Commentary

Air quality is a key aspect for South Africa to consider in this time of COVID-19

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Air pollution as a risk factor to respiratory infections

Exposure to air pollution has significant impacts on human health, with increased exposure associated with increases in morbidity (e.g. cardiovascular and respiratory illness) and mortality (e.g. WHO, 2005; Cohen et al., 2017). Additionally, it has been found that exposure to ambient (outdoor) air pollution leads to an increased risk of respiratory viral infections (Ciencewicki and Jaspers, 2007). The linkages between air pollution and COVID-19 infection and mortality rate are still being unraveled by the research community as the virus spreads. Early studies suggest an association between exposure to air pollution and mortality rates, though more research is needed to robustly quantify the association (e.g. Conticini et al., 2000; Wu et al., 2020).

Air pollution increases in winter

This is concerning, as many areas in South Africa experience peak pollution in winter. This is especially clear in long-term air quality records for pollutants such as particulate matter (PM), sulphur dioxide (SO_2) and nitorigen dioxide (NO_2) in regions that experience rainfall in the summer. These increases are due to seasonal shifts in atmospheric chemistry, changes in meteorology to more stable conditions (trapping pollutants closer to the surface), and increasing emissions of pollutants, such as those from households that use fuels such as wood and coal for cooking or heating and wind-blown dust (Hersey et al., 2015; Lourens et al., 2011). These increases are often more pronounced in low-income settlements (Hersey et al., 2015), thus exacerbating the vulnerability of these communities to COVID-19.

Thus, understanding the linkages between poor air quality and COVID-19, especially in urban areas and low-income settlements where pollution levels and vulnerability to COVID-19 are both high, is critical and an area of on-going research worldwide. This is an issue that the recently formed South African COVID-19 Environment Reference Group (CERG) is investigating. CERG, which the CSIR is a participant in, is a team of leading South African environmental scientists, from a range of institutions, formed under the auspices of the Department of Science and Innovation (DSI) to consider the environmental aspects (including weather, climate and air pollution) of the epidemic in this country and the region.

Recent changes in air quality

With the recent restrictions on travel and many countries implementing forms of lockdown measures, there has been enormous focus on the air quality impact of curtailing the emissions of air pollutants from these sources. Being able to understand and quantify the impact of such changes in emissions on air quality will provide important information for air quality management and improvement going forward. In urban areas, emissions from vehicles contribute a great deal to poor air quality, but it is difficult to quantify the impact of policy interventions (e.g. increases in public transportation) on air quality, with certainty. This lockdown period provides a practical opportunity to investigate the impact of decreasing source activity (e.g. road vehicle traffic) on air quality. In South Africa, the full impact on emissions is still evolving; however, the lockdown and travel restrictions have likely impacted emissions from air and ground transport. Additionally, Eskom has reported decreases in demand, which would affect power station emissions.

Collaborative team working to understand lockdown impacts

A team of CSIR researchers is working in collaboration with satellite observations expert Dr Eloise Marais from the University of Leicester, United Kingdom, to understand the impact that the lockdown in South Africa has on air quality. This can be achieved using multiple sources of available air quality data and information.

Quantifying this change is not trivial, as it will vary spatially and temporally, and will be affected by the fact that we would normally expect pollution levels to be increasing slowly towards winter. Additionally, attributing changes in air pollution to specific actions is not simple, as ambient pollution can be influenced by many factors, including changes in meteorology, such as temperature, rainfall, wind speed and direction, as well as changes in close and distant emission sources.

Preliminary results focusing on the NO_2 and SO_2 pollution in the Highveld region are highlighted here. Both of these pollutants can have a negative impact on health, and their ambient concentrations are regulated in South Africa through the National Ambient Air Quality Standards.

In South Africa, large sources of nitrogen oxides (NO_X; $NO_X = NO + NO_2$) include vehicle traffic, industrial activities (e.g. mining and petrochemicals), and energy generation (mostly our coal-fired power plants). There are also natural sources of NO_2 like lightning, bacteria in soils, as well as semi-natural sources like biomass burning. The latter includes natural and human-induced fires (for crop and general vegetation clearing). Natural sources tend to be seasonal with the burning season in South Africa occurring in late winter through spring. The largest sources of SO_2 emissions in South Africa are coal-fired power plants and industrial activity that uses or processes materials containing sulfur (e.g. coal).

Observations of NO_2 from the TROPOMI instrument on the Sentinel-5P satellite platform have already been presented extensively in the media and on Twitter over the past month to demonstrate the decline in air pollution over China, India, Italy, Spain and the UK associated with the lockdown due to the Coronavirus. We are using NO_2 and SO_2 observations from the same instrument to determine whether there is also a visible decrease in air pollution in South Africa due to the lockdown that started on 27 March 2020.

Satellite observations are publicly available (https://s5phub.copernicus.eu/dhus/#/home) and provide complete coverage of South Africa, but are influenced by cloud cover that obscures the ability of the satellite to see air pollution down to the surface. Satellites also observe concentrations of pollutants throughout the atmosphere (e.g. not just where people breathe), and so can be influenced by air pollution above the Earth's surface. In addition, the Sentinel-5P satellite used here only passes overhead once per day at midday (about 13:30 local time), missing morning and evening rush hour when NO_X emissions from vehicle traffic peak under normal conditions. But these data are still valuable in the absence of surface observations, or as a first look to identify locations where the lockdown may have influenced air quality and for further targeted assessment of surface observations (if available) and/or appropriate air quality modeling. Satellite data were analysed for the period before (15 to 26 March 2020) and after the lock-down was implemented (27 March to 20 April 2020).

Ground-based monitoring stations measure ambient pollution levels that people are exposed to. They represent the air quality in the areas immediately around the measurement site. Monitored ambient air quality data were downloaded from the South African Air Quality Information System website (http://saaqis.environment.gov.za/) that is run by the South African Weather Service and were then quality controlled before use.

Preliminary findings

Our preliminary analysis of the satellite data shows that TROPOMI observes decreases in NO_2 and SO_2 (Figure 1). Over the Highveld (domain sampled: 25.7-27.2°S, 27.8-30.6°E), NO_2 concentrations decreased by 23% after the lockdown (using data from 27 March to 20 April 2020) compared to before (using data from 10 to26 March 2020), and SO_2 concentrations are 47% lower during the lockdown (using data from 27 March to 17 April 2020) compared to before. This change in NO_2 and SO_2 is only calculated for the average of the grid-squares with valid data in both time periods. As mentioned above, there are numerous aspects that could impact the pollutant concentrations; therefore it would be premature to attribute this change solely to the decreases in emissions because of the lockdown. Confirmation with surface observations and a model is required and on-going.

Spatially, there is a large decrease in NO_2 in and around Gauteng, as would be expected from a decrease in vehicle use. There is also a substantial decline in NO_2 over the industrialised Highveld region. Preliminary results from ground-based monitoring stations in the Highveld domain show a high variability in trends of NO_2 when comparing the pre-lockdown and the lockdown period. As described above, ground-level pollution concentrations are expected to increase over this period (i.e. in the run up to winter), and thus the team is also looking at comparing these measurements to average measurements from previous years. An example of this analysis and the complexities of such an analysis are highlighted by the preliminary look at the Kliprivier station in Gauteng. This station has shown a decrease in NO_2 24-hour average concentrations during lockdown as compared to previous years. This change was not seen in the SO_2 24-hour average concentrations (Figure 2). This could be driven by the fact that the station is impacted by emissions from traffic (i.e. a source of NO_2), but it is not strongly impacted by coal-fired power plants (i.e. a source of SO_2), but analysis is continuing to quantifying reasons for these changes. Analysis of additional stations and pollutants across South Africa is on-going, in order to provide a more comprehensive and conclusive analysis.

A decline in air pollutant concentrations observed by these instruments is not always due to decline in local pollution sources. An air quality model can help to tease out the different drivers of pollution. Thus, as our analysis continues, we will run a 3D air quality model with a detailed representation of sources, meteorology, atmospheric chemistry, and transport that has been developed specifically for application to the polluted Highveld.

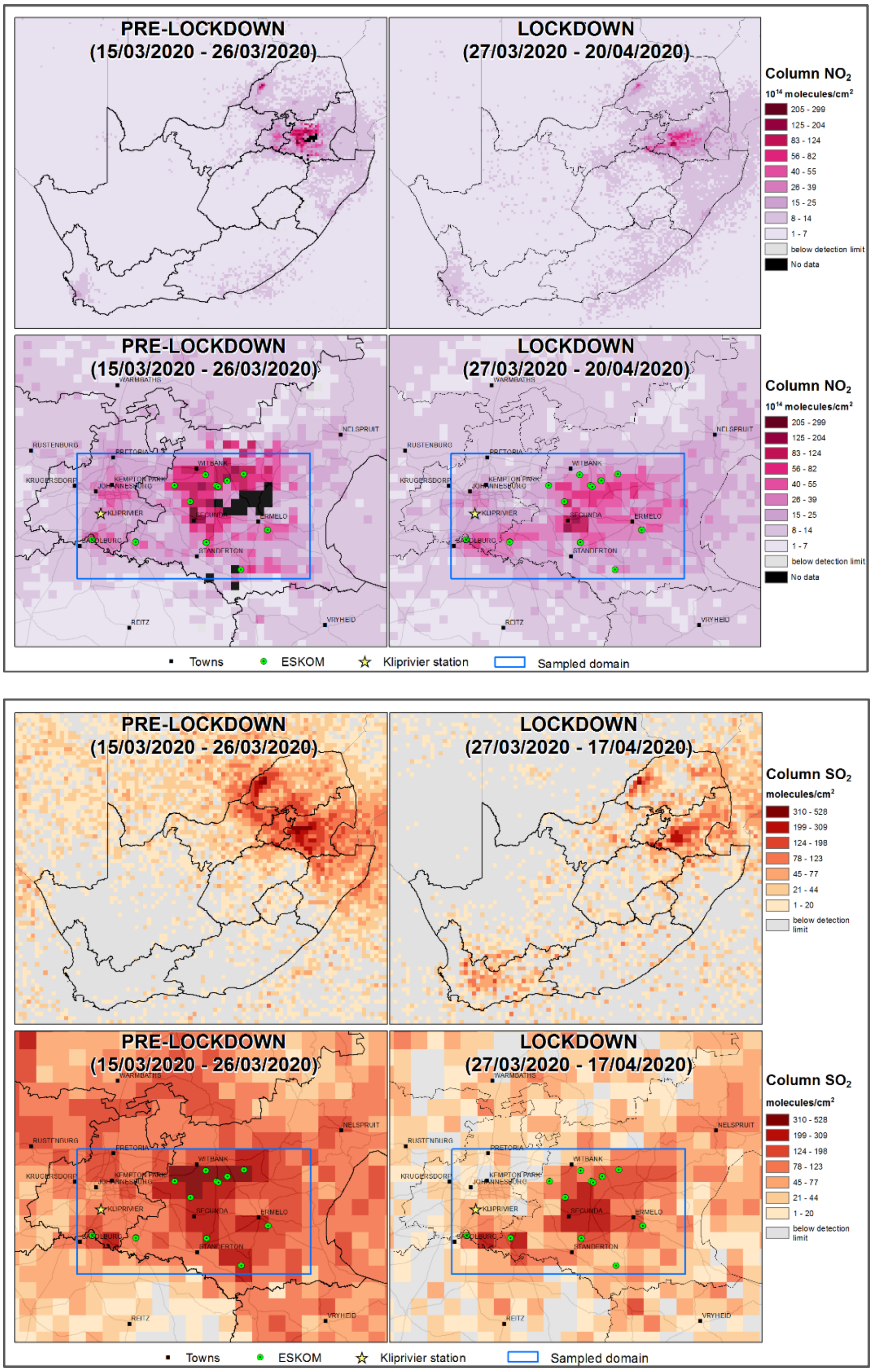

***Figure 1**: Concentrations of the air pollutant NO_2 (top) and SO_2 (bottom) before and after the lock-down due to COVID-19. Data are median values from the TROPOMI NO_2 and SO_2 instrument on the Sentinel-5P satellite for the whole country (top of each figure) and the Highveld (bottom on each figure) before (left) and after (right) the lockdown. The blue box is the Highveld sampling domain where the decreases were quantified (in text). Green circles indicate the locations of power plants. Black grid-squares in the NO_2 data show missing data due to the presence of clouds. The location of the Kliprivier station is shown by the yellow star.*

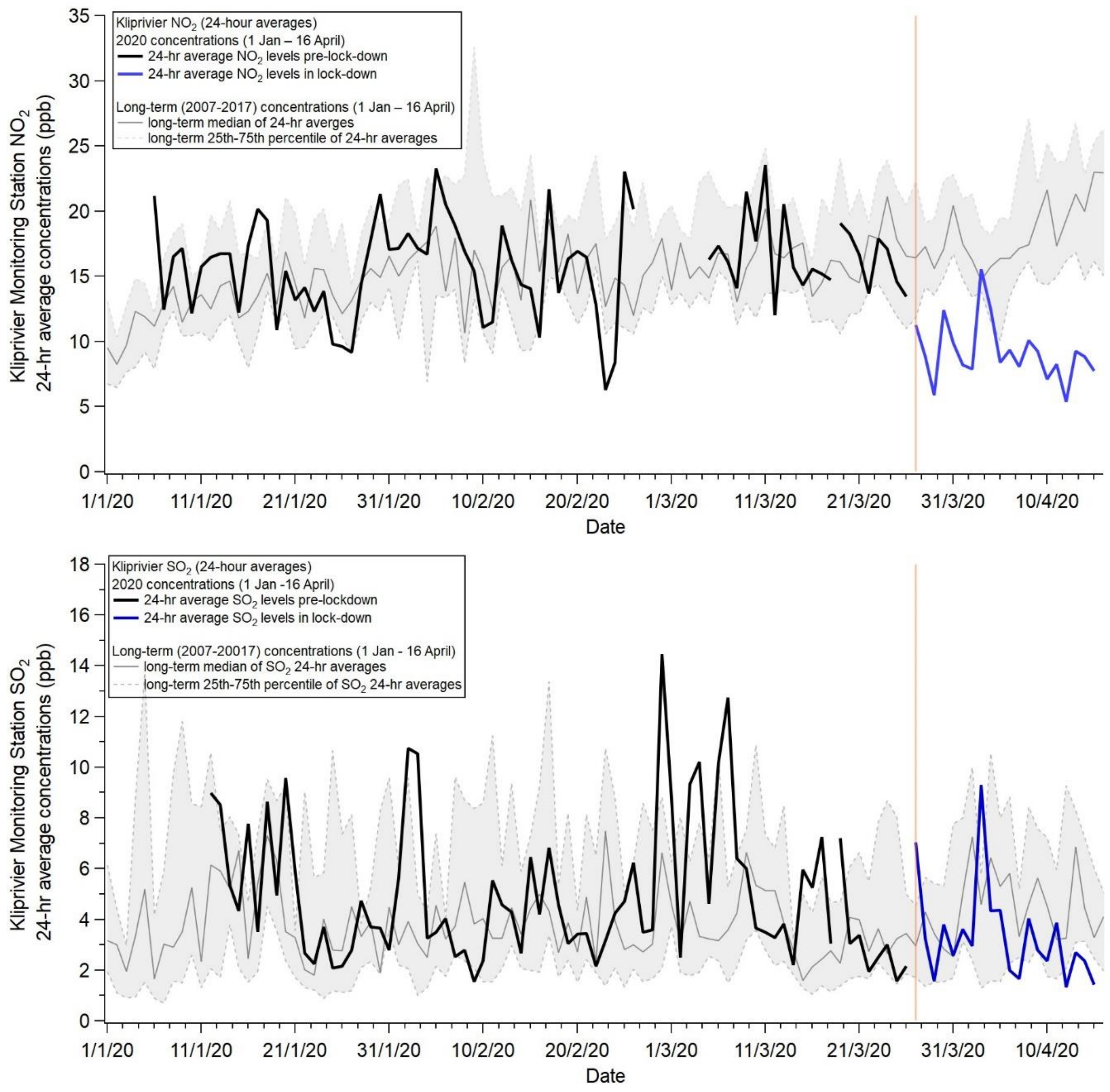

Figure 2*: Preliminary analysis of daily averages for ambient NO_2 (top) and SO_2 (bottom) concentrations at the Kliprivier site in Gauteng. The black lines show the 24-hour average values pre-lockdown (1 January to 16 April 2020), the light orange vertical lines show the start of lockdown (27 March 2020), and the blue lines show the 24-hour averages values after lockdown (27 March 2020-16 April 2020). The light gray solid lines show the long-term median values of the 24-hour averages for 1 January to 16 April for 2007-2017. The grey shading extends to the 25th percentile (on the bottom) and the 75th percentile values (on the top) of the long-term 24-hour averages. This information on the long-term concentrations highlights the "expected" range of pollution levels during this time. This is a preliminary analysis to start to understand if changes are seen in pollution concentrations during lockdown. Air quality data were downloaded from* http://saaqis.environment.gov.za/.

Summary

Air quality is a key aspect to consider in this time of COVID-19. Exposure to air pollution may put people at greater risk from COVD-19. Additionally, in periods of economic strain, households may need to switch from electricity to cheaper fuel sources (i.e. coal and wood) that would then increase their exposure to harmful air pollution. Thus, the air quality of an area, as well as trends in fuel use during COVD-19, should be considerations in the government's COVID-19 response.

In addition, the links between air pollution and COVID-19 infection and mortality rate is an important research area that is rapidly evolving. In order to assist with decreasing the risk of communities to the SARS-Cov-2 virus, the findings from this research must be able to be easily taken up by governments in the on-going epidemiological modelling of the spread of the disease.

Finally, the decreases in emissions of pollutants globally from lockdowns and travel restrictions have led to changes in air quality. This change is only temporary, though. However, this period does provide us with an opportunity to learn lessons about the linkages between policy interventions (e.g. lockdowns), changes in emissions, and resultant air quality that can be applied by government after the COVID-19 pandemic for sustained improvement in air quality.

This commentary contains a preliminary assessment of air quality considerations during COVID-19 performed by a collaborative team of researchers.

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