Interactive comment on ""Measurement report: Statistical modelling of long-term atmospheric inorganic gaseous species trends within proximity of the pollution hotspot in South Africa" by Jan-Stefan Swartz et al. (Ref. No.: acp-2020-166)

(Reviewers' comments are indicated in black and the response to reviewers are indicated in blue)

Anonymous Referee #1

Received and published: 4 May 2020

Overview & Recommendation Sixteen-to nineteen-year records of three important air quality constituents, sulfur dioxide (SO2), ozone (O3), nitrogen dioxide (NO2), that are important over the South African Highveld - ranging from highly populated and industrialized to savanna parkland, are presented for the mid-late 1990s through 2015. The measurements were made at three stations with varying pollution influences, with passive (time-integrated) samplers. The monthly variation and trends in the three trace gases have been identified through a standard multilinear regression model (MLRM). Analysis of the predominant forcings is carried out using terms representing "regional" influences, local meteorology, humidity, proxies for emissions, vs "global" (e.g., ENSO, SAM, IOD, season). A comparison of South African stations with passive sampler results from other locations concludes the paper. The three South African stations represent a contrast of ecosystem and levels of pollution. Levels of certain pollutants are similar to those in polluted Asian areas. Improvements in air quality standards and implementation made progress in reducing emissions around 2000 in the Highveld "pollution hot spot" area, but by 2005 an uptick with more economic development was observed. The results of this study are of great interest, analysis techniques are novel and they are presented with appropriate interpretation. They will be of interest to scientists and policymakers alike. Recommend publication.

We would like to thank Referee #1 for the extremely positive review of this paper whereby the relevance of the scientific work is acknowledged, which will be of interest to the broader scientific community and policymakers. We are also very thankful for recommending publication of the paper without any revisions.

Anonymous Referee #2

Received and published: 12 May 2020

South African Highveld area is a heavily industrialized pollution hotspot with a significant regional impact and an area which demonstrates the impacts of growing urban population. There are only limited number of air pollution observations from this kind of areas, and long-term observations are even more scarce.

The limitation of the method (observations) applied in this paper is the monthly time resolution, which prevents the use of the method on e.g. AQ observations required by the legislation. In addition, due to the regional circulation pattern, the applied measurement sites are often upwind of the most polluted region, so they do not necessarily represent the highest regional concentrations in the Highveld area, which is also clear when Figures A4 and A5 are compared with the maps in Figs 1 and 2.

As the manuscript is well-written and provides a rare data set with regional / global scientific importance, I recommend the publication of the manuscript, after the following minor issues are addressed.

We would like to thank Referee #2 for the very positive review of this paper and recommending publication of the manuscript, through realising the value of this long-term atmospheric gaseous dataset for this regionally and globally important region. We would also like to thank Referee #2 for the minor suggestions made, which were each carefully considered and addressed/implemented in the paper. Below is a point-by-point response to each of these comments/questions. In addition, a marked-up version of the revised manuscript is also provided indicating all changes made throughout the manuscript.

1) Abstract: please provide some numeric values for average monthly SO2, NO2 and O3-concentrations observed.

We thank Referee #2 for this suggestion. We have included the average monthly SO_2, NO_2 and O_3 concentrations at the three sites in the Abstract as requested as follows:

"…north-eastern interior in South Africa. The interdependencies between local, regional and global parameters on variances in SO_2, NO_2 and O_3 levels were investigated in the model. Average monthly SO_2 concentrations at Amersfoort (AF), Louis Trichardt (LT) and Skukuza (SK) were 9.91 µg/m^3, 1.70 µg/m^3 and 2.07 µg/m^3, respectively, while respective mean monthly NO_2 concentrations at each of these sites were 6.56 µg/m^3, 1.46 µg/m^3 and 2.54 µg/m^3. Average monthly O_3 concentrations were 50.77

µg/m^3, 58.44 µg/m^3 and 43.36 µg/m^3 at AF, LT and SK, respectively. Long-term temporal trends indicated seasonal and inter-annual variability at all three sites, which could be ascribed to…"

2) One of the basic principles in ACP is the open-access data following FAIR principles. Please include the obligatory "Data availability" paragraph and provide the data, with necessary metadata, shown in Figures A1, A2 and A3. Extracting the data from these figures is in any case very straightforward process, so having it directly in numeric format will save some time for co-scientists using the dataset e.g. as ground-truth for remote sensing observations, or reference data for global models. If the data are not provided, please give a proper justification.

We agree with the open-access data policy and FAIR principles followed by ACP. However, these datasets were collected in the INDAAF (International Network to study Deposition and Atmospheric composition in Africa) network, which is part of the DEBITS (Deposition of Biogeochemical Important Trace Species) project endorsed by the International and Global Chemistry (IGAC) programme (www. https://indaaf.obs-mip.fr/). It is indicated on the INDAAF website that data will be made available upon request, since there are data sharing policies that entail co-authorship on papers utilising data collected within this network. Therefore, data is made available upon request and agreement with our data sharing policies. Furthermore, these datasets are also currently utilised in other papers being currently prepared. We have included the obligatory "Data availability" section in the paper as follows:

"**5. Data availability**

The data of this paper are available upon request to Pieter van Zyl (pieter.vanzyl@nwu.ac.za) or Paul Beukes (paul.beukes@nwu.ac.za)."

3) Please indicate AF, LT and SK sites in the figures A4 and A5, as this comparison provides information on regional significance of the observations (i.e. what are the concentrations at these sites compared to areas with highest concentrations in the area).

We completely agree with Referee #2 that inclusion of AF, LT and SK in these figures would assist in contextualising these sites within this region. However, these figures were extracted from the NASA Giovanni satellite data on the NASA website (as indicated in the figure captions) and we are therefore not able to make any changes on these figures. It might be possible to conduct edits manually by using imaging software, but the sites will not be accurately located on the map (exact coordinates) and it could also possibly decrease the quality of these maps. In addition, these maps are only included as supportive material in the Appendix to contextualise the location of the three sites as discussed in **Section 3.3**

Contextualisation. We are of the opinion that relating Figure 1 to these two figures does assist the reader do contextualise the location of these sites to the satellite date presented for this region in these two figures.

4) In several parts of the manuscript, results/trends are explained to be due to the changes in economy and/or population. Annual data on GDP, population and energy production is easily available on IEA and World Bank www-pages (and potentially also from Statistics South Africa). To support the explanations in the manuscript, please include a figure showing these three societal variables for the period 1995-2015, and refer to this figure in the text.

We thank Referee #2 for this comment and completely agree that GDP, population and energy production data would support the observed trends. A figure was compiled including the South African population and GDP as obtained from the World Bank website (https://data.worldbank.org/country/south-africa), while electricity production data was acquired from the International Energy Agency (https://www.iea.org/data-and-statistics/data-tables?country=SOUTHAFRIC). This figure (Fig. A4) was included in the Appendix:

"

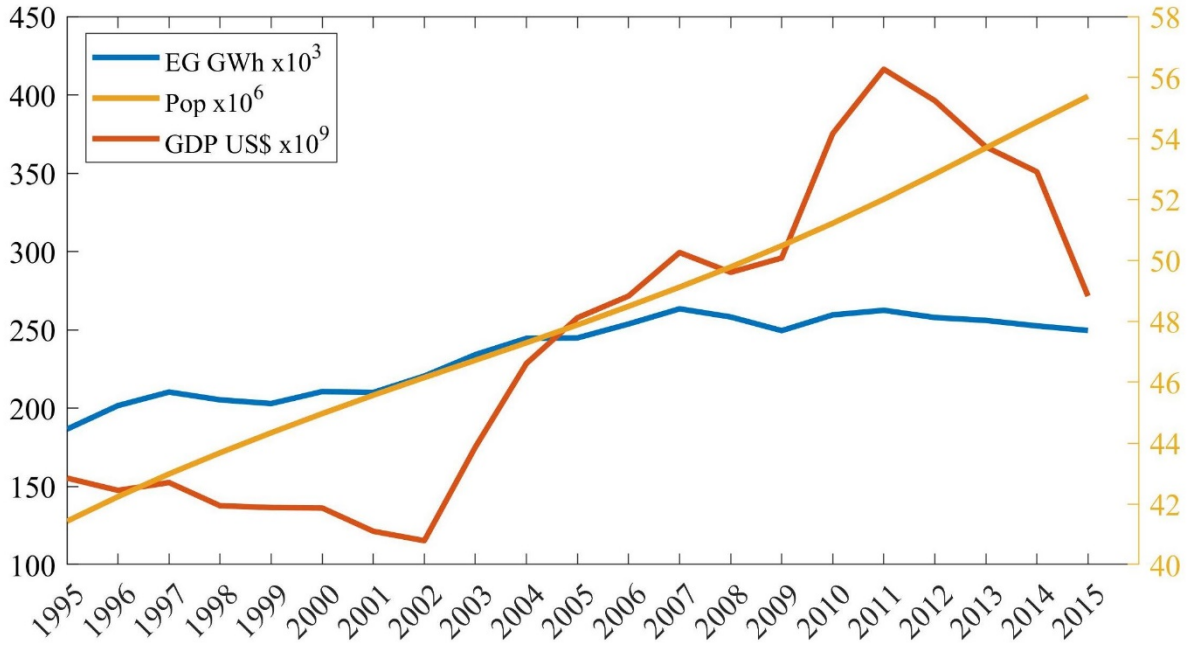

Figure A4: South African population (Pop) and GDP from 1995 to 2015 (World Bank, 2019), as well as electricity generation (EG) during this period (International Energy Agency, 2020)"

The following sentences were added in the third paragraph of Section 3.2.1 Sulphur dioxide (SO_2), which refers to this new figure:

"…activities, e.g. increased production by pyrometallurgical industries (ICDA, 2012), as well as the increase in population growth accompanied by higher energy demand (Vet et al., 2014). In Fig. A4, the South African population and GDP from 1995 to 2015 according to the World Bank (World Bank, 2019) are presented together with the electricity generation (EG) in South Africa during this period as indicated by the International Energy Agency (International Energy Agency, 2020). A continuous growth in population is observed from 1995 to 2015, while the GDP trend reflects economic growth during this period corresponding to the observed periods of decreased and increased SO_2 concentrations. A general increase in electricity production over this period is also evident. Electricity consumption is a good indicator of increased anthropogenic activities, with Inglesi-Lotz and Blignaut (2011) indicating…"

The following references were also added to the Reference list:

"International Energy Agency. 2020. Data and statistics [Online]. Available: https://www.iea.org/data-and-statistics/data-tables?country=SOUTHAFRIC [Accessed 14 May 2020]"

"World Bank. 2019. Data [Online]. Available: https://data.worldbank.org/country/south-africa [Accessed 15 May 2020]."

These two references were also cited in the first paragraph of the Introduction as follows:

"…generation (Rorich and Galpin, 1998; Tiitta et al., 2014). Atmospheric pollution associated with South Africa is compounded by high population growth that, in turn, drives further economic and industrial growth leading to an ever-increasing energy demand (Tiitta et al., 2014; World Bank, 2019; International Energy Agency, 2020). The extent of air pollution…"

5) For clarity, if possible, please change color axes in Figs A4 and A5 to include less decimals

As indicated in our response to Comment 3 of Referee #2, these figures were extracted from the NASA Giovanni satellite data on the NASA website (as indicated in the figure captions) and we are therefore not able to make any changes on these figures, which include changes to decimals and colour axes.