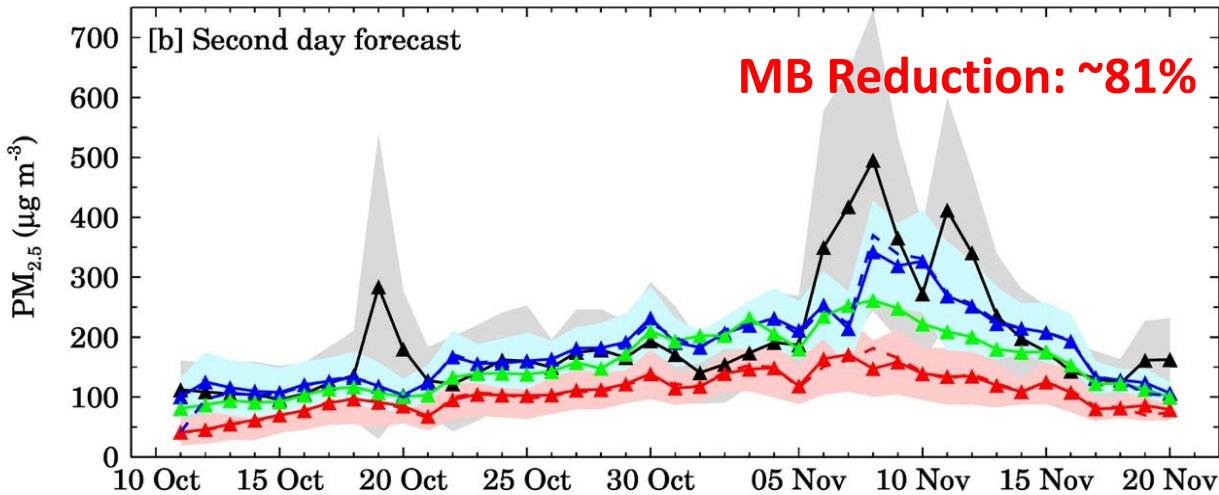
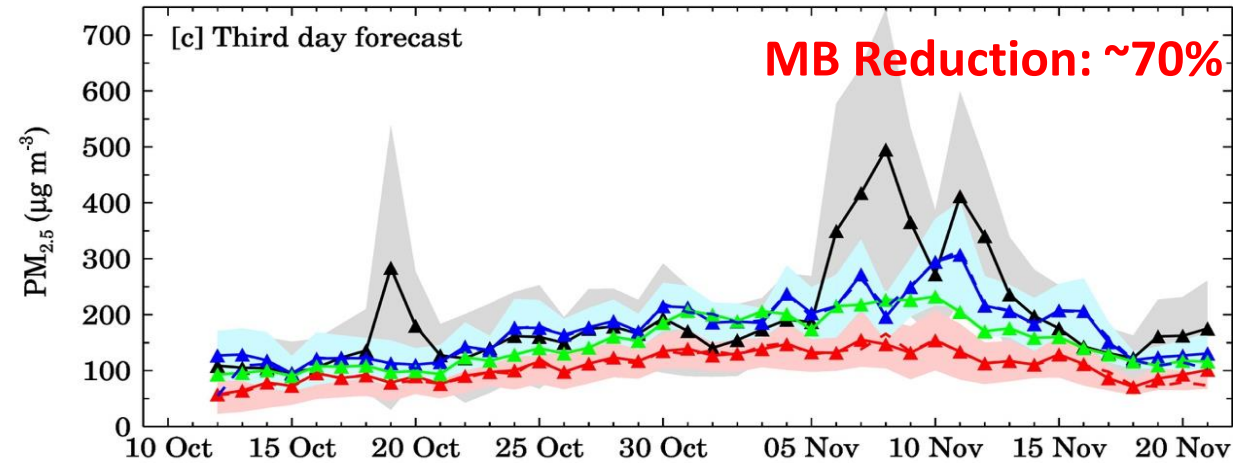
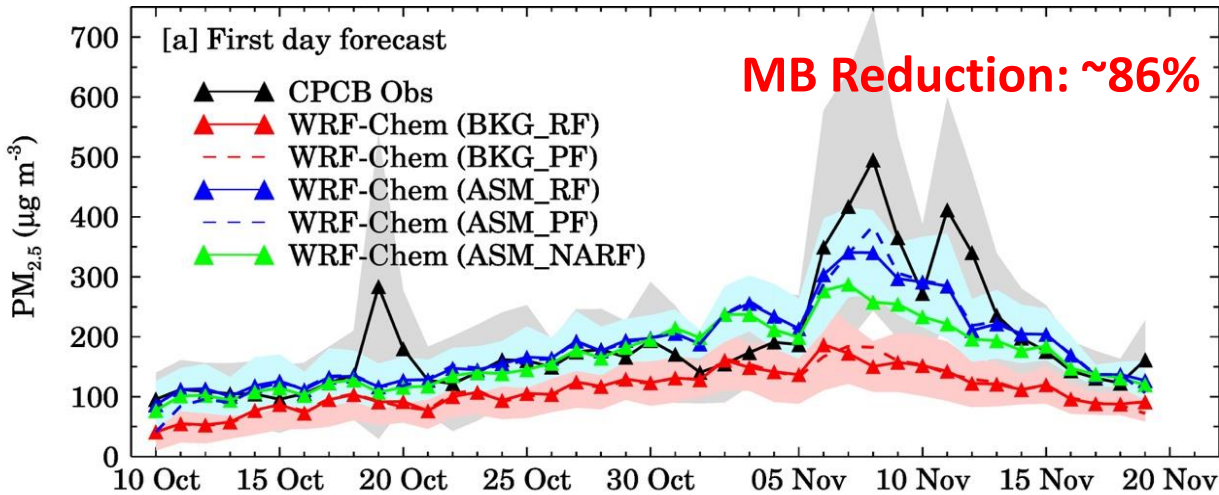


Earth Observations, Models, and/or Technologies



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: 3-hours	Assimilation under testing
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 model

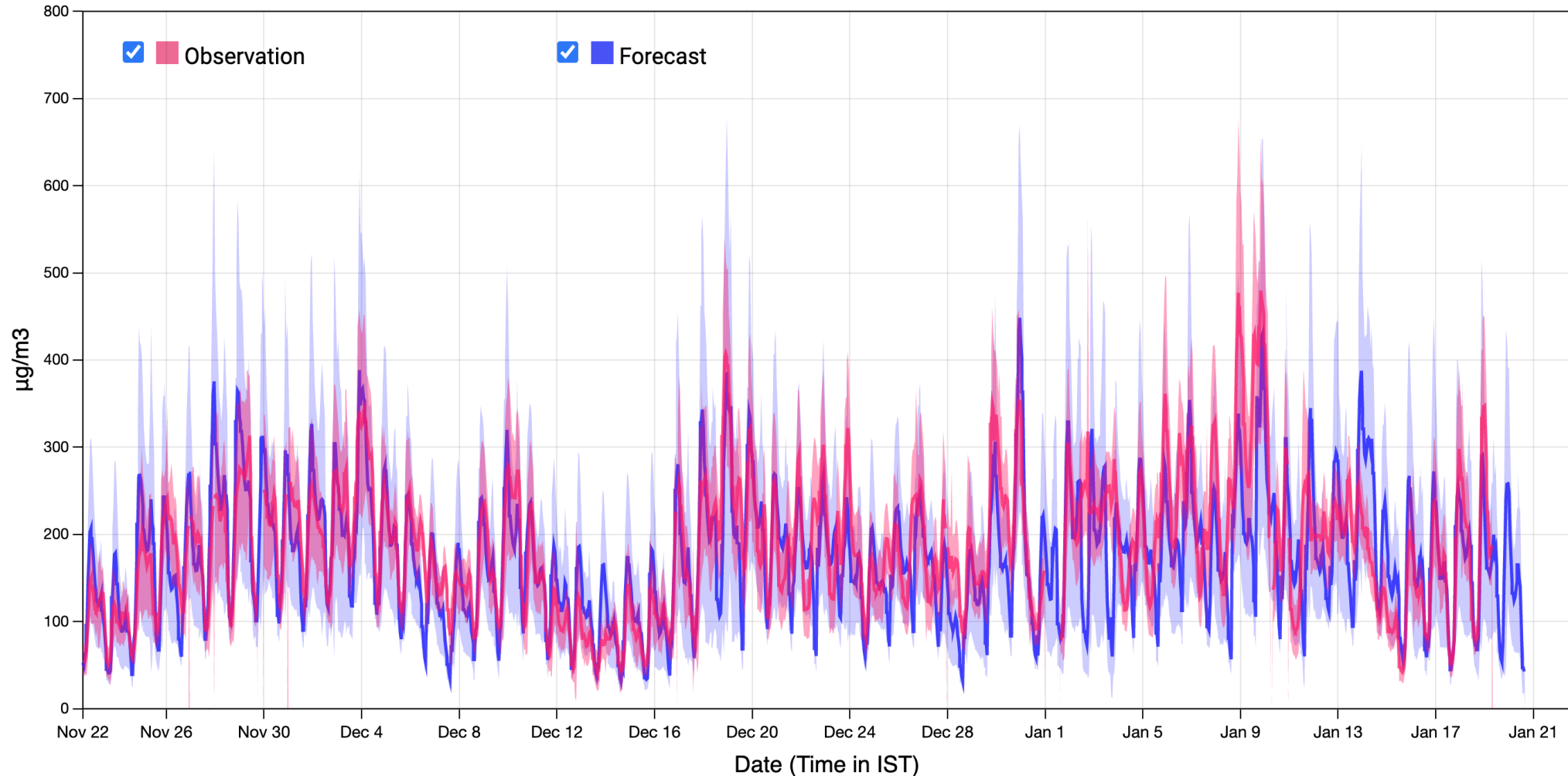
Improvements in daily average PM_{2.5} Forecasts



- About 75% improvement in the forecast result from assimilation of MODIS AOD.
- About 25% improvement is due to interaction of aerosols with radiation.
- Persistent fire emission assumption works fairly well in northern India.

[Kumar et al., 2020]

Delhi air quality forecast evaluation (22 Nov 2022 – 21 Jan 2023)



Our air quality forecasts constrained via assimilation of MODIS AOD observations reproduce the observed variability very well during the last winter season in Delhi.

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

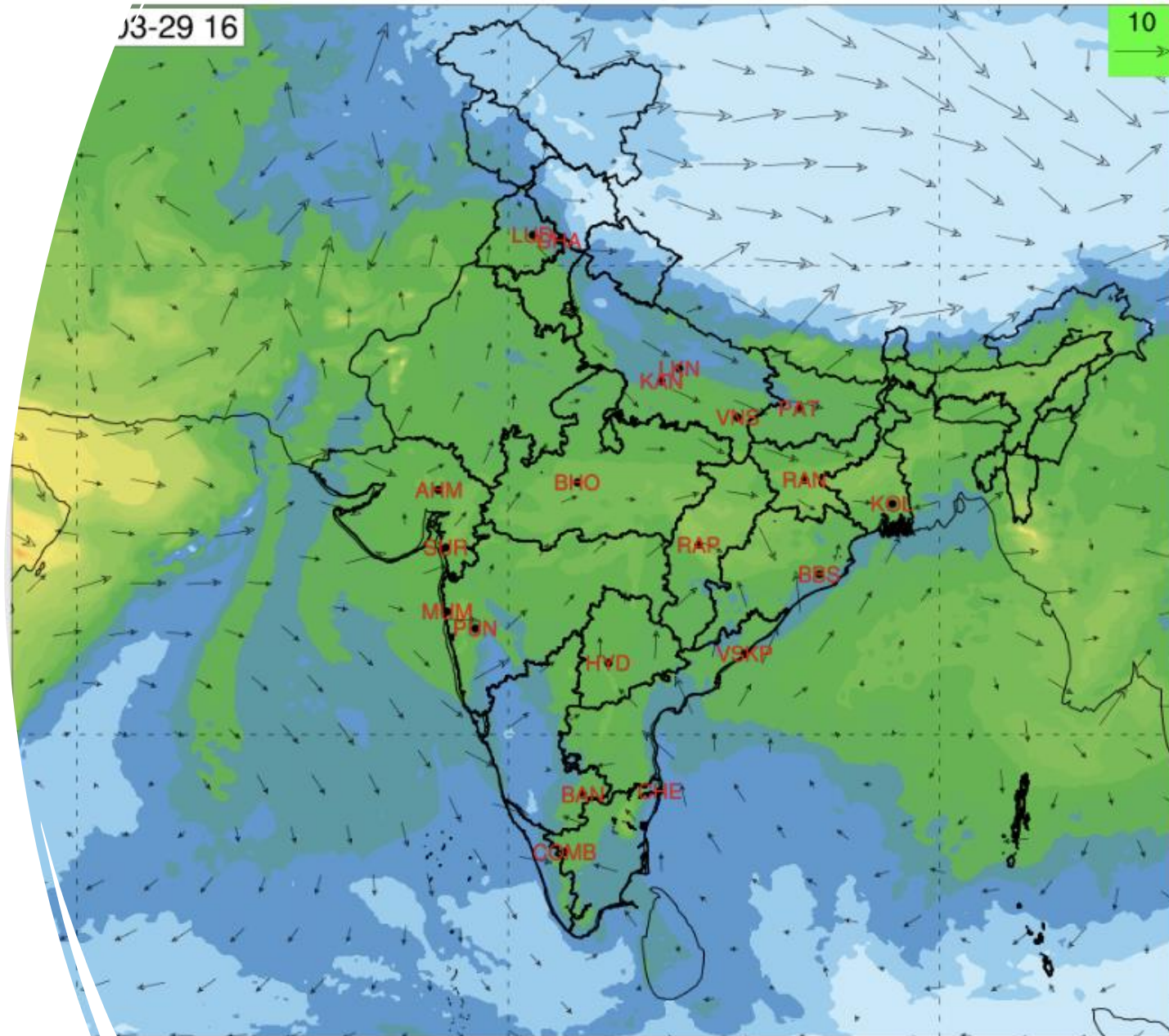
The screenshot shows the website header with logos for ESO, IITM, and the Ministry of Earth Sciences, Government of India. The main content area is divided into three columns: 'Air Quality Forecast (IST)' with a regional map, 'Delhi Air Quality Forecast' with a city map, and 'Observation' with a night photograph of the India Gate. Below these are three sections: 'Bulletin & Message' containing a text-based air quality and weather bulletin for Delhi NCR dated 27.03.2023; 'Air Quality Index at Delhi' featuring two circular gauges showing a current AQI of 109 and a forecast AQI of 114 for 2023-03-28; and 'Air Quality Forecast Over India' with a map of India showing forecasted air quality levels.

- 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.

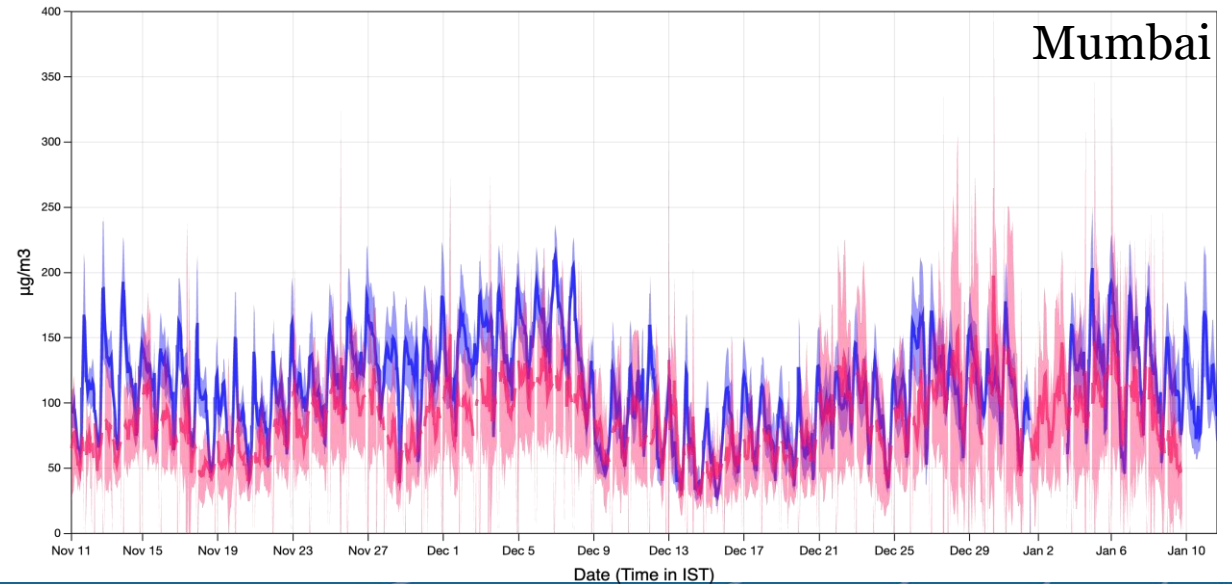
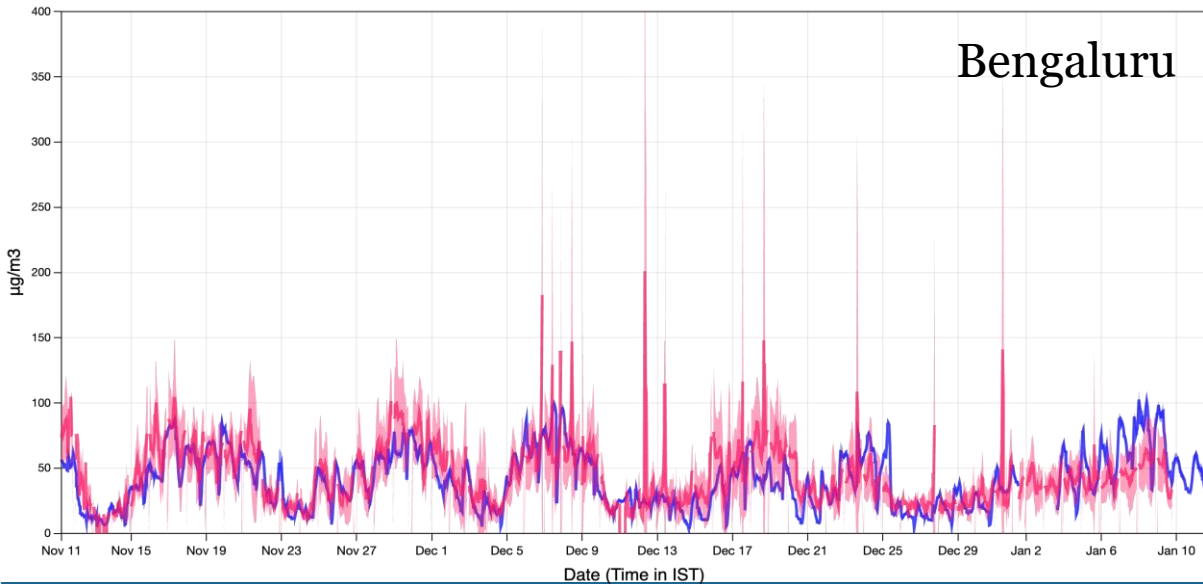
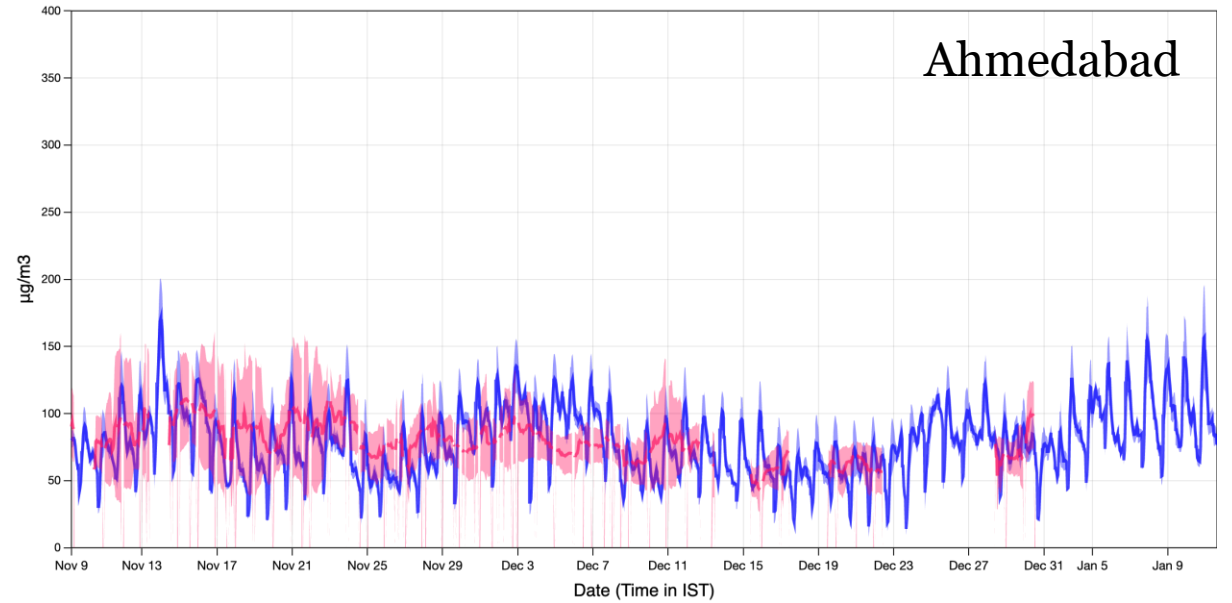
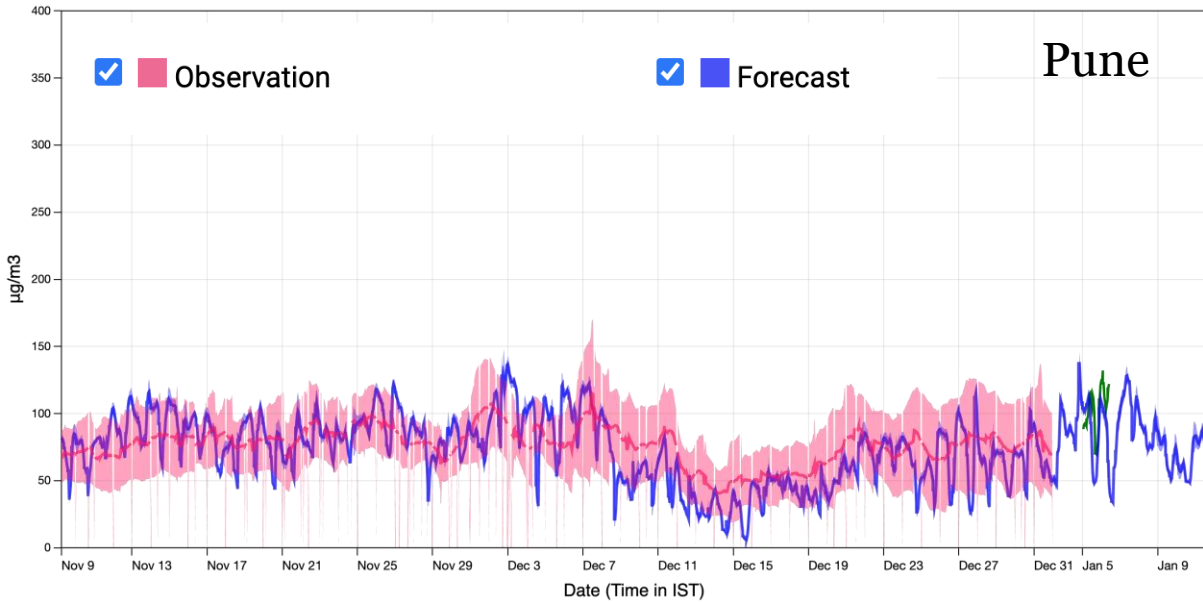
Expansion of the 10 km domain to whole South Asia

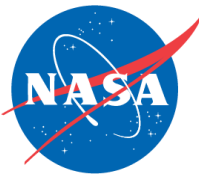
- We have now expanded the outermost domain of our air quality forecasting system to entire India at 10 km resolution.
- MODIS AOD retrievals are also assimilated for entire India now.
- India-wide forecasts are also being assimilated through the same website as is used for Delhi forecasts:

<https://ews.tropmet.res.in/>



Initial evaluation in other megacities of India





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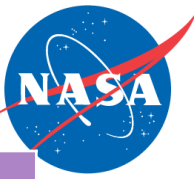
Project End-users & Stakeholders

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

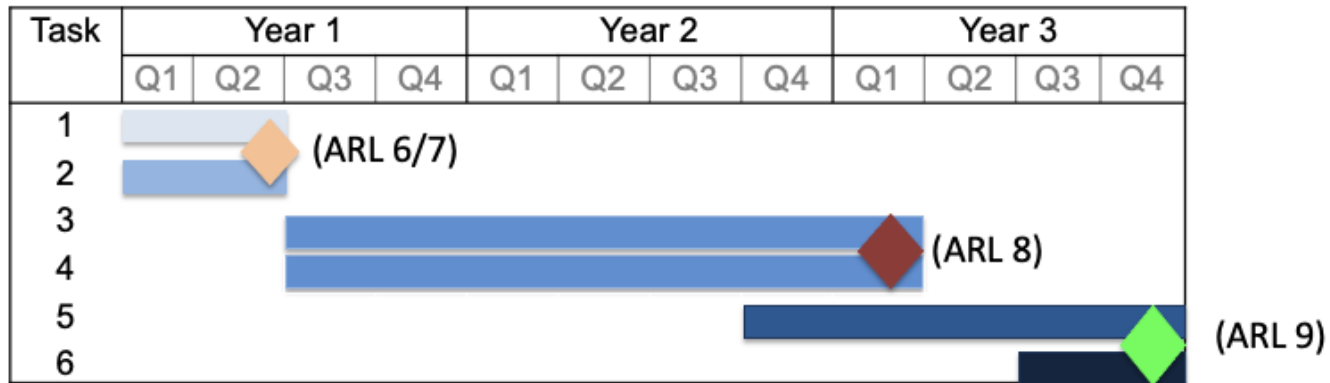
Stakeholder engagement

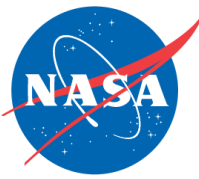
- I meet with the stakeholders every week. Over the last quarter, the discussion has mostly focused on developing a computationally efficient physics-based decision support, and on replacing MODIS AOD retrievals with VIIRS AOD retrievals for the assimilation.
- Sachin Ghude (IITM) visited NCAR from 14 Feb – 10 Mar 2023 to work on our project activities.



Schedule & Milestones

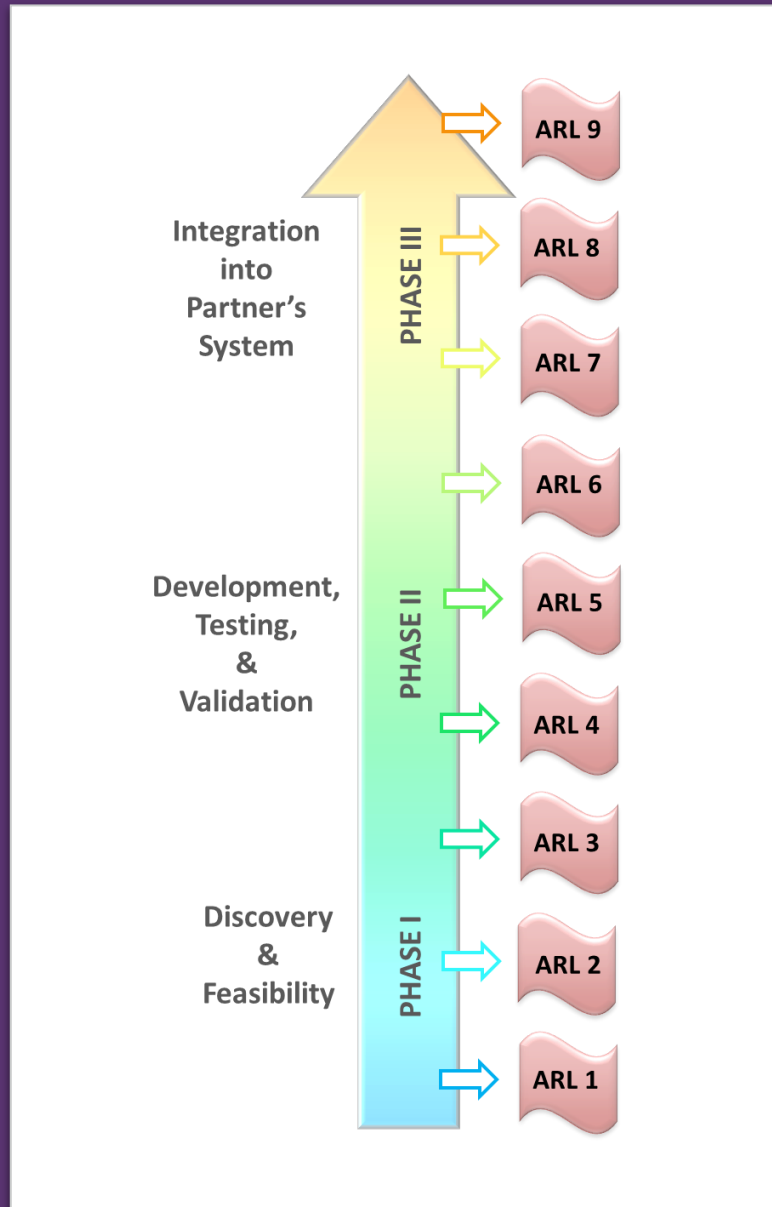
Task #	Description	Status
1	Set-up air quality forecasting system	Ongoing
2	Set-up Chemical data assimilation system	Ongoing
3	Developing machine learning based decision support system	Ongoing
4	Developing AQWES for urban areas of India	Not started yet
5	Integrating new capabilities in the information dissemination system	Ongoing
6	Transition to operations of the new air quality forecasting capabilities	Not started yet





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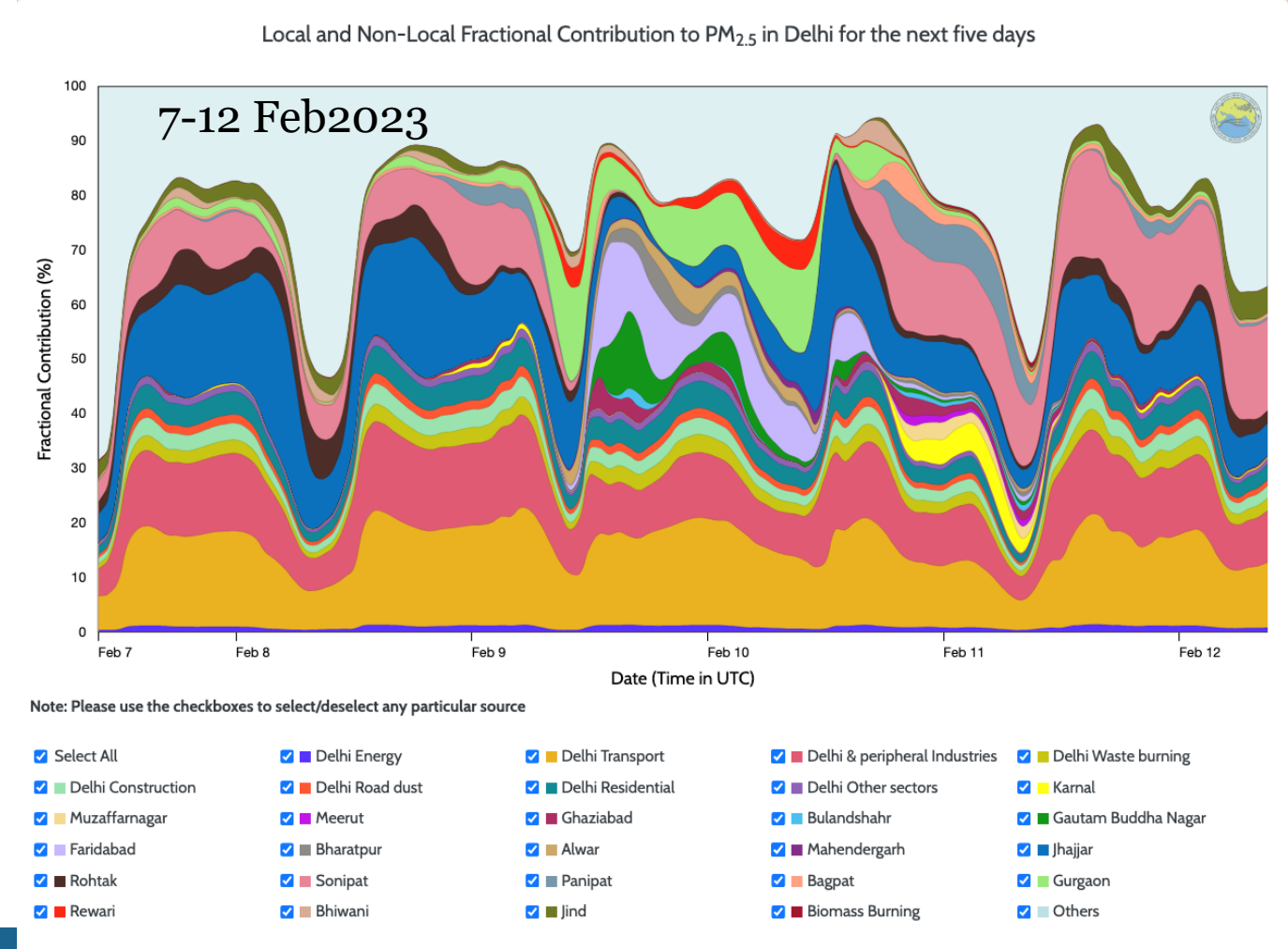
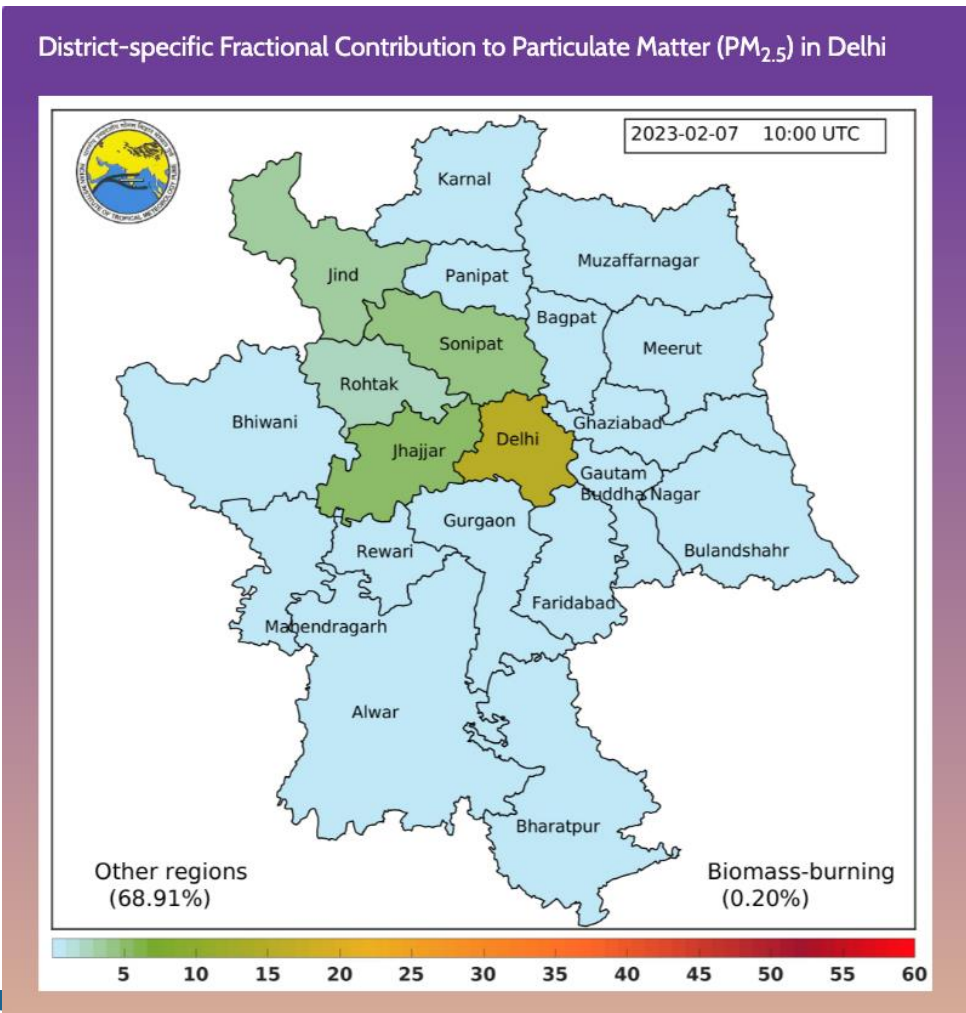
ARL Performance



- 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 = 6 (10 Feb 2023)
 - We are currently in the process of testing the assimilation of VIIRS AOD retrievals and examine if similar improvements in the model performance can be achieved as we saw with MODIS AOD assimilation. (ARL 6)
 - High-resolution emission inventories are being prepared for other cities in India. (ARL 6)
 - A physics-based decision support system has been tested in end-user's operational environment. (ARL 7)

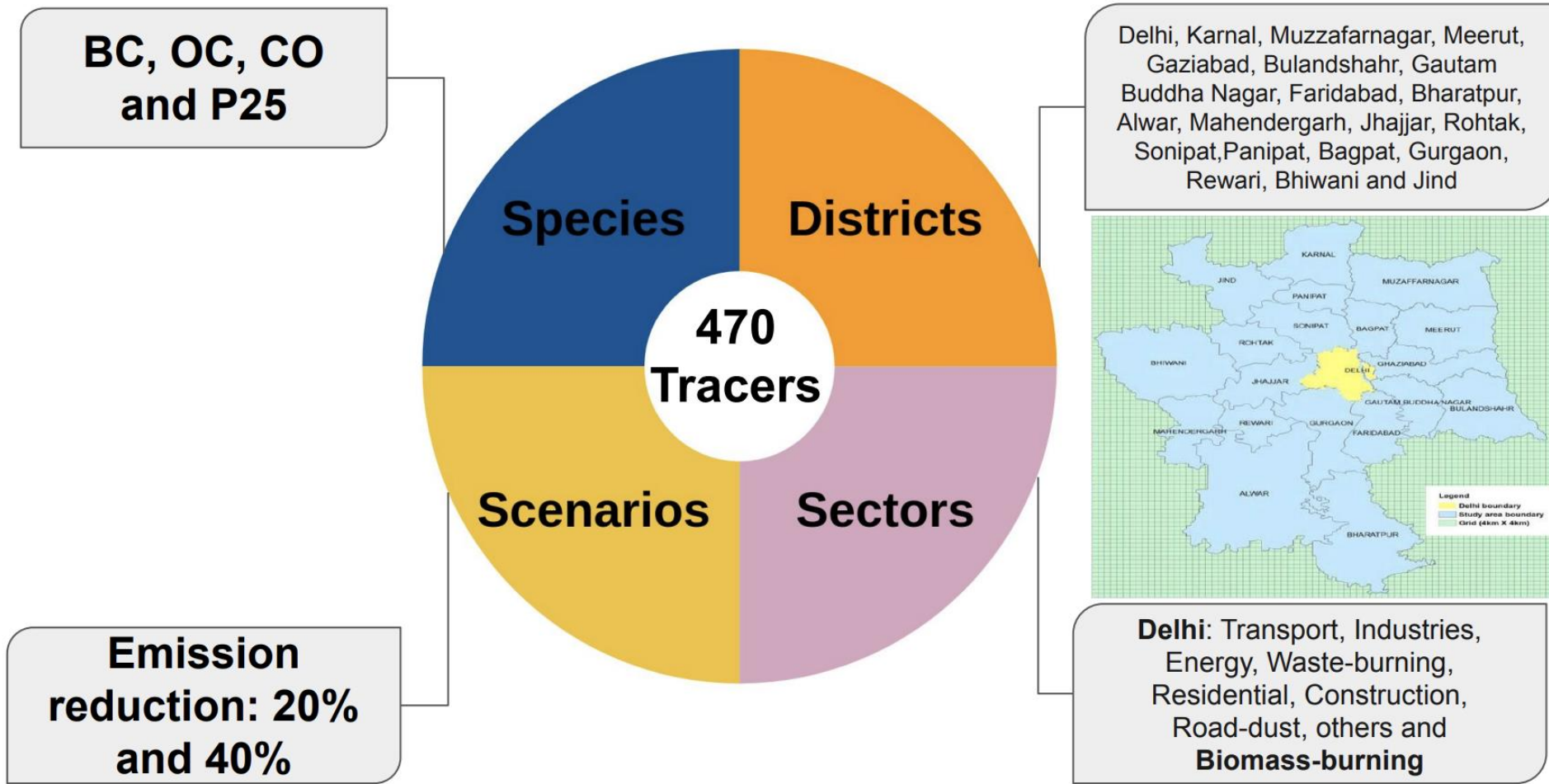
Current ARL-Supporting Evidence

Decision Support System – website integration (<https://ews.tropmet.res.in/dss/index.php>)



Current ARL-Supporting Evidence

Decision Support System - Design

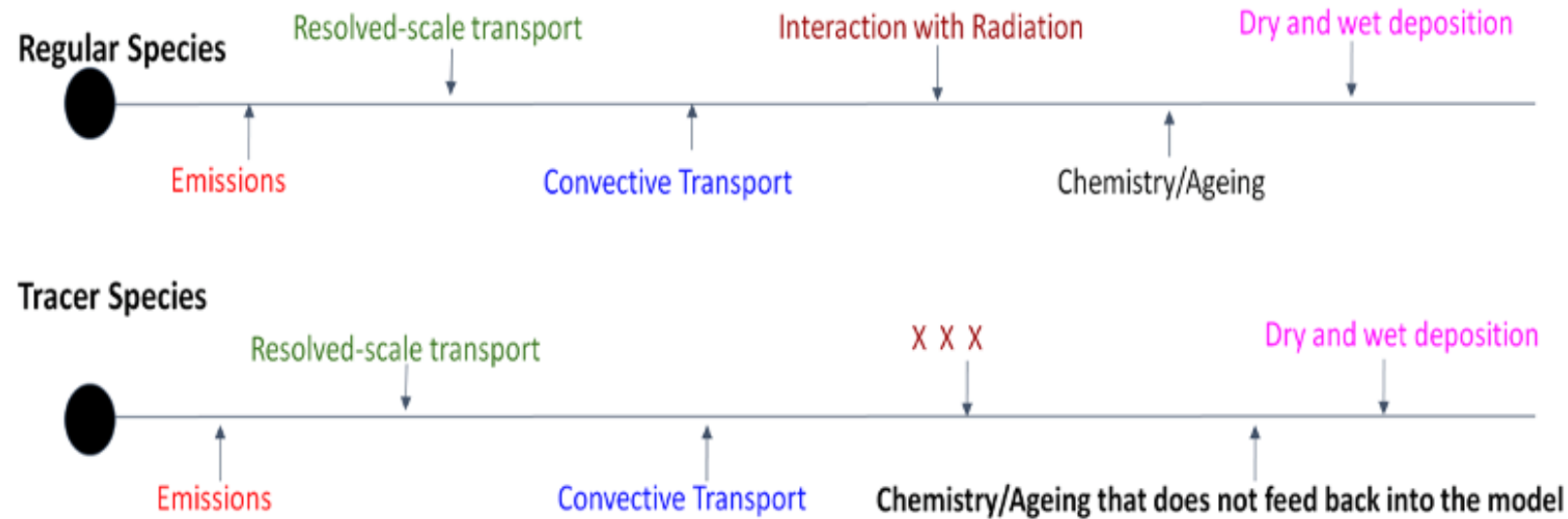


A total of 470 tracers have been implemented in the WRF-Chem model to track the contribution of different emission sectors and regions in the WRF-Chem model.

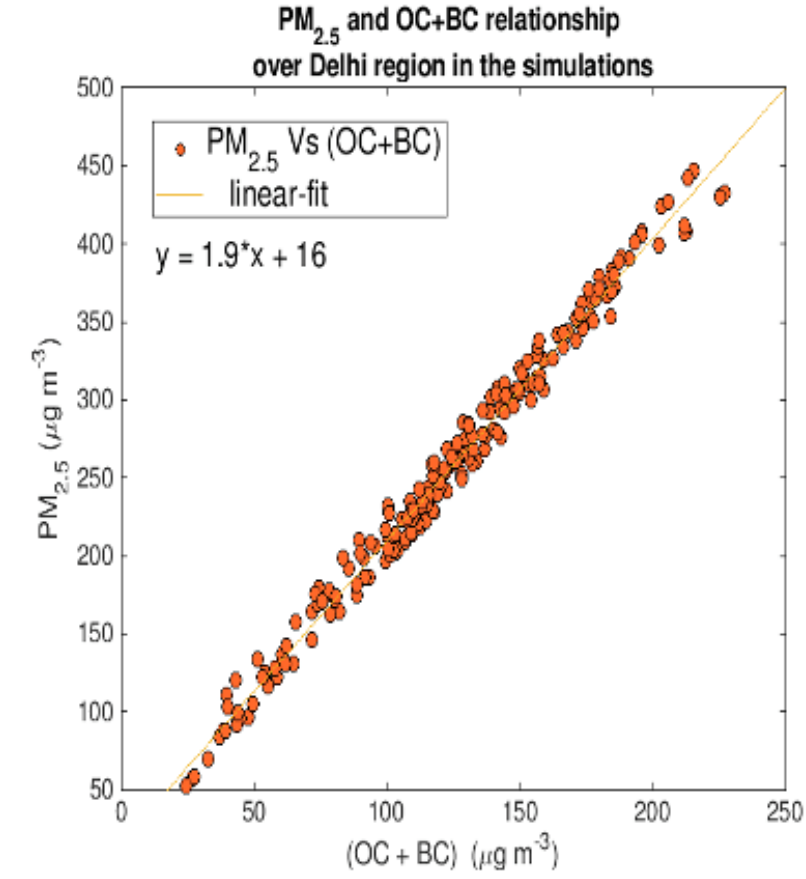
Current ARL-Supporting Evidence

Decision Support System - Methodology

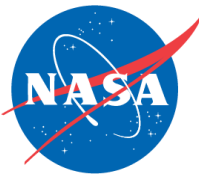
- CO, BC and OC, P₂₅ (BC1_tracer -> BC2_tracer in 2.5 days OC1_tracer -> OC2_tracer in 2.5 days) variables are tagged to identify and quantify the emission sources and regional contributions.
- In the model, each of the tracers is considered as an individual transported species. E.g.



- Non-interactive chemistry/ageing:



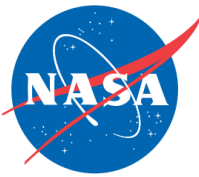
Challenges and Risks



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Rank	Type *	Risk	Mitigation Action	Date first noted/Date resolved (if applicable)
1	M and B	I lost a NCAR staff member in June 2023 who was assigned to work on this project. That staff moved to a different institution last year.	Opened a new staff position in July 2023 and hired a new staff member. The new staff started their position in mid November 2022. The new member is now spun up on the project and is ready to work efficiently.	Date noted: July 2022 Date resolved: November 2022
2	S and B	While the project started in May 2023, we received the budget late and a spending account key was set up in August 2023.	We attempted to hire the new staff as quickly as possible but it still took 3-4 months. With this new staff ready now, our spending rate is going to increase significantly in the next quarter.	Date noted: July 2023
3	M	Both of our WRI collaborators have left WRI and moved to different institutions.	We are working with the WRI Co-PI (listed on the proposal) and the current WRI colleagues to figure out the best way to set up a subcontract.	Date noted: October 2023

Accomplishments



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- Include a brief summary of major accomplishments and results during the reporting period



सत्यमेव जयते

राष्ट्रीय राजधानी क्षेत्र और निकटवर्ती क्षेत्र
वायु गुणवत्ता प्रबंधन आयोग
Commission for Air Quality Management in
National Capital Region and
Adjoining Areas



No.120017/27/GRAP/2021/CAQM

Dated: 15th January, 2023

ORDER

Sub.: Revocation of actions under Stage III ('Severe' Air Quality) of GRAP and intensifying actions under Stage-I & II of revised Graded Response Action Plan.

Based on the decision of the Sub-committee on GRAP, actions upto Stage-III of the GRAP were invoked on 06.01.2023 in the NCR, pursuant to prediction of a significant deterioration in the average Air quality of Delhi due to calm wind and stable atmospheric conditions as per forecast of IITM/IMD.

2. The Sub-committee in its meeting held on January 15, 2023 further reviewed the air quality scenario in the region as well as the IMD/IITM forecasts for meteorological conditions and air quality index of Delhi and observed as under:

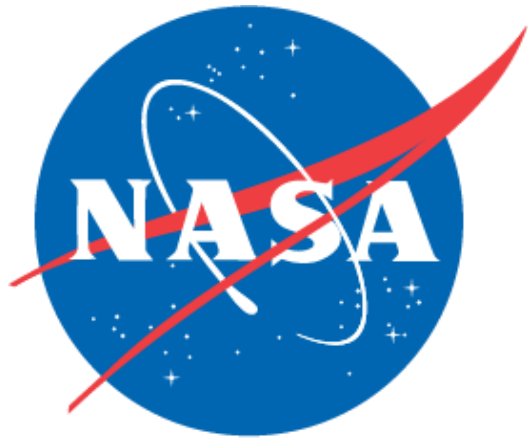
3. AQI of Delhi has since improved from the level of 353 (Very Poor) on 14th January, 2023 and exhibiting a decreasing trend since last three days, and has been recorded as 213 (Poor) on 15.01.2023. Preventive/restrictive GRAP-III measures invoked on 06.01.2023 seems to have helped the AQI levels and forecast by IMD also predicts that the AQI will remain largely in 'Poor/Very Poor' category in coming days.

- This image shows an order issued by the Commission for Air Quality Management to implement Stage III of Graded Response Action Plan on 15 Jan 2023 based on the air quality forecasts generated by our end user organizations (IITM and IMD).
- The forecasts generated by IITM and IMD are initialized with the assimilation of MODIS AOD retrievals from both Terra and Aqua.

Presentations/Publications

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.

Gaurav Govardhan , Sachin Ghude, Rajesh Kumar , Sumit Sharma, Preeti Gunwani , Chinmay Jena, Prafull Yadav, Shubhangi Ingle, Sreyashi Debnath, Pooja Pawar, Prodip Acharja , Rajmal Jat , Gayatry Kalita, Rupal Ambulkar , Santosh Kulkarni , Akshara Kaginalkar, Vijay Soni , Ravi Nanjundiah, and Madhavan Rajeevan, Decision Support System version 1.0 (DSS v1.0) for air quality management in Delhi, India, under review, Geoscientific Model Development.



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Thanks for your attention!