Introduction

Here we show the results for events with excess NO, results for calculation of aerosol surface area and the rates for aerosol uptake, mixing ratios of NO₃, N₂O₅ and ClNO₂, Isoprene reactivity and daytime NO₃ loss, and comparison of NO₃ production rate to other measurements around the world.

Excess NO and low ozone event

Nitric oxide, NO, plays a dual role in regulating the atmospheric oxidation capacity. At moderate levels, it promotes the recycling of OH through reaction with HO₂ and increases its oxidation rates. At very high concentrations, NO titrates ozone, especially
during nighttime, and suppresses the production of both OH and NO₃, thus reducing the atmospheric oxidation capacity.

Events of high NO (>5 ppbv) and low ozone (<30 ppbv) occurred in almost 17% of the measurements (Figure S1) taken during the period before the lockdown. During these events, secondary production is low due to the low mixing ratio of ozone, which leads to a low mixing ratio of OH and NO₃. Figure S10 shows the average diel cycles during these events and the model results.

**Figure S1.** Occurrence percentage of nighttime events before the lockdown, during the strict lockdown, and upon lockdown relaxation. The ozone is titrated with a high NO mixing ratio (the first category); averaging of the “before” period with these conditions will obscure the nighttime chemistry of events without high NOₓ.
Figure S2. Events before the lockdown with excess NO that end with a full titration of ozone. Top panel – NO and ozone measurements during the period before the lockdown; the rectangular on the upper left denotes these excess-NO events occur. Bottom panel – the entire NO and ozone measurements in the period before the lockdown; shaded areas mark the excess-NO events.

Aerosol uptake coefficient

In order to determine the effect of the aerosol uptake coefficient on the nighttime oxidation cycles, we modeled the main results using three different values of the uptake coefficient (0.001, 0.01, and 0.04). This is necessary due to lack of N$_2$O$_5$ measurements that could be used to constrain $\gamma_{N_2O_5}$. However, the selected range encompasses the distributions found in urban influence air on other continents. The uptake coefficient is affected by many factors such as aerosol water content, aerosol composition, organic coatings and other atmospheric conditions. This non-linear relationship between $\gamma_{N_2O_5}$ and other atmospheric factors complicates its measurements and, as a result, its accurate representation in atmospheric models. McDuffie et al., (2018) used aircraft measurements over the eastern United States to empirically parameterize $\gamma_{N_2O_5}$. Yu et al., (2020) used a similar approach to calculate the empirical parametrization of $\gamma_{N_2O_5}$ at four different sites in China. In the IGP, without additional measurements of species such as NO$_3$ and N$_2$O$_5$ this method cannot be applied. Figure S4 shows the model results of a sensitivity test of
three different $\gamma_{\text{N}_2\text{O}_5}$ values. The aerosol composition data required to implement existing parameterizations was not available from this study, so the sensitivity test approach is the best method to predict the dependence of model outcomes on the possible range of $\gamma_{\text{N}_2\text{O}_5}$.

Figure S3. Sensitivity test of $\gamma_{\text{N}_2\text{O}_5}$ and its resulting impact on (top to bottom, left to right): $\text{N}_2\text{O}_5$ heterogenous uptake, $\text{NO}_3$ lifetime, inorganic to organic ratio, $\text{NO}_3$ concentration, $\text{N}_2\text{O}_5$ uptake rate, calculated maximum potential ClNO$_2$ production, $\text{NO}_3$ production, and $\text{N}_2\text{O}_5$ concentration. The $\gamma_{\text{N}_2\text{O}_5}$ has little effect on the 50th percentile of $\text{NO}_3$ lifetime, $\text{NO}_3$ and $\text{N}_2\text{O}_5$ concentration after the lockdown relaxation.

The results of the sensitivity test show that although the impact on the nighttime chemical cycle vary in magnitude, the overall trends between the three studied periods remain unchanged. For example, median $\text{NO}_3$ reactivity is quite sensitive to the $\text{N}_2\text{O}_5$ uptake coefficient in the top left panel, leading to large changes in its predicted overnight lifetime. However, as expected, it scales less than linearly due to other $\text{NO}_3$ loss processes (i.e., a fourfold increase in the uptake coefficient leads to less than a fourfold increase in the $\text{NO}_3$ reactivity). Similarly, the maximum potential ClNO$_2$ production
scales with the uptake coefficient, such that a fourfold increase leads to a 45% increase in potential ClNO₂ production. These results demonstrate the need for in-situ measurements of NO₃, N₂O₅ and ClNO₂ in the Indo-Gangetic Plain to constrain the magnitude and branching of nighttime chemical processes.

Figure S4. Diel average of the calculated surface area from measurements of PM₂.₅ and PM₁₀ (top), N₂O₅ first-order loss rate (middle) and NO₃ first-order loss rate (bottom). The shaded area shows the standard deviation. The high NO₂ mixing ratio before the lockdown highly affects the NO₃ uptake onto aerosols.
Figure S5. Box and whisker plot distributions of the production rate of the nitrate radical, P(NO₃), during nighttime in Seoul during 2015, in Los Angeles during 2010 (Brown et al., 2017), and in Mohali during the three lockdown periods studied in 2020. Horizontal lines are 25th, 50th and 75th percentiles, whiskers are 10th and 90th percentiles. The calculations from Seoul, Los Angeles, and Mohali were all from the same season (May–early June). The average NO₃ production rates in India after the lockdown relaxation exceeded those in South Korea and the US.
Figure S6. Percentage of NO$_3$ reactivity toward AVOC, NO, isoprene, photolysis, heterogeneous uptake and DMS during the period before lockdown (top), during the strict lockdown (middle) and after relaxation of the lockdown (bottom). Reduction in aerosol surface area dramatically decreased heterogeneous loss of NO$_3$ and increased its atmospheric lifetime.
Figure S7. Left panes – daytime ratios of the first-order loss rate coefficient for NO\textsubscript{3} due to reaction with isoprene, DMS and AVOC to the sum of total NO\textsubscript{3} loss to NO, isoprene, photolysis, heterogeneous uptake, DMS and AVOC before the lockdown (top), during the strict lockdown (middle) and upon relaxation of the lockdown (bottom). Right panels – the amount of produced NO\textsubscript{3} lost to isoprene, DMS and AVOC during the day before the lockdo\textsubscript{wn} (top), during the strict lockdown (middle) and upon relaxation of the lockdown (bottom).
Figure S8. Integrated maximum production of ClNO\textsubscript{2} (bottom) and the production rate of heterogeneous uptake of N\textsubscript{2}O\textsubscript{5} (top) during the four studied periods: before lockdown (brown), events of high NO and low ozone before lockdown (dashed brown), strict lockdown (red) and relaxation period (pink) COVID-19 lockdown. The highest potential ClNO\textsubscript{2} production occurs before the lockdown restrictions, during wintertime, and may reach up to 5.5 ppbv. Note that HNO\textsubscript{3} production is equal to that of ClNO\textsubscript{2} in this scenario, in which a ClNO\textsubscript{2} yield, $\phi$(ClNO\textsubscript{2}) = 1 was assumed.
Figure S9. Isoprene reactivity towards OH, ozone and NO$_3$ before the lockdown (top), during the strict lockdown (middle) and upon lockdown relaxation (bottom). The black line denotes the percentage of isoprene oxidized by NO$_3$. 
Figure S10. Diel cycles at 10-minute time resolution before COVID-19 lockdown during events of high NO and ozone titration.

The left panel in figure S11 shows the NO$_3$ reactivity during high-NO and low-ozone events before the lockdown. It is clear that due to ozone titration by NO, the chemistry is completely suppressed. Only during the early night, when NO$_3$ production is high, NO$_3$ reactivity toward heterogeneous uptake, isoprene, DMS and AVOC together is only 12.5%. This high level of NO$_3$ production at sunset also impacts isoprene reactivity, as can be seen in the right panel in figure S11, where the percentage of isoprene reactivity toward NO$_3$ peaks at 60%. However, absolute isoprene reactivity ($<0.05$ $10^{-3}$ s$^{-1}$) is much lower compared to the reactivity in the equivalent period without these events ($>0.1$ $10^{-3}$ s$^{-1}$).

Figure S11. Left panel - NO$_3$ reactivity toward AVOC, NO, isoprene, photolysis, heterogeneous uptake and DMS during events with excess NO and low ozone in the period before the lockdown. NO dominates the NO$_3$ chemistry during this period. Only a slight impact can be seen at sunset. Right panel - Isoprene reactivity
towards OH, ozone and NO$_3$ during events of high NO and low ozone in the period before the lockdown. The black line indicates the percentage of isoprene oxidized by NO$_3$. Although the isoprene loss to NO$_3$ peaks at 60% at sunset, the absolute isoprene reactivity is very low.

**NO$_3$ and N$_2$O$_5$ mixing ratio**

Figure S12 and Figure S13 show the modeled NO$_3$ and N$_2$O$_5$ mixing ratios in the surface layer and residual layer, respectively. Although the production of NO$_3$ is similar in both layers, the mixing ratio of this oxidant in the surface layer remains much smaller due to consumption from emissions in this layer. Similar trends overnight are observed (increase during the early night followed by a slow decrease until sunrise). The NO$_3$ and N$_2$O$_5$ mixing ratios during events with excess NO and ozone titration are suppressed.
Figure S12. Average relative humidity, average temperature and modeled OH, NO$_3$ and N$_2$O$_5$ mixing ratios during the four studied periods: before lockdown (brown), events of high NO and low ozone before COVID-19 lockdown (dashed brown), strict lockdown (red) and lockdown relaxation (pink).
Figure S13. Modeled N$_2$O$_5$ (top) and NO$_3$ (bottom) mixing ratio in the residual layer.
**AVOC speciation**

The speciation for the sum of C8 aromatics and sum of C9 aromatics measured using the PTR-MS were conducted in light of previous measurements from the same site conducted in summer of 2018 using thermal desorption gas chromatography flame ionization detection. Details of the analytical system including QA/QC as well as ambient measurements performed for winter, which showed similar speciation to summer of 2018, have been reported previously (A Kumar et al., 2020; Ashish Kumar et al., 2021). As these compounds are emitted primarily by anthropogenic sources the speciation of the compounds was not expected to change due to seasonality or emission decreases. The attribution of isoprene to m/z 69 and DMS to m/z 63 has also been extensively discussed in previous studies from the site, where a chemical reactor and the TD-GC-FID system were used to detect the presence of isoprene and also documented its sources at the site (V. Kumar & Sinha, 2014; Mishra & Sinha, 2020; Vettikkat et al., 2020). Thus, for sum of C8 Aromatics the speciation used in the model simulations was: ethylbenzene 50%, m/p Xylene 40%, o-xylene 10%, and the sum of C9 Aromatics the speciation was as follows: 1,2,3- trimethyl benzene 16%, 1,2,4- trimethyl benzene 9%, 1,3,5- trimethyl benzene 13%, m-ethyl toluene 27%, p-ethyl toluene 15%, o-ethyl toluene 11%, and i-propyl benzene + n-propyl benzene 9%.

**Table S1.** Measured VOCs, categorization and rate coefficients used to initialize the model.

| VOC                  | Type      | \( k_{\text{NO}_3} \) [cm\(^3\) s\(^{-1}\)] | \( k_{\text{O}_3} \) [cm\(^3\) s\(^{-1}\)] | \( k_{\text{OH}} \) [cm\(^3\) s\(^{-1}\)] |
|----------------------|-----------|---------------------------------|---------------------------------|---------------------------------|
|                      |           | min. temp. | max. temp. | min. temp. | max. temp. | min. temp. | max. temp. |
| Isoprene             | BVOC      | 6.6x10\(^{-13}\) | 7.3x10\(^{-13}\) | 9.9x10\(^{-18}\) | 1.5x10\(^{-17}\) | 1.0x10\(^{-10}\) | 9.6x10\(^{-11}\) |
| Dimethyl sulfide     | DMS       | 1.2x10\(^{-12}\) | 1.0x10\(^{-12}\) | 8.6x10\(^{-12}\) | 6.3x10\(^{-12}\) |
| Benzene              | AVOC      | 3.0x10\(^{-17}\) | 3.0x10\(^{-17}\) | 1.2x10\(^{-12}\) | 1.2x10\(^{-12}\) |
| Toluene              |           | 6.8x10\(^{-17}\) | 6.8x10\(^{-17}\) | 5.9x10\(^{-12}\) | 5.5x10\(^{-12}\) |
| Methyl ethyl ketone  |           | 1.0x10\(^{-15}\) | 1.0x10\(^{-15}\) | 1.1x10\(^{-12}\) | 1.1x10\(^{-12}\) |
| Styrene              |           | 1.5x10\(^{-12}\) | 1.5x10\(^{-12}\) | 1.7x10\(^{-17}\) | 1.7x10\(^{-17}\) | 5.8x10\(^{-11}\) | 5.8x10\(^{-11}\) |
| Ethylbenzene         |           | 1.2x10\(^{-16}\) | 1.2x10\(^{-16}\) | 7.0x10\(^{-12}\) | 7.0x10\(^{-12}\) |
| 1,3,5-trimethylbenzene| aromatic AVOC | 8.8x10\(^{-16}\) | 8.8x10\(^{-16}\) | 5.7x10\(^{-11}\) | 5.7x10\(^{-11}\) |
| 1,2,4-trimethylbenzene| aromatic AVOC | 1.8x10\(^{-15}\) | 1.8x10\(^{-15}\) | 3.3x10\(^{-11}\) | 3.3x10\(^{-11}\) |
| 1,2,3-trimethylbenzene| aromatic AVOC | 1.9x10\(^{-15}\) | 1.9x10\(^{-15}\) | 3.3x10\(^{-11}\) | 3.3x10\(^{-11}\) |
| M-xylene             |           | 2.6x10\(^{-16}\) | 2.6x10\(^{-16}\) | 2.3x10\(^{-11}\) | 2.3x10\(^{-11}\) |
| O-xylene             |           | 4.1x10\(^{-16}\) | 4.1x10\(^{-16}\) | 1.4x10\(^{-11}\) | 1.4x10\(^{-11}\) |
| m-xylene             |           | 5.0x10\(^{-16}\) | 5.0x10\(^{-16}\) | 2.3x10\(^{-11}\) | 2.3x10\(^{-11}\) |
| 2-ethyltoluene       |           | 7.1x10\(^{-16}\) | 7.1x10\(^{-16}\) | 1.2x10\(^{-11}\) | 1.2x10\(^{-11}\) |
| 3-ethyltoluene       |           | 4.5x10\(^{-16}\) | 4.5x10\(^{-16}\) | 1.9x10\(^{-11}\) | 1.9x10\(^{-11}\) |
| 4-ethyltoluene       |           | 8.6x10\(^{-16}\) | 8.6x10\(^{-16}\) | 1.2x10\(^{-11}\) | 1.2x10\(^{-11}\) |
| Propylbenzene        |           | 1.4x10\(^{-16}\) | 1.4x10\(^{-16}\) | 5.8x10\(^{-12}\) | 5.8x10\(^{-12}\) |
| Formaldehyde         | oxygenated VOC | 5.5x10\(^{-16}\) | 5.5x10\(^{-16}\) | 8.6x10\(^{-12}\) | 8.4x10\(^{-12}\) |
| Acetaldehyde         |           | 2.2x10\(^{-15}\) | 3.2x10\(^{-15}\) | 1.6x10\(^{-11}\) | 1.4x10\(^{-11}\) |
|                 |         |         |         |         |
|-----------------|---------|---------|---------|---------|
| Methanol        | $1.3 \times 10^{-16}$ | $1.3 \times 10^{-16}$ | $8.6 \times 10^{-13}$ | $9.2 \times 10^{-13}$ |
| Methacrolein    | $3.4 \times 10^{-15}$ | $3.4 \times 10^{-15}$ | $9.4 \times 10^{-19}$ | $1.5 \times 10^{-18}$ | $3.0 \times 10^{-11}$ | $2.8 \times 10^{-11}$ |
| Methyl vinyl ketone | $1.2 \times 10^{-16}$ | $1.2 \times 10^{-16}$ | $4.3 \times 10^{-18}$ | $6.0 \times 10^{-18}$ | $2.2 \times 10^{-11}$ | $1.9 \times 10^{-11}$ |
| Acetone         | $3.0 \times 10^{-17}$ | $3.0 \times 10^{-17}$ |         |         | $1.6 \times 10^{-13}$ | $1.9 \times 10^{-13}$ |

**References**

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