WRI INDIA

CLEAN AIR FOR ALL: FINANCING CLEAN AIR IN INDIA, REPORT TO THE XVTH FINANCE COMISSION, GOVERNMENT OF INDIA

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REPORT SUMMARY

Coordinating Lead Author

Dr. Jessica Seddon,
Director of Integrated Urban Strategy,
WRI Ross Center for Sustainable Cities

Authors and Contributors

Dr. Ajay Nagpure, Head, Air Quality, WRI India
Dr. Rajesh Kumar, Project Scientist, NCAR (Section 4)
Dr. Beatriz Cardenas, Head, Air Quality, WRI Mexico (Appendix 1)
Elizabeth Moses, Associate, WRI (Appendix 1)
Dr. Piyush Bhardwaj, Vistor, NCAR (Appendix 2)

TABLE OF CONTENTS


AUTHENTIC

EXECUTIVE SUMMARY

Reducing pollution from a wide variety of sectors across multiple administrative jurisdictions and maintaining clean air quality as India continues to grow will require a new model for air quality management. Our analysis of success stories in air quality management around the world has identified three critical building blocks for success: information - or knowledge of the levels of air pollution, their variation, and the range of contributors; mainstreaming – or linkage between public investment and planning decisions and their air quality impacts; and airshed-level action – systematic, institutionalized cooperation among the administrative areas that share their air. Information provides the basis for effective finance by allowing "clean air returns" to be quantified and compared. It also helps build public support for emissions reduction strategies that may not have immediately obvious links to clean air. Mainstreaming ensures sustainability by ensuring that resources channeled into meeting peoples' needs for energy, mobility, waste management, and other aspects of everyday life also do so in a way that leads to cleaner air. Airshed-level strategies allow the most cost-effective solutions for all to be identified and addressed.

This study describes the current state of and critical gaps in these three areas and outlines an agenda for strengthening these building blocks for financing clean air. The hope is that action on these recommendations would increase the impact of India's intended investment in clean air.

1.0 Introduction
Air Quality for All: Financing Clean Air in India

India's air pollution is one of the country's most significant development challenges. The cities where air pollution is measured are among the most polluted in the world (WHO, 2016).[1] World Health Organization (WHO) (2018)'s list of the 15 most cities in the world most polluted by particulate matter included 14 from India. There is evidence that the problem extends far beyond these areas. The air in rural areas and unmonitored cities is often not much better. Satellite-based surface air quality, ground-based observations, and air quality simulations show a blanket of particulate matter over much of the Indo-Gangetic plain and in other regional hotspots (Karambelas et al., 2018; Krishna et al., 2019; Kumar et al., 2018). Ozone, too, extends beyond cities into rural areas and *in situ* observations at suburban sites show high levels (Lal et al., 2017).

Air pollution affects India's most crucial resource: its people and productivity. The Indian population has one of the world's highest levels of exposure to air pollution globally (Cohen et al., 2017). Nearly 77% of the country's population lives with ambient PM2.5 pollution above both the WHO guidelines and the National Ambient Air Quality Standards. Seven and a half percent of total deaths in 2017 were attributable to ambient particulate matter exposure (excluding deaths attributed to exposure to indoor pollution, which accounted for another 5.5% of deaths). More than half of the deaths due to particulate matter exposure were in people younger than 70.[2] Ozone, which is less well recognized and monitored, also took its toll: 146,000 (18%) of the 818,000 deaths estimated to have been caused in India in 2017 by air pollution were related to ozone exposure (State of Global Air, 2019).

Air pollution is not only associated with lung disease, but also with cardiovascular disease and an increase in diabetes - Nearly 40% of the disease burden due to air pollution in India from the latter two causes. PM2.5 exposure has also been reliably linked to low birthweight, chronic kidney disease, and neurodegenerative diseases, though the links have not specifically been studied in India (Hua et al., 2018).[3] Long-term ozone exposure has been linked to risk of human respiratory and circulatory system – related mortality (Turner et al., 2016; Jayaraman G Nidhi, 2008). With respect to the land use, industrial areas show higher ozone levels compared to non-industrial area (i.e. commercial and residential), with an associated increase in numbers of patients with chronic respiratory symptoms (Kumar et al., 2004). Ghude et al (2016) estimated the economic cost of estimated premature mortalities linked with PM2.5 and O_3 exposure in India to be about 640 (350–800) billion USD in 2011.

It also endangers food security. Poor air quality in India has been shown to be responsible for a nationally aggregated (wheat and corn) crop loss sufficient to feed about 94 million people in India (Ghude et al., 2014). A detailed study of the impact of ozone on southern Asian wheat, maize and rice cultivars, using high-quality in-situ ozone measurements, finds that these crops may be twice as sensitive to damage as European and American varieties. Sinha et al (2015) find relative yield losses of 27 to 41 % for wheat, 21 to 26 % for rice, 3 to 5 % for maize and 47 to 58 % for cotton due to exposure to high ozone (Sinha et al., 2015). Particulate matter pollution also appears to be affecting the regional monsoon rainfall and circulation in India (Lal et al., 2017, Li et al., 2016).

Air pollution also affects the prospects for India to meet its solar power ambitions. It reduces solar roof top efficiency by 11.5% in the National Capital Region (NCR), also requiring more regular cleaning of solar panels due to dust stagnation, ultimately affecting generation of electricity (Peters et al., 2018).

And it contributes to local and global climate change. The impact of air pollution varies depending on the pollutant, such as Black Carbon (BC) contributes to warming effect while lighter-colored particulate sulfates reflect energy back into space, effectively "masking" surface warming that would otherwise take place (Orru et al., 2017). On a global basis, the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) estimate that reducing "short-lived climate pollutants" (SLCP), such as Black Carbon and ground-level ozone levels could reduce global

[1] The majority of cities in India far exceed the World Health Organization (WHO) particulate matter, PM10, standard of 20 µg/m and half of the world's most polluted cities are in India.
[2] The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017 India State-Level Disease Burden Initiative Air Pollution Collaborators* Lancet Planet Health 2019; 3: e26–39. The annual population-weighted mean exposure to ambient particulate matter PM2.5 in India was 89·9 µg/m3 in 2017. NAAQS limit is 40 µg/m3.
[3] New Initiative aims at expanding Global Burden of Disease estimates for pollution and climate.

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TABLE 1: Types of Pollutants and Sources

POLLUTANTS	TYPE OF POLLUTANT AND SOURCES
Ground-level Ozone (O_3)	**Secondary** Created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight Sources: Vehicles, power plants, industrial boilers, refineries, chemical plants
Particulate Matter (PM_{10}) & Particulate Matter ($PM_{2.5}$)	**Primary** (e.g. BC, OC, dust, and sea-salt) and **Secondary** (e.g., sulfate, nitrate, ammonium, and secondary organic aerosol) Primary Sources: traffic, combustion and agriculture crop burning, domestic biomass fuel burning, road dust, solid waste burning, and industrial activities Secondary Sources: Chemical reactions between NOx and VOCs produce semi-volatile organic compounds that partition between gas and particle phase depending upon atmospheric thermodynamics
Nitrogen dioxide (NO_2)	**Primary** Sources: combustion processes (heating, power generation, and engines in vehicles and ships)
Sulfur dioxide (SO_2)	**Primary** Sources: traffic, combustion and agriculture crop burning, domestic biomass fuel burning, road dust, solid waste burning, and industrial activities
Ammonia (NH_3)	**Primary** Manure management, over-fertilized soils, industrial point sources

warming by about 0.5° C (2010-2050) (WHO, n. d.). Air pollution appears to be associated with regional variation in surface warming trends in India (Ross, et al, 2018). Black carbon and dark particulate matter deposition on the Himalayan glaciers is accelerating melting and disruption of critical natural storage capacity that will affect South Asia's water security.

In short, choosing not to act to improve air quality will have significant costs. Deciding to act to improve air quality will result in multiple benefits to human health, crop yields, and climate change.

Tackling this pollution to achieve clean air will require strategic, integrated, and sustained action across jurisdictions and sectors. While the general contributors to criteria pollutants are known (Table 1) the specific origins of pollution vary across states and regions of India.

While more active enforcement of existing caps on emissions and requirements for emissions control from industry, vehicles, and other sources can reduce pollution, India is unlikely to achieve clean air without also reducing the emissions associated with everyday life and the pursuit of opportunities. Transport emissions, for example, increase when people buy two wheelers and cars as incomes rise. Policy decisions can play a significant role in modulating consumer choices and affecting air quality, but the required incentives often extend beyond regulation to include investment. Many commercial operators might happily consider CNG instead of diesel engines for taxis, 3-wheelers and LDV's due to the longer lifetime and lower operating cost of CNG engines. However, insufficient number of CNG refueling stations outside metropolitan cities and long waiting times at the pump makes diesel the favorite commercial fuel choice. Household emissions in India, another significant source, cannot be banned – the higher-emitting fuels must instead be replaced.

This paper draws on analysis of air quality management practices and successes around the world to identify three opportunities to build a stronger ecosystem for financing clean air. India's Air (Prevention and Control of Pollution) Act of 1981 was one of the earlier clean air legislations in the world and India has since developed a comprehensive formal system of air quality targets. The Central Pollution Control Board, established in 1974 under the Water (Prevention and Control of Pollution) Act is also one of the longer-standing environmental regulatory authorities in the world, and some of the state pollution control boards are even older. The pollution control boards have had mandates for air pollution control under national and state legislations for decades. The country also has a thriving scientific community, with a deep bench of talented researchers distributed across institutions. Government has engaged in and supported air quality relevant research through the Ministry of Earth Science, Ministry of Environment and Forests, the Indian Space Research Organisation (ISRO), Department of Science and Technology, and other agencies.

Bringing the expertise in these groups together more together more effectively would also help support targeted, efficient, policy and public investment for clean air. It is imperative to build on this foundation to help achieve clean air for India by:

- **Expanding regulatory capacity**, in particular the ability to detect and track emissions that combine to produce air pollution, and the ability to engage policymakers and civil society as allies in enforcing technical and scientific evidence-based clean air action plans. Comprehensive monitoring, and more detailed, dynamic, timely data on emissions is a necessary, though not sufficient condition for enforcement or other means of creating incentives to reduce emissions. Civil society and non-regulatory policymakers under pressure to provide clean air can be allies for regulators in using these data to guide follow-through on clean air action plans. Information is the basic foundation for finance, as it allows the most effective investments to be identified, clean air returns to be assessed, and performance-based incentives to be used.

- **Mainstreaming air quality - directing more ongoing public investment in infrastructure and services toward clean air returns as well as other social and economic goals.** Waste burning and decomposition for example, are significant contributors to particulate matter, ozone precursors, and hazardous air toxics.[4] Better implementation of waste management rules and regulation might reduce burning, for example, but limiting certain types of decomposition requires investing in segregation and waste handling – decisions that must be made in the context of urban planning and investment (Ahluwalia & Patel, 2018).[5] Similarly, choosing between alternative solutions for an air-pollution linked problem should be directed to consider air quality impacts. “Better” waste management from certain type of waste to energy plants can increase pollution rather than reduce it. Mainstreaming air quality investment harnesses the full power of India’s infrastructure and planning framework to ensure that lower-emission alternatives for meeting household, industry, business, and farmers’ needs are available.

- **Airshed-level governance - building institutional infrastructure for managing airsheds** that extend across existing administrative boundaries. Cities and states in India are under increasing pressure to produce clean air for their constituencies, but many of the contributors to pollution lie outside their control. They can and should act to reduce pollution, but expectations of what any subnational entity can unilaterally achieve must be realistic in order to be effective. Joint, multi-state, air quality management should also be more explicitly supported to ensure that clean air goals are met quickly and cost-effectively. Airshed level investment planning allows those seeking clean air to more effectively invest in eliminating sources of pollution that would otherwise fall outside their control. It allows for the most cost-effective solutions to be identified and implemented.

As Einstein said, “We cannot solve our problems with the same thinking we used when we created them.” Obtaining clean air will require encouraging, enabling, and investing in cleaner infrastructure, services, and practices in addition to regulating and

[4] Decomposition produces mainly ozone precursors and greenhouse gases while burning produces particulate matter and hazardous air toxics.

[5] Both better collection services and waste treatment (e.g. in Indore, Madya Pradesh) and enforcement of within-household composting or biogas use and discontinuation of collection of wet waste (Alappuzha, Kerela) have both been successful in mitigating the waste related emissions and reducing the waste management associated costs of the respective Municipal cooperation.

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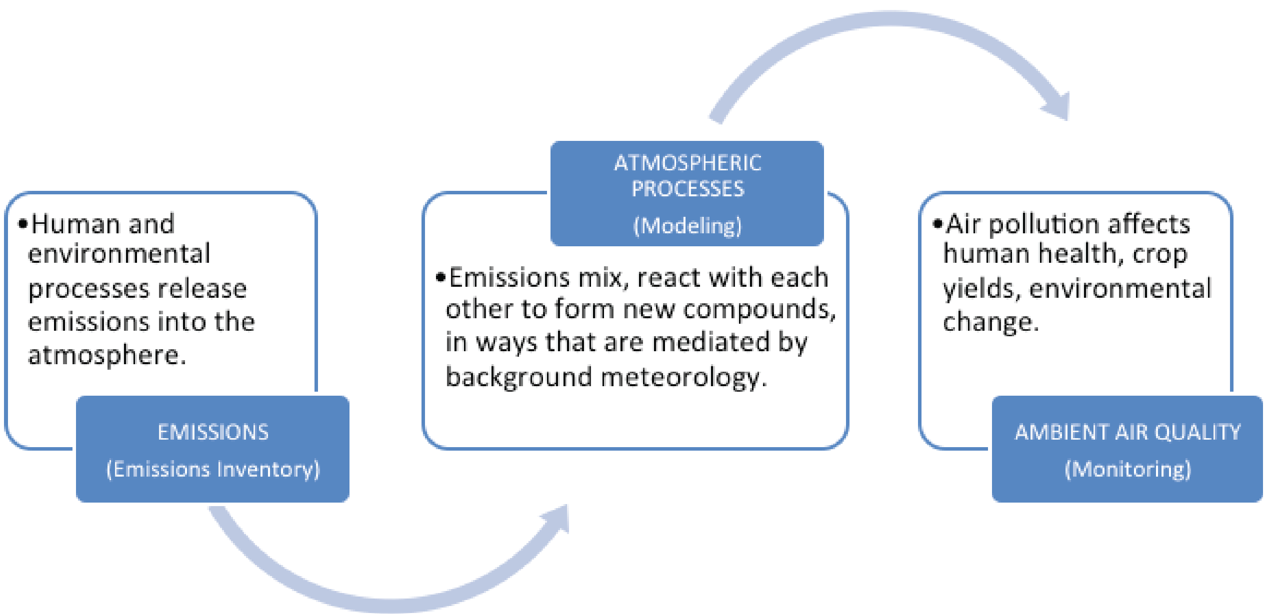
disincentivizing polluting activities. Government, business, and communities must work together to offer alternative ways of pursuing these essential aspects of social and economic life.This report is meant to contribute to such a comprehensive approach by outlining a set of institutional building blocks that will allow India to more effectively finance the transition to cleaner air.

Sections Two, Three, and Four discuss the rationale for, current status, and way to strengthen each pillar of an evidence based clean air investment ecosystem. Section Five concludes with a summary of strategic investment recommendations for the XVth Finance Commission. Appendix One provides case studies of cities and regions that have successfully combined scientific evidence with governance innovation to improve their air quality, using approaches that are relevant for India's federal democratic setting. The South Coast Air Quality Management District for the Los Angeles metropolitan region and Mexico City's Megalópolis Environmental Commission offer two models for urban-centric clean air governance embedded in a broader federal (and airshed) context. Both cases also illustrate the process of achieving clean air. The third case, the Long-Range Transboundary Air Pollution Protocol describes an international arrangement centered on the European airshed, but offers important lessons for future inter-state air pollution collaboration in India. Appendix Two offers a technical summary of new findings on interstate transport of pollutants in India.

2.0 Regulatory Capacity – Key Points

Air quality management requires a governance framework that includes clear targets, investments in data and scientific analysis, action plans, and a legal institutional framework that supports implementation of these plans. It also requires a clear communication strategy to engage the common interest of citizens and policymakers in seeing the implementation of clean air action plans through since linkages between air pollution control policies (which aim at controlling emissions) and air quality (which results from emissions and their interaction in and with the atmospheric context) can be challenging to explain. Figure 1 illustrates the basic link between emissions and air pollution; the middle stage of atmospheric processes is not readily visible.

Figure 1: Link Between Emissions and Air Pollution



The ability to monitor the state of the air, identify the sources of pollution, and assess the effectiveness of control measures is a critical part of the ecosystem for financing clean air. Without this information, the highest-return measures for emission reduction cannot be identified, nor can the returns on investment be assessed. Our review focuses on monitoring and emissions inventories. Improvements in these two areas would have spillover effects for air quality modeling since they would help to improve both model inputs and allow more specific validation of results of models.

Monitoring

Our review of regulatory and scientific monitoring in India highlights three major gaps.

First, there are not enough stations to cover a territory or population of this size. While the specific number of stations required depends on the purpose, the number of stations available is not even in line with the CPCB's own "Guidelines for Ambient Air Quality Monitoring" and their specification for the number of air quality monitoring stations required for a location (CPCB, 2003).

Second, the current focus on monitoring few major criteria pollutants does not provide sufficient information to move from knowledge of the level of pollution to knowledge of the sources of pollution. The measured pollutants are emitted from a variety of sources and cannot readily be assigned to specific emitting sectors for accurate quantitative source apportionment.

Third, and perhaps most significantly, the quality of data from the existing monitoring network is not reliable. The formal NAMP data flow process includes various quality checks, but data quality starts first and foremost with the point of collection – the measurement. The placement, maintenance, and operation of the sensors is a critical factor for data quality. The CPCB has a comprehensive set of guidelines in place for siting and maintenance of monitoring stations, and Regional Directorates review the functioning of monitors and transmission of data. Implementing this system, however, requires trained personnel and considerable investment, neither of which is currently adequate.

Our preliminary recommendations for addressing these gaps in monitoring emphasize the opportunity to quickly upgrade India's monitoring network by harnessing more of the academic and private sector capacity that exists.

- **Immediate and comprehensive audit of existing stations and central/state pollution control board processes to identify the extent of current equipment and immediate steps to ensure that it is all used consistently and professionally.** This may start with review of the inspection reports and data systems by a third-party expert reviewer. Looking ahead, it is important to develop a composite, nationally standardized, online inventory of monitoring sites including up to date specifications of the equipment, maintenance and calibration records, location of the monitoring stations, and staff and budget assigned. This comprehensive and integrated record of the data generating process will help to ensure that the State Pollution Control Board monitoring network data can be combined into a comprehensive basis for interstate action.

- **Expansion of network via a public-private- academic partnership overseen by an expert committee.** The monitoring rollout required must be far faster than the historic rate of growth and must include a simultaneous step change in the operations and maintenance of the network. Simple financial investment will not fill the gap – human capacity must be built and deployed quickly. A platform approach that can recognize and combine data from academic institutions and certain vetted non-government sources along with monitoring observations from the pollution control board network would offer the fastest way to generate the information required to guide investment and assess air quality returns on action. Government. Interagency partnerships that include MoES, DST, ISRO, and CPCB/ MoEF&CC are an important foundation, but the Finance Commission may also consider innovative models for funding the operations and maintenance of this network including eligibility for corporate social responsibility (CSR) funding.

- **Outsource operations and maintenance of air quality monitoring stations to a third-party contractor.** A third-party maintenance contract would allow for rapid aggregation of personnel with the required skills as well as enable economies of scale in deploying the personnel across states and regions. This approach has precedents. The US Environmental Protection Agency has commissioned operations to a private entity, and Paris contracts Air Parif, a non-profit organization accredited by the Ministry of the Environment to run monitoring stations the air quality model. Beijing is a combined model in which both government technicians and scientists are in charge of the program but subcontract private companies for specific parts of the monitoring. Regular performance audits could be used to evaluate the proficiency of the operator.

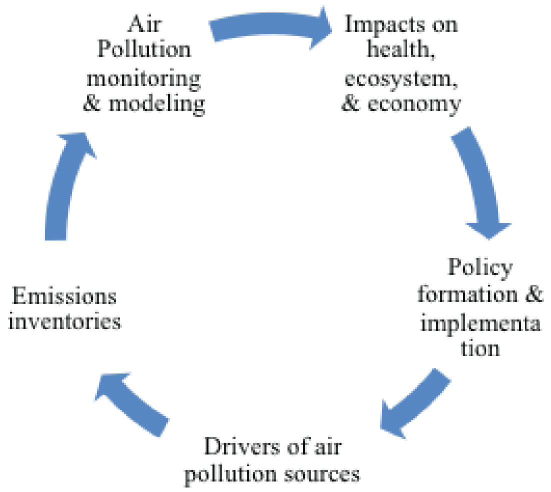
- **Develop regional centers of excellence for air quality monitoring, analysis, and technology assessment.** Professors and graduate students at key institutions around India could help examine and validate data, develop analyses of local and regional pollution control opportunities, and otherwise support Pollution Control Boards. Regional centers of excellence, perhaps built around existing monitoring efforts, would also ensure that researchers are familiar with local pollution sources, meteorology, and other factors that affect air quality. The center of excellence structure has been used to create a platform for combining academic and public sector talent to address complex problems; air quality is an additional area for application.

Emissions Inventories

Emissions inventories are one of the most critical parts of a system for identifying air pollution sources and assessing opportunities to improve air quality (US EPA, 2017; CPCB, n.d.). Emissions are the raw material of air pollution, and knowledge of them is necessary (though not sufficient[6]) to diagnose the causes of air pollution. Dynamic emissions inventories can also help policymakers to assess the effectiveness of their policies and its benefits by providing a record of the evolution of emissions.

There is no official open source, bottom-up high-resolution national emission inventory of air pollutants available for India, nor is there at official department at the state or central level that is responsible for the emission inventory development in India. The available emissions inventories are limited to few cities and, in the case of the SAFAR-India decadal anthropogenic inventory, a few species of pollutants (CO, NOx, and BC). None of these emission inventories or the other available academically generated inventories are able to provide a clear picture of the various sources. They are currently based on differing, and often crude, data or assumptions about economic activity. Emissions factors for some sectors (i.e., municipal solid waste burning, road dust emissions, industrial emissions) are also still uncertain. Other emissions factors are based on measurements done in North America and Europe even though the underlying activity and associated emissions may vary from the activities for which factors were documented.

Figure 2: Emissions Inventory and Policy Support



Emissions inventories are typically developed and refined progressively based on available information. At this point is important for India to speed up the process – to act quickly to aggregate and synthesize available information from public, private, and academic sources to develop more accurate emissions inventories that better represent the evolving patterns of activity that contribute to air pollution. Creating a coordinating platform to bring together the many additional sources of economic and social data that could improve activities data and collate the findings on observed emissions factors for India and similar contexts could advance emissions inventories substantially.

[6] Air pollution results from the combination and chemical interaction of these emissions in a given meteorological context, so emissions inventories must be combined with additional data and process understanding in order to predict pollution.

Our preliminary recommendations are to:

- **Develop an open repository for published emissions factors to be evaluated for regulatory use.** The research community continues to work on improving emissions factors that can be used to accurately characterize emissions from practices in India and similar contexts. This is a useful asset that could be better harnessed for the development of inventories for city, state and national use in India. An expert committee could be constituted to review the literature and select preferred factors from scientific studies rather than borrowing from regulatory agencies operating in different contexts.

- **Sponsor research on high-priority uncertainties in emissions factors.** China, for example, worked with the scientific community to identify the activities with the greatest uncertainties and develop some of them. This approach could also be used to develop greater certainty about the emissions and air pollution gains from targeting specific activities.

- **Develop a public-private-academic platform for harmonizing activity data and matching it to particular scales.** Emissions inventories need to be treated as a data collaborative – an institutional framework for managing flows of data from different sources for a continuously updated knowledge base – rather than a one-time study. The state of economic activity is often measured using a combination of public sector and private data; this approach could also significantly enhance activities data in emissions inventory. Satellite products also offer an important potential source of insight in an inverse modeling framework.

3.0 Mainstreaming Air Quality as an Investment Goal - Key Points

India's Clean Air Act and related legislation sets out targets for air quality, but these can only be met if the actions that produce emissions are either limited or replaced by lower-emission ways of achieving the same ends. Regulation, or defining and enforcing maximum permissible emissions for certain activities (such as vehicle emissions standards or industrial emission controls) can only go so far in producing these outcomes. Many of the activities that produce emissions – household cooking, for example - cannot reasonably be banned without specific investment in enabling alternatives. In other cases, the economic burden of forcing individuals to replace banned activities or technologies is neither politically viable nor socially just. Consider small and informal businesses, for example, that may be using polluting energy sources because they do not have access to cleaner fuels at a reasonable cost. Third, the social costs of private, individualized, emissions reduction can be higher than collective emissions reduction. A mass shift to lower-emission vehicles, for example, would still mean congestion and road deaths. Better end-to-end integration of public transport, on the other hand, would reduce air pollution and have other co-benefits. In short, infrastructure investment is an important part of air pollution strategies and needs to be seen and incentivized as such.

India currently has a process for project-level Environmental Impact Assessments (EIA), but does not have any form of formal consideration of air quality impacts or benefits for larger programmatic investments. This is an important oversight, since public investment in infrastructure and services can offer significant clean air returns, particularly if technologies and processes that minimize emissions are chosen. The absence of a project focus on clean air returns means that an important lever for pollution reduction does not often get used.

Moving to programmatic review requires first, policymakers to have the capability to systematically review projects and groups of projects or policies for projected consistency with clean air goals; and second, for this review to be a formal, credible, and enforceable, part of the investment and permitting process. Strengthening monitoring, emissions inventories, and modeling as discussed in Section 2 is an important foundation for ensuring that public investment is better directed toward choices that generate clean air returns.

Our preliminary recommendations are to:

- **Strengthen and standardize air quality assessments built into current EIA guidelines.** The recommendations made earlier on monitoring and emissions inventories will strengthen the field application of the existing EIA process. In addition, more focused compilation of ex-post assessment data for representative projects would help to inform ex-ante reviews.

- **Introduce programmatic-level analysis of clean air benefits into urban and other investment initiatives beyond the National Clean Air Action Plan.** Urban, energy, transport, agriculture, and other infrastructure sectors have a strong role to play in reducing emissions. The choices that are made about technology and processes should be better motivated to keep clean air as a goal in addition to meeting the immediate infrastructure purpose. At times the clean air option will cost more than business as usual, but this incremental cost should be more systematically compared to the air quality benefits that that could accrue.

- **Open an evidence-based financing window for to provide incremental funding for demonstrated clean air co-benefits stemming from project choices.** Such a window would allow more flexibility for state and local leaders to make choices that improve air quality. This financing window could, for example, allow commissioners to access clean air funds to ensure a fully segregated waste cycle, with appropriate investment in showing emission reduction.

4.0 Airshed Governance – Key Points

Air quality in a state depends on emissions within that state and from upwind states. Criteria air pollutants such as ozone (O3), particulate matter (PM) of an aerodynamic diameter smaller than 2.5 µm (PM2.5) or 10 µm (PM10), and precursor species (e.g., carbon monoxide, nitrogen dioxide, and black carbon etc.) have lifetimes ranging from about a week to more than a month – more than enough time to move across administrative boundaries and combine with emissions from other sources. A single state may be both a recipient (receptor) of pollution from other states and a contributor (source) of pollution to others. For instance, if the winds are north-westerly in the Indo-Gangetic Plain, Punjab and Haryana will act as a source region for Delhi (which is receptor of pollution from Punjab and Haryana) while Delhi will act as a source region for the receptor Uttar Pradesh and beyond.

Figure 3-8 illustrates some of these relationships for Black Carbon (BC) and carbon monoxide (CO), an ozone precursor as well as an often-used indicator for other pollutant traveling through the atmosphere.

Figure 3: Time series of contribution from different states also marked by their respective regions (marked by dotted lines) to average surface CO mixing ratios over Delhi.

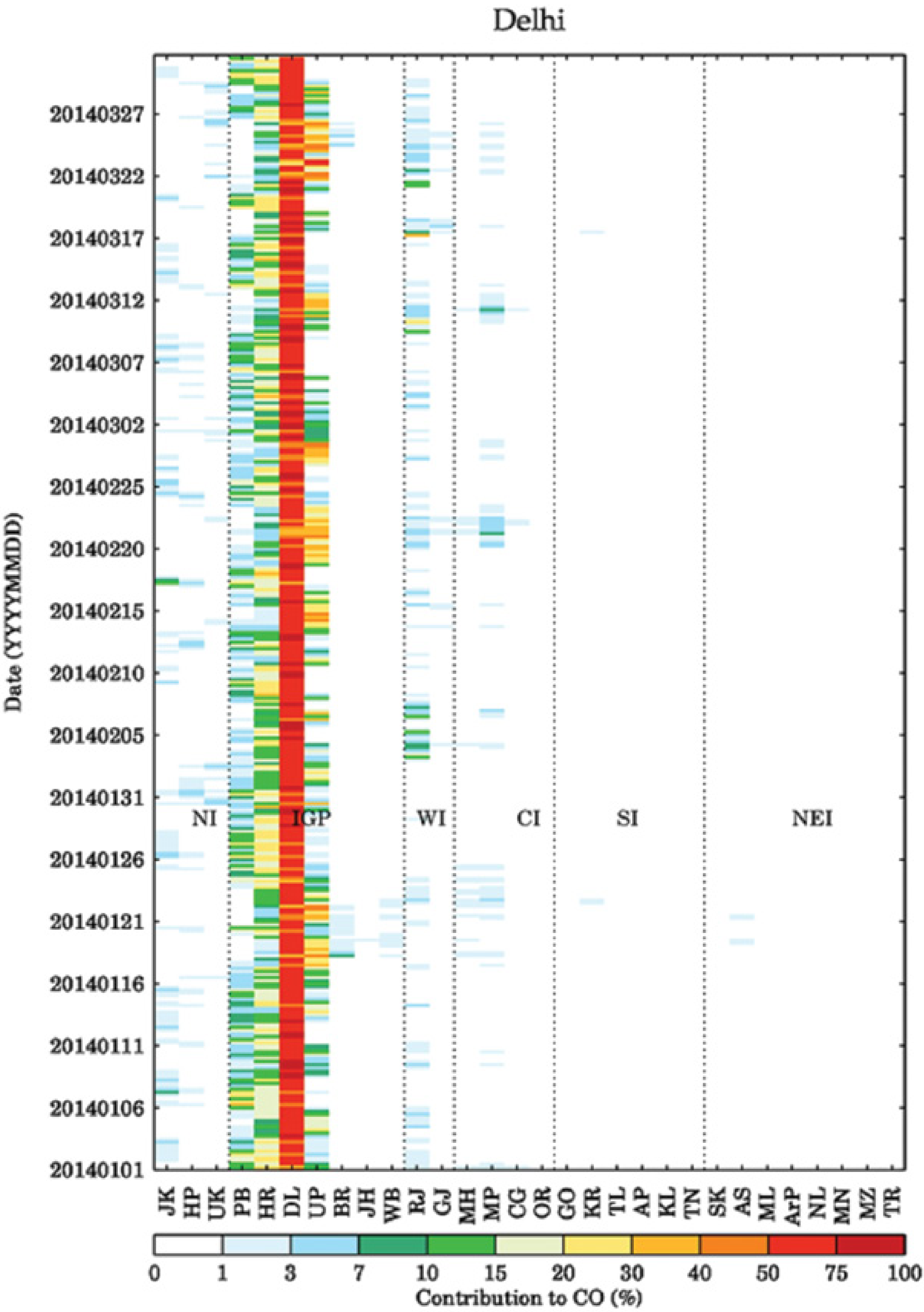


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Figure 4: Time series of contribution from different states also marked by their respective regions (marked by dotted lines) to average surface CO mixing ratios over Mizoram.

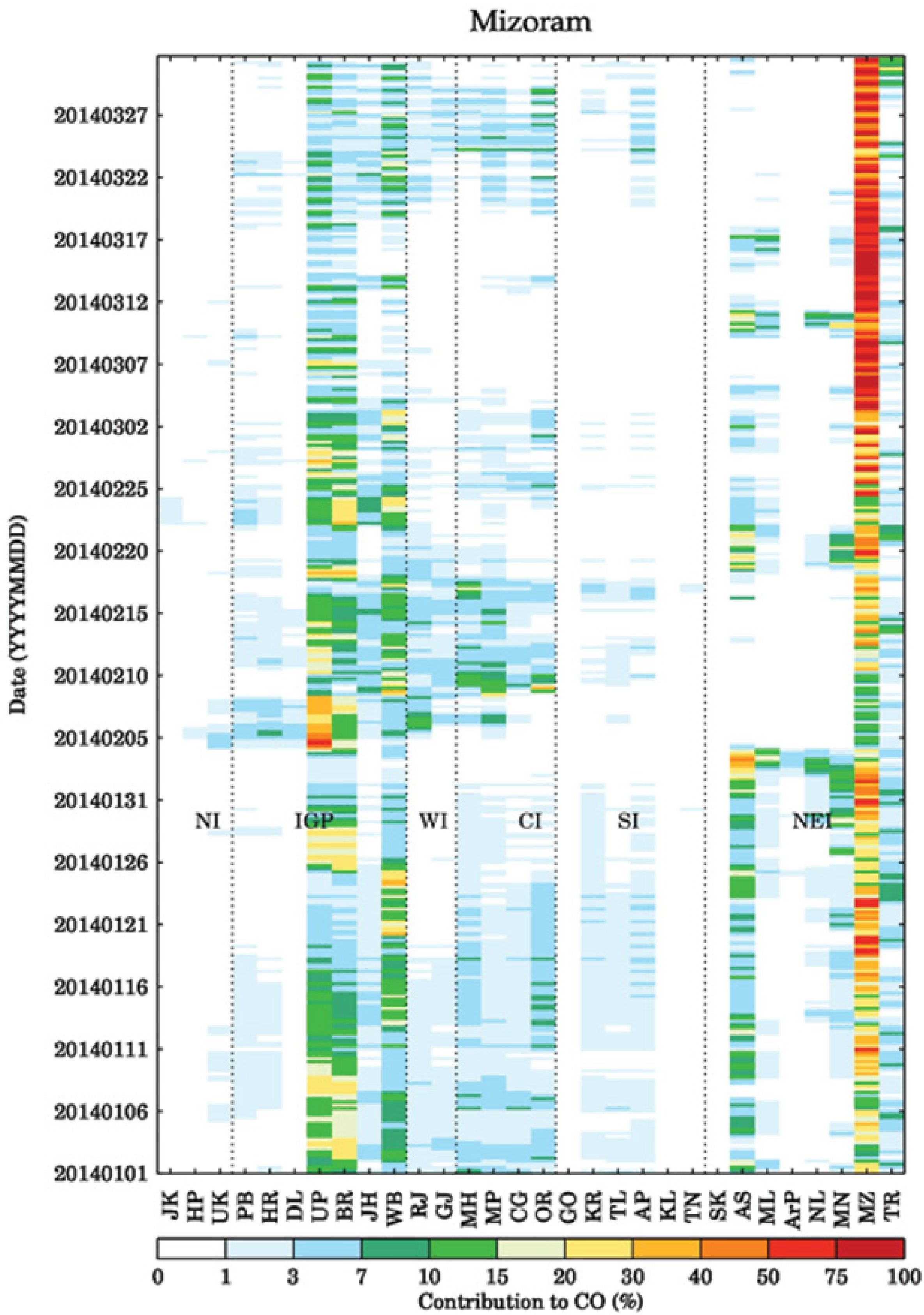


Figure 5: Time series of contribution from different states also marked by their respective regions (marked by dotted lines) to average surface CO mixing ratios over Kerala.

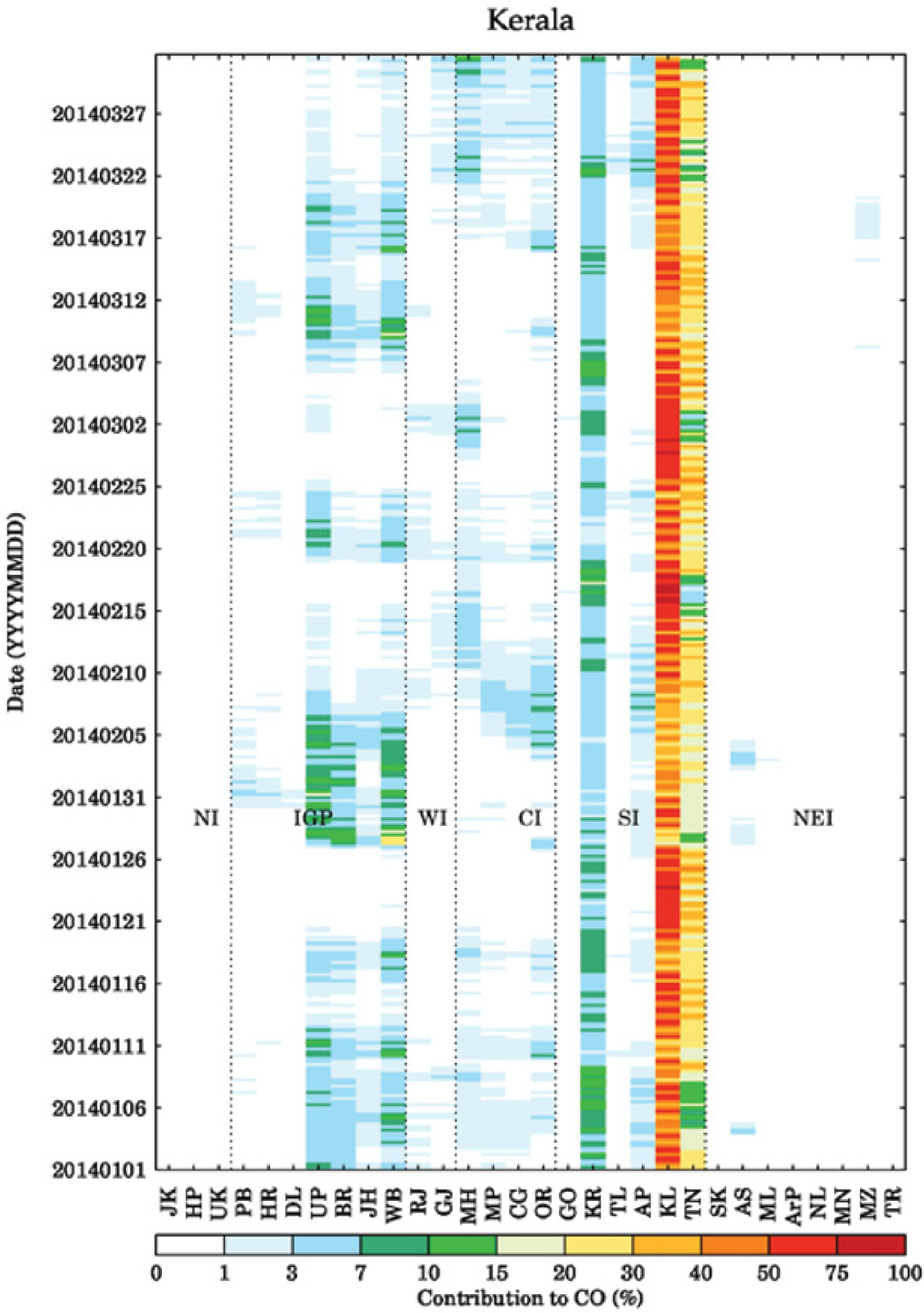


Figure 6: Time series of contribution from different states also marked by their respective regions (marked by dotted lines) to average surface BC mixing ratios over Delhi.

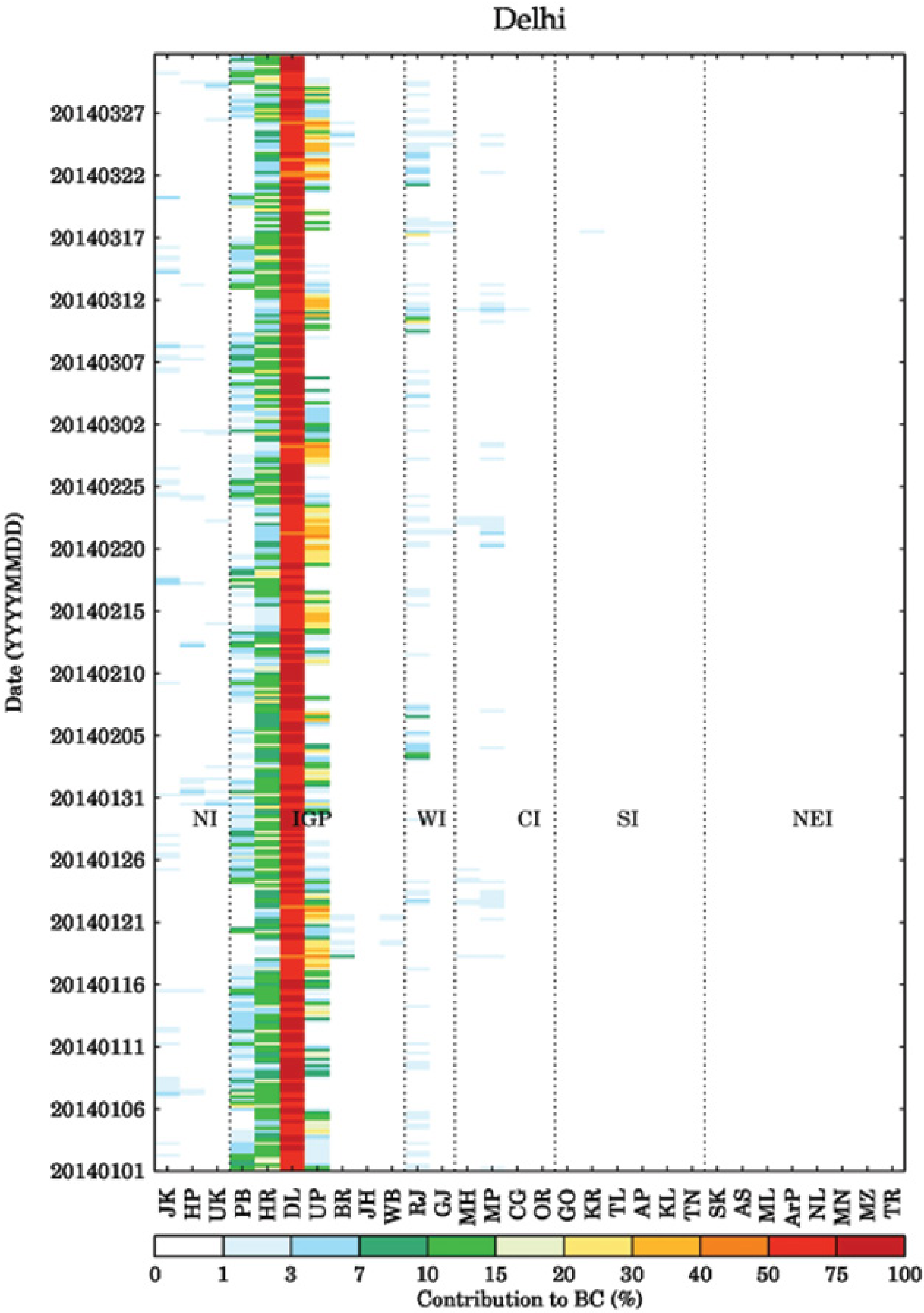
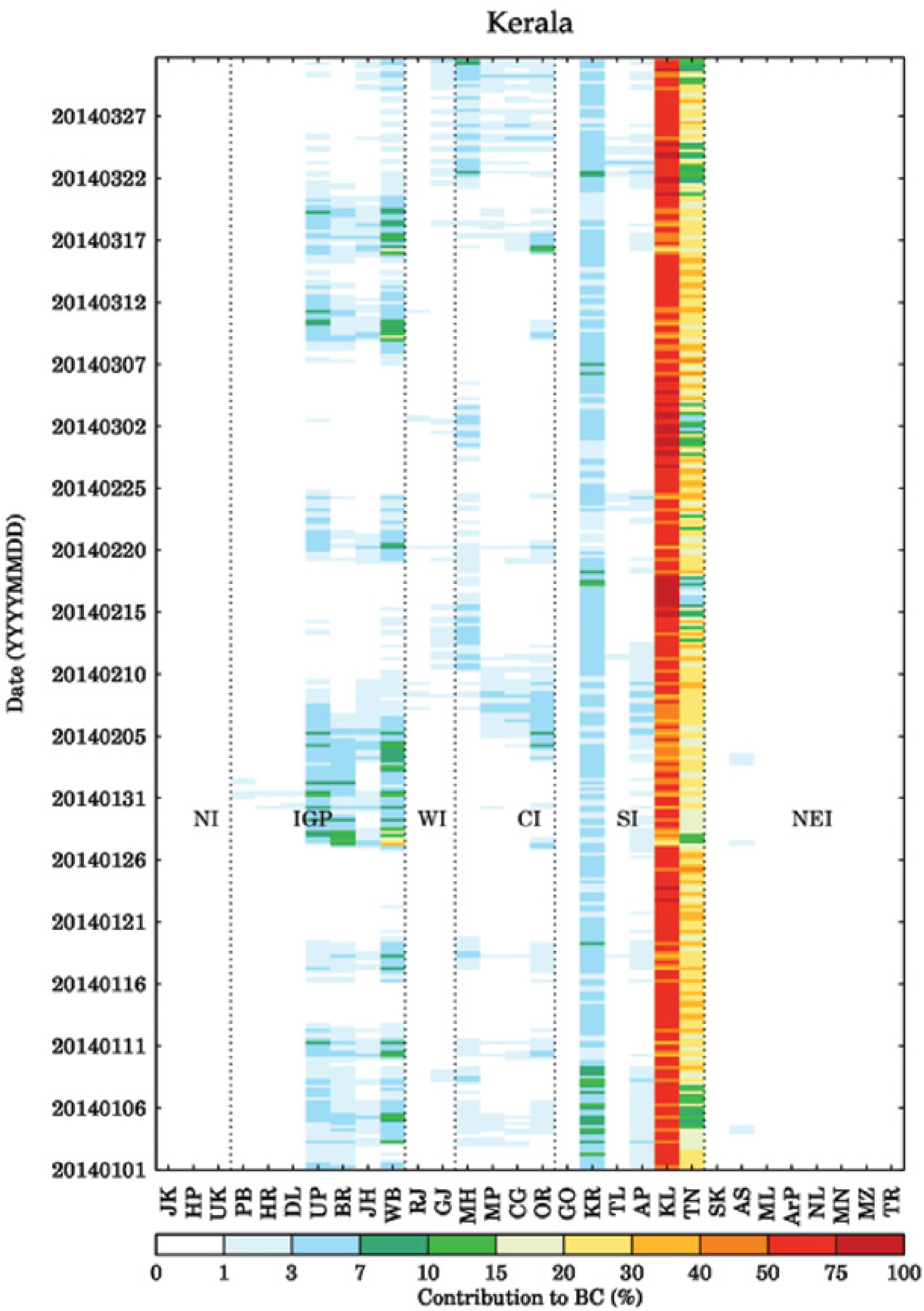


Figure 8: Time series of contribution from different states also marked by their respective regions (marked by dotted lines) to average surface BC mixing ratios over Kerala.



This analysis builds on a larger body of evidence that air pollution in nearly any given place is a function of emissions that take place outside that state or city. The evidence from both receptor and chemical tracer methods is clear: source-receptor relationships between states vary seasonally and are often significant, with upwind regions providing a majority of a given jurisdiction's pollution.

This reality has driven ad hoc interactions between states. In some cases, both the identification of interstate transport and the response to it is informal: in background interviews we heard of cases in which researchers were consulted by state pollution control board members, who then then conferred with counterparts in other PCBs after receiving a kind of informal forensic analysis. These kinds of interactions are valuable and deserve further recognition and support. Shared airsheds are also more formally recognized in some aspects of pollution control. The National Green Tribunal, for example, regularly issues multi-state orders to Delhi, Rajasthan, Haryana, Punjab, and Uttar Pradesh to curb pollution in the shared airshed (NGT, 2018; NGT, 2016). Union government oversight of state air pollution control also convenes state leaders to develop joint action plans at times (NGT, 2018). There is, however, no formal mechanism for cities, states, or regions to work with other regions on airshed-level plans. Interstate and inter-jurisdiction movement of air cannot be ignored.

Airshed management that recognizes the fact that air pollution is the cumulative impact of multiple in and trans-boundary activities, is a more step for India to take. The extent of air mixing means that the prospects for obtaining clean air from single-jurisdiction action are slim. Political and fiscal incentives aimed at driving clean air action will be inherently limited in the results that they can produce if policymakers do not have a relatively frictionless way to advance emissions reductions outside of their jurisdictions. Strengthening incentives for cities in particular to act without increasing their ability to influence pollution sources outside their boundaries may also backfire. It is a basic finding of mechanism design that strong incentives for effort do not work without some degree of certainty that effort produces results. The prospect of taking costly action for no reward (if the effort is offset by some random error, or, in the case of air quality, a shift in winds or weather) discourages effort. It is also basic political economy. Cities that miss air quality targets always have others to blame. Airshed based air quality management also has several administrative advantages; for example, it deals with air pollution sources with area-wide uniformly approach, enforcement, and standards. This allows workforce and research facilities to be utilized in more effective way and avoids duplications and delays.

Our preliminary recommendations in this section draw on the history of airshed-level institutions, with particular reference to the cases selected as having relevant lessons for India. The Mexico City and Los Angeles air quality management approaches offer a model for city-driven air quality management; while the LRTAP, an international agreement, has design features are well suited to India's federal context and the extent of multi-state air pollution transport, particularly in the north.

- **Use NCAP funding to leverage metropolitan regional action rather than city-specific action plans.** Funding that supports multi-jurisdiction collaboration will have higher leverage than funding that simply duplicates existing infrastructure flows. Mexico City's CAM-e offers a model for informal collaboration, while the Los Angeles South Coast Air Quality Management district is a more structured option. Both were formed and expanded on the basis of scientific findings about the size of the relevant airshed.

We also recommend taking progressive steps toward institutionalizing airshed management. The case studies in Appendix 1 illustrate three different trajectories for building inter- jurisdictional joint action. The basic steps in their evolution are captured below.

- **Appoint an expert working group with representatives from MoEF&CC, Ministry of Earth Science, and relevant academic institutions to develop a shared air quality model for assessing transboundary air pollution flows and their impacts in India.** A credible common model is an important precondition for shared management of an airshed. It helps policymakers assess the relationships between pollution sources and receptors in a transparent manner so that effort can be directed at improving air quality rather than verifying pollution causes. The emphasis on impacts not only helps to explain action to the public but ensures that control measures are determined with the end goal in mind. New models attuned to India's meteorological conditions, combination of primary emissions, and other unique aspects of the context, are also important for enabling airshed-level management. Models must be improved especially for better representation of India's meteorological conditions, combination of primary emissions, and better representation of atmospheric chemistry. are also important for enabling airshed-level management.

- **Ease inter-state collaboration - Develop an informal working group of state and city leaders, particularly around pollution hotspots, to discuss non-binding joint action.** The LRTAP and SCAQMD cases illustrate that airshed level institutions can be self-reinforcing, once a minimal space for dialogue is created. In both cases, local jurisdictions under pressure to comply with regulations and respond to political demands were strongly motivated to identify they best ways to achieve this; and the institutional architecture for dialogue helped. Mexico City's metropolitan-level collaborations developed from a similar dynamic of pressure to solve a problem leading to incentives to collaborate – which happened faster when there were formal channels to do so. Such collaboration can lead to more formal cooperation as trust is built. The SCAQMD was divided into county agencies when it was first formed, but quickly shifted to a more integrated structure with more formal joint decision-making (described below) and informal interaction through workshops, calls, and working relationships.

- **Create a more formal coordinating body under the auspices of the NITI Aayog or similar federal institution.** LRTAP was initially conceived as a flexible framework for cooperation on a problem that had clearly been proven to be one that extended past country boundaries. Scientific studies had documented the transboundary nature of pollution by the 1960s and 70s, but policymakers were not prepared for joint action until somewhat later (Kjetil Tørseth, 2019). As the effects of pollution on forests (affected by acid rain), fish death, and other environmental damage become more apparent however, the attention shifted toward finding a solution. Questions about whom to blame and the growing understanding of the transboundary nature of the problem motivated much of the investment in further air pollution modelling that then, in turn, became the basis for joint action (Peringe Grennfelt, 2019). The framework has grown into a platform through which binding obligations are negotiated and monitored. Parties to the Convention have agreed upon eight protocols over time to reduce emissions of ground-level ozone, persistent organic pollutants, heavy metals and particulate matter related to industrialization, agricultural modernization, and fossil fuel consumption. Some of the protocols involve multiple emissions.

5.0 Case Studies – Summary of Key Findings

5.1 Los Angeles Metropolitan Region: South Coast Air Quality Management District

This case study highlights a number of important drivers of strong air quality management for a metropolitan region with pollution stemming from fixed and mobile sources in a challenging topography that allows limited natural "clean out."

The Los Angeles County Board of Supervisors appointed a Smoke and Fumes Commission in 1943 to study the problem. By 1947, multiple studies, many from local university California Institute of Technology (CalTech), demonstrated that air pollution was the combined product of a range of sources from multiple cities and that separate local efforts were ineffective against such a regional program. The nation's first air pollution control district, the Los Angeles County Air Pollution Control District, was formed in 1968 in response to the scientific finding. (The federal Environmental Protection Agency was formed slight later in 1970).

During the following decade, air pollution control districts (APCDs) were formed in Orange County, Riverside and San Bernardino counties. These had the joint task of developing investment plans consistent with meeting state and national clean air goals, and, in 1977, the four county agencies were combined to form the South Coast Air Quality Management District (SCAQMD) through adoption by the California Legislature of the Lewis Air Quality Act (now known as the Lewis-Presley Air Quality Management Act). The new agency was charged with developing uniform air quality management plans and programs for the South Coast Air Basin, consistent with federal planning requirements.

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Today, the Los Angeles metropolitan area is home to over 16.8 million people about half the population of the state of California. Although it remains one of the more polluted areas in the United States, the region has made tremendous progress (SCAQMD, 2017). Some of the factors involved in its success include:

- **Time and resources over the long term are a key to success:** The State of California and SCAQMD invested over decades to address a wide variety of sources including industry, power generation, vehicle emissions, the port and shipping industry, and home heating, etc. These policies often went beyond federal required mandates.

- **A single district cannot manage air quality alone; a unified regional wide strategy over the entire airshed is required.** State-level agency California Air Resources Board put in place the formal process that mandated airshed-level control strategies, but local districts used the process in order to achieve clean air goals that their residents and federal regulators were seeking to motivate. This framework helped to drive cooperation and collaboration across sectors, local agencies, and stakeholder groups, in terms of policy and application of financial and human resources.

- **Robust application of monitoring and modeling data.** The comprehensive modeling and emission monitoring done by SCAQMD provides important data for not only measuring progress in achieving standards but has been used to address larger challenges around cumulative risk, vulnerable populations, and development impacts.

- **Incentive funding can drive implementation and development of new technologies.** Developing and leveraging innovative funding mechanisms focused on achieving air quality outcomes rather than specific emission control technologies helped to ensure both agencies and specific stakeholders had both the incentives and the resources to meet pollution control requirements.

- **Strong public participation, enforcement and political will are critical enabling factors.** Although spurred by a crisis, California has been able to sustain the political will to address air quality over decades, without sacrificing economic opportunity. The backdrop of clear communication, transparent action, and frequent interaction with stakeholders has built trust that has, in turn allowed agency management staff to more effectively apply strong scientific analysis and data to drive policy making. The investment in quantifying health impacts of air pollution also helped to justify compliance costs by showing a clear offsetting benefit.

Figure 3: South Coast Air Quality Management District

- **Strategic use of Advisory Committee.** SCAQMD utilizes a wide variety of Advisory Committee to help coordinate and develop the range of policy, technical, and modeling practices required for an effective AQMP. The transparency around the membership and operations as well as the specific mission and responsibilities of each group creates an important accountability and implementation driver that ensure their expertise is appropriately incorporated into the planning process.

5.2 Mexico City Metropolitan Area: SEDEMA & the Metropolitan Environmental Commission (now Megalópolis Environmental Commission, CAME)

Thanks to decades of industrialization, a growing population and a geography of high mountains and frequent thermal inversions, air pollution in Mexico City and its surrounding Metropolitan Area (MCMA) was infamous by the 1990's. The region was singled out as the most polluted megacity in the world by the World Health Organization (WHO) and the UN Environment Programme (UNEP) in 1992. Dense smog and endless traffic jams plagued the millions of people living there, causing respiratory problems and other health impacts, school closings, and a huge public outcry (Luisa T. Molina & Mario J. Molina, 2002).

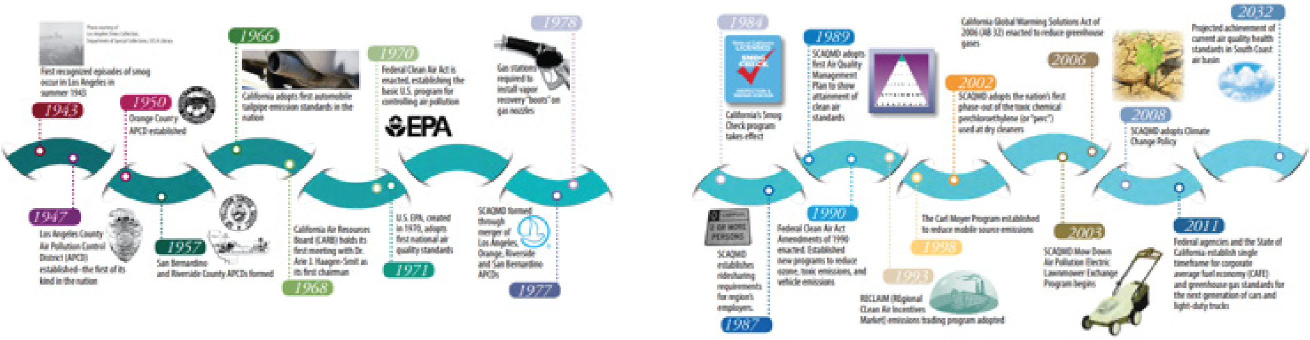
Since that time, the greater metropolitan area has made great strides in reducing air pollution. According to the 2018 Air Quality Life Index, for example, particulate matter pollution has declined by 57% since the introduction of the 1990 air policies—allowing residents to live more than two years longer ("AQLI Policy Impacts—Mexico City," n.d.).
A combination of innovative air quality management plans, utilization of sophisticated air quality monitoring systems, strong government and scientific coordination and technical partnerships across jurisdictional boundaries have allowed the city to focus on "win-win" strategies that promote social development as well as environmental benefits.

Mexico City's success in reducing air pollution is grounded in a political commitment to address air pollution, coordination with federal government and surrounding states to develop a regional approach to air quality, and a comprehensive air quality management program that leverages scientific expertise to drive innovations. Key factors of success include the following:

- **Investment in extensive ambient air quality monitoring and emissions inventory program data has greatly expanded the evidence base for policy making.** Data and knowledge about ambient air pollutants and sources of emissions have been key elements to update regulations and set emission control priorities to protect public health and the environment. Based on these two elements, an air quality model was developed to forecast air quality every day to inform the population in a timely manner to reduce risk of exposure. The air quality model is also being used to build scenarios to evaluate cost-effectiveness of the different actions to improve air quality.

- Public-private and international scientific partnerships have accelerated the evidence base. The use of outside expertise in conjunction with special field studies and strong scientific partnerships has provided new insights on emission sources and air

Figure 4: Air Quality Historical Timeline.



pollution science that have not only informed local strategy but have had broader global impact.

- Air quality management strategies that leverage evidence in dialogue with the public have been effective. The partnership with local scientists and from the Harvard School of Public Health to document the benefits toward public health and the sharing of air quality information to the public is an important tool for designing, implementing and evaluating air pollution control policies.

- Health impacts of air quality improvements over the last three decades are well documented thanks to all these years of strengthening health effects and air quality monitoring and generating robust data on health and pollutants concentrations in Mexico City. Due to air quality improvements from 1990 to 2015, 22,500 premature deaths have been avoided and life expectancy has increased to 3.5 years for Mexico City inhabitants.

- The different types of coordination that have been implemented, even the first informal, but regular, regional coordination has shown benefits over time. The coordinating body for the Mexico City metropolitan area has grown to include more stakeholders from science, civil society, and levels of government from city to national and evolved to have a more formal role in building consensus in the region recognizing air pollution as an air shed problem in which many actors are involved in both its causes and solutions. Regional and multi government level coordination remains relatively weak in terms of budget and enforcement powers but has still brought coherence to the city airshed air quality management.

- Regional coordination on financing is important. Recognition of the need to finance the coordination and harmonizing of monitoring programs across the region has created a clear set of recommendations that, have not yet been implemented in full but could allow MCMA or even the megalopolis region to improve implementation of PROAIRE and improve air quality in the whole region.

- The key ahead will be to not only continue to improve the monitoring, modeling and emission inventory methodologies and approaches but find the funding and political will to incorporate this evolving science into air quality management plans in a manner that supports effective implementation and measured reductions of air pollution faster.

5.3 The Convention on Long-Range Transboundary Air Pollution (LRTAP)

The Convention on Long-Range Transboundary Air-Pollution (LRTAP) was established to address acid rain in 1979 under the auspice of United Nations Economic Commission for Europe (UNECE). It was intended to protect humans and the environment against air pollution and ultimately reduce and prevent air pollution including long-range transboundary air pollution. Entered into force in 1983, 32 countries across Europe, along with the United States and Canada, signed the original LRTAP convention. To date 51 countries are party to the convention.[7]

LRTAP remains a widely recognized example of how close coordination between scientists and policy makers can drive effective action and achieve documented reductions in air pollution across jurisdictional boundaries in an airshed. Key factors in success include:

- LRTAP has demonstrated over the last four decades, that policy and science should not be viewed as separate – science and the co-production of policy in fact can be a tool that fosters political cooperation as parties to an agreement jointly discover the most effective responses to a visible shared problem.

- LRTAP developed and has used the critical loads concept, a metric that focuses efforts on reducing the impacts of pollution rather than controlling emissions per se, as an entry point for better coordination and negotiation. The focus on determining the best strategy for reducing air pollution impact also help to drive integration between science and policy.

- The consistent generation and free exchange of data between participating countries, within the well-functioning European Monitoring and Evaluation Program (EMEP) was a crucial driver of progress.

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[7] Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia & Herzegovina, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, European Union, Finland, France, FYR of Macedonia, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Montenegro, the Netherlands, Norway, Poland, Portugal, Rep. of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States of America.

- The ability of LRTAP to drive political and policy negotiations was grounded in its dynamic organizational structure that provided significant opportunities for scientists, policy makers, and politicians to communicate and engage in peer learning.

- The use of external commitments, workshops, evaluation space within the Executive Body, and outside assessments created a reflective, adaptive, and flexible decision-making environment. The outcomes of these reflections were widely and effectively communicated through institutionalized mechanisms to help shape broader knowledge as well as understanding and acceptance of control measures.

- Efforts under LRTAP have resulted in valuable science-policy interfaces and infrastructures and have formed an important knowledge base for emission inventories, models, observations and impact assessments of pollutants. This infrastructure allows scientific facts to shape political decisions and also helps drive compliance with protocols under LRTAP.

- The LRTAP Convention arose to tackle the challenge of international cooperation on the transboundary part of air pollution. This remains its greatest challenge but also but also the area in which the institutional lessons is offers are most applicable for air quality improvements around the world.

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ACKNOWLEDGMENTS

We thank many people named, and unnamed for their inputs and reviews of versions of this paper. These include, without implicating them in any errors or omissions, OP Agarwal, Director, WRI India; Madhav Pai, Director, Cities, WRI India; Professor Vinayak Sinha, IISER Mohali; Professor Baerbel Sinha, IISER Mohali; and Dr. B. Sengupta, former Member-Secretary Central Pollution Control Board (Selected inputs as noted). We thank Bhavay Sharma, Associate, WRI India for his contributions to the report.

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