

# Responses to interactive comments

**Journal:** Atmospheric Chemistry and Physics

**Manuscript ID:** acp-2020-903

**Title:** “Impact of reduced anthropogenic emissions during COVID-19 on air quality in India”

Dear Dr. Sharma,

We appreciate your comments to help improve the manuscript. We tried our best to address your comments and detailed responses and related changes are shown below. Our response is in blue and the modifications in the manuscript are in red.

**Comments:** The paper presents the percentage reduction in concentrations of air pollutants (PM<sub>2.5</sub>, O<sub>3</sub>, CO and NO<sub>2</sub> etc.) in India during lockdown period using ground observations (at Delhi, Lucknow, Kolkata, Ahmedabad, Mumbai, Hyderabad, Bangalore and Chennai during 21 February to 24 April 2020) and air quality models (WRF and CMAQ). The paper also described the percent reduction in secondary inorganic aerosols/species of PM<sub>2.5</sub> over the region. A quick search on the web shows numerous studies on these lines published in the various reputed journals over Delhi and other locations of India. Some of them are cited in the present papers. A comprehensive study on the air quality of India during and before lockdown period has been carried by Kumar et al. (2020) in Sustainable Cities and Society (2020): 102382 and they have also compared most of the recent studies.

The only advantage of this manuscript is that the authors have used the 7 stations ground based observation datasets (PM<sub>2.5</sub>, O<sub>3</sub>, CO and NO<sub>2</sub> etc.), validated the WRF and CMAQ models and extrapolated the pollutants for the country. This advantage gives the merit for publication of the paper in journal. However, the following points may also be considered before publication in ACP.

**Response:**

We appreciate the positive comments and helpful suggestions from Dr. Sharma on this paper. Below is the response to each specific comment.

**Comments:** Authors are suggested to search all the recent articles published on these line in various journal over Indian and other region of the globe and make a summary Table and include in Introduction

section. Also highlights how the present study is different from the previous studies as well new scientific information are going to be add in existing knowledge.

**Response:**

Thanks for the comments. The summary Table including recent studies about COVID-19 has been summarized by Kumar et al. (2020) (Table 1 in their paper) comprehensively before, so we didn't duplicate the table in our manuscript. In the revision, more discussions about previous studies are added to reinforce the comparison with previous studies in the Introduction section.

**Changes in manuscript:**

**Introduction (Lines 52-53 in the revision):** “Therefore, it is significant to understand the mechanisms involving in air pollution formation before and after dramatic emission changes comprehensively, in addition to the comparison of air pollution levels.”

**Introduction (Lines 55-56 in the revision):** “Srivastava et al. (2020) reported the concentrations of primary air pollutants are drastically lowed as a result of emission reduction.”

**Introduction (Lines 57-59 in the revision):** “These studies pointed out that the air quality was improved during the lockdown period compared with the period before lockdown and depends on the duration of the lockdown (Kumar et al., 2020; Mor et al., 2021).”

**Introduction (Lines 59-64 in the revision):** “Besides, compared with the same period in previous years, Gautam (2020) claimed that aerosol concentration levels are at their lowest in the last 20 years during lockdown based on satellite data. Selvam et al. (2020) stated that Air Quality Index (AQI) was improved by 58% in Gujarat state of western India during lockdown (March 24, 2020 – April 20, 2020) compared to 2019. Kabiraj and Gavli (2020) concluded that the mean concentration of PM<sub>2.5</sub> decreased by 42.25% from January to May in 2020 compared with 2019. Similarly, Das et al. (2020) also showed that great reductions of PM<sub>2.5</sub> were found across cities in the Indo-Gangetic Plain (IGP) compared with 2018 and 2019.”

**Comments:** A number of publications are published recently on temporary reduction of concentrations of pollutants over India and other country during lockdown period. Hence, the present paper should be scientifically different and should add new information for scientific community.

**Response:**

We appreciate the comments. We comprehensively evaluate the impact of the nationwide lockdown on air quality in India, which also provides reliable recommendations for the improvement of emission reduction policies.

First, we determined the response of air quality in India under the synergetic impacts from the meteorological conditions and anthropogenic emissions during the pre-lockdown and lockdown periods. For instance, we directly quantified the change in air quality during lockdown due to the reduced anthropogenic emissions through differences between Case 1 (without emission reductions) and Case 2 (with emission reductions) during the lockdown. This casts lights on the policy implementation in India, which may help to mitigate air pollution in the future.

Second, we are the first study that explored the impacts of COVID-19 lockdown on Indian air quality on a regional scale. It allows us to figure out the changes of primary and even secondary pollutants during two periods (pre-lockdown and lockdown) and illustrate their differences in urban and rural areas. This could be a great help to formulate the city-level control policy in India.

Third, in atmospheric chemistry, we developed a better understanding of the secondary pollutants formations by investigating their non-linear responses to the precursors' changes during the lockdown. In particular, the sensitivity of PM<sub>2.5</sub> secondary components (Fig. 6 in the revised manuscript) and the change of spatial distributions of O<sub>3</sub> production sensitivity (Fig. S5 in the revised supplement) due to emission changes during the lockdown give us a more in-depth discussion on secondary pollutants.

In the revised manuscript, we added such information to the Introduction to make it clear.

**Changes in manuscript:**

**Introduction (Lines 64-68 in the revision):** “However, the role of meteorological conditions and chemical reactions involving changes in air quality is not clear from these observation-based studies, which only showed the phenomenon of concentration reduction and switch of major primary pollutants mainly in urban cities. Further, the number of monitoring stations in the country is way below the guidelines by the governing bodies and not uniformly distributed, which results in observation data limitations in India (Sahu et al., 2020).”

**Introduction (Lines 69-74 in the revision):** “In this study, the Community Multi-Scale Air Quality (CMAQ) model was used to investigate changes in air pollutants during the pre-lockdown (from February 21, 2020 to March 23, 2020) and lockdown (from March 24, 2020 to April 24, 2020) periods throughout Indian region. We explored the synergetic impacts from the meteorological conditions and

anthropogenic emissions during the pre-lockdown and lockdown periods. Besides, we directly quantified the change in air quality during the lockdown due to the reduced anthropogenic emissions by comparing the differences between Case 1 (without emission reductions) and Case 2 (with emission reductions).”

**Conclusion (Lines 308-309 in the revision):** “However, more stringent mitigation measures are needed to achieve effective control of air pollution from secondary air pollutants and their components, particularly in rural areas.”

**Comments:** Conclusion sections may be improved with avoiding the repetitive information from the abstract.

**Response:** Thanks for the comments. We removed duplicate information from the Conclusion section and added policy recommendations.

**Changes in manuscript:**

**Conclusion (Lines 304-305 in the revision):** “The drastic decline in PM<sub>2.5</sub> and its major components during the lockdown period in Case 2 compared with Case 1 shows the positive impacts of emission control measures, especially for SIA.”

**Conclusion (Lines 308-309 in the revision):** “However, more stringent mitigation measures are needed to achieve effective control of air pollution from secondary air pollutants and their components, particularly in rural areas.”

## Reference

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