From Air Pollution to Climate Change

Project COALESCE Enriches India's Aerosol Science

Adapted from "Indian Network Project on Carbonaceous Aerosol Emissions, Source Apportionment, and Climate Impacts (COALESCE)," by **C. Venkataraman** (Indian Institute of Technology), **M. Bhushan, S. Dey, D. Ganguly, T. Gupta, G. Habib, A. Kesarkar, H. Phuleria, and R. Sunder Raman**. Published online in *BAMS*, July 2020. For the full, citable article, see [DOI:10.1175/BAMS-D-19-0030.1](https://doi.org/10.1175/BAMS-D-19-0030.1).

India, home to a fifth of the world's population, employs a far-ranging spectrum of polluting technologies and fuels with societal consequences. Important gaps remain, however, in understanding human activities influencing emissions, aerosol thermodynamic and optical properties, and atmospheric processes, specifically related to carbonaceous aerosols, which have important impacts on the region's climate and air quality. Some of the problems regional and global climate models have in simulating the aerosol influences on South Asia's climate may be linked to a severe paucity of measurements of the region's emissions.

Regional observational network *
site, Mohali, Punjab, India.

To fill these gaps, India launched a 5-yr project, COALESCE (Carbonaceous Aerosol Emissions, Source Apportionment, and Climate Impacts), in July 2017. The project attempts to identify and quantify not only commonly studied greenhouse gas emissions such as CO₂ but also emissions from otherwise overlooked sources that lead to short-lived climate pollutants (SLCPs). As a result, COALESCE focuses on the origin and fate of carbonaceous aerosols such as black and brown carbon, especially notable in India—SLCPs that not only reduce air quality now but also reduce monsoon rainfall and help drive unique climate impacts in the region, including feedback in which climate change may further worsen air quality.

COALESCE (<https://ncapcoalesce.iitb.ac.in/>) involves 22 institutions led by the Indian Institute of Technology Bombay, working in coordination with the Indian Ministry for Environment, Forests, and Climate Change. It involves more than 40 investigators, in consultation with representatives from government agencies, with expertise in aerosols, air pollution, radiation, and monsoons, among others, as well as more than 70 research students and staff. Training students and research staff as multidisciplinary scientists is part of the capacity-building effort, as are the adoption of standard science protocols and data formats and the dissemination of decision-making tools. For example, as part of the project, an emissions decision support system to manage inventories and generate future scenarios is under development. COALESCE is envisaged as a first step toward building an integrated aerosol, air pollution, and climate research community in South Asia, with links to India's national plans regarding air quality and international climate change commitments.

In the first phase of the project COALESCE launched field campaigns across India to estimate human sources (including technologies and fuels) that constitute key carbonaceous aerosol

(a) Locations in the COALESCE national-scale survey of dominant sources of carbonaceous aerosol emissions, such as residential biomass cooking, field burning of agricultural residues, road transport, and fired-clay brick production. **(b)** Field sites in the regional observation network.

Field studies on brick production—traditional clamp kilns, Nagpur, Maharashtra, India.

emissions. Emissions are tallied based on field studies of actual use and measurements of emissions factors; COALESCE also set up a regional observation network and identified, evaluated, and deployed a suite of regional and global climate models.

The COALESCE network will aim to fill current gaps in regionally representative observations, especially in regard to aerosol chemistry, physics, and optics, in the pan-Indian region. The project is generating important observational data that are feeding a hierarchy of models, from energy emissions to chemical transport to regional and global climate models.

The project's concept integrates "bottom-up" approaches, or emissions-driven climate modeling, with "top-down" methods, or source apportionment. The former evaluates sources of carbonaceous aerosols to determine their influence on climate, while the latter uses observations to quantify the sources. This harmonization of source influence estimates by bottom-up and top-down approaches would reduce uncertainties in the emission inventory.

Additional specialized GCM and RCM experiments are planned as part of COALESCE to better understand processes that influence the life cycle of aerosols and their feedback to climate. Among them is quantifying the radiative forcing due to aerosols and aerosol effects on

clouds. Further, the response of temperatures and the Indian monsoon system to changing emissions of aerosols, which include solar radiation-absorbing black carbon (a soot-like pollutant) and brown carbon (a typical product

Measurement of emissions from biomass cooking stoves, Hathwari, Rajasthan, India.

of wildfires), will be evaluated using GCM and RCM experiments over specified periods (1, 10, and 30 years). Additional experiments will study the sensitivity of the aerosol radiative forcing to changes in aerosol emissions, mixing state, and optical properties, as well as aerosol impacts on remote ecosystems like the Himalaya.

The project is a key step toward understanding SLCs in India to underpin decision-making

related to regional climate change. The network of regional PM_{2.5} monitoring stations and increased capacity in quantitative source apportionment would inform national PM_{2.5} control strategies and assessments of health impacts of regional air pollution. A multidisciplinary approach, using both measurements and modeling, will be further developed in coming years. ●●

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BAMS: What would you like readers to learn from this article?

C. Venkataraman (Indian Institute of Technology): *The air pollution and climate communities have historically been distinct from each other, working in supposedly nonintersecting realms of atmospheric science and environmental policy. Yet, they have basically arrived at similar questions and problems. How do we set standards or targets, whether those relating to pollutant levels or climate variables, to protect humanity from harm? Which human actions most strongly govern the degradation of these desirable levels? What mitigation and policy actions would best serve these targets? Through consultations we came to realize that aerosol science, embedded within multiscale atmospheric phenomena, would be an ideal bridge between these two communities. Specifically, carbonaceous aerosols are important air pollutants and short-lived climate forcers.*

BAMS: How do you bring these two communities together?

CV: *We thought it would be interesting for the COALESCE project to integrate scientific methods used by the climate and air-quality communities, bringing together both observations and models. Hopefully, this intersection will be of interest to readers as well.*

BAMS: And ultimately what are the benefits of the project focusing on the methodological intersection successfully?

CV: *We believe the COALESCE project will assist in creating an integrated air pollution and climate research community in the South Asian geographical domain, while making key links to international scientists. We also wish to find ways to strengthen links between scientists and stakeholders who will potentially use this knowledge in the wider contexts of policy and action.*

BAMS: How did you become interested in the topic of this article?

CV: *Originally, I became interested in carbonaceous aerosols in the context of toxic air pollutants and their fate in the environment. By the early 2000s, through collaboration in the multi-institutional international Indian Ocean Experiment and other Indian region studies, I became convinced that understanding carbonaceous aerosols holds the key to helping alleviate regional climate and air quality problems. We were also acutely aware of the significant gaps in regionally representative observations in the pan-Indian region, especially in regard to aerosol abundance, chemistry, and optical properties. So it is thrilling to have the opportunity to understand the regional life cycle of carbonaceous*

aerosols and the underlying science that governs their climate effects.

BAMS: What was the biggest challenge you encountered while doing this work?

CV: *Luckily, an Indian initiative, the National Carbonaceous Aerosols Program, was launched in 2011. From there on, it was an exciting five-year roller coaster ride to conceptualize the COALESCE project, persuade investigators to join the consortium, and convince the Indian Ministry of Environment, Forest and Climate Change to support work on this scale! Holding together as a massive research team, with 40 investigators and 70 students and staff, has been a very challenging and enriching experience.*

BAMS: What's next? How will you follow up?

CK: *Our immediate aim is to develop the COALESCE observational and modeling network and adopt standard data formats and protocols. A data management system, DELVE (Data Exploration Analysis Visualization and Extraction system) has been set up for practical data-sharing arrangements and subsequent long-term availability of datasets. We are developing an emissions inventory data management system, SMOG-India (Speciated Multi-pollutant Generator-India), to exploit the extensive field survey and measurements data.*

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