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Misleading paper with major flaws. Needs fundamental revisions and more years with data.

Anonymous Referee #1

Referee comment on "Technical note: Northern midlatitude baseline ozone – long-term changes and the COVID-19 impact" by David D. Parrish et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-424-RC1, 2022

The manuscript tries to address how unusual the free tropospheric ozone anomalies observed in 2020 during and after the COVID related emission reductions were in a context of longer term ozone trends. The underlying big question is which "normal" ozone would have been expected for 2020, without COVID related emission reductions. Essentially, the manuscript claims that their parabolic trend used to describe "normal background" ozone in a previous publication (and based on data from 1979 to 2018 only, Parrish et al., 2020), would have continued in the same form throughout 2020 and would have resulted in ozone levels similar to the observed low ozone of 2020. If this claim were true, there would have been no COVID related ozone reductions in 2020 - in stark contrast to a number of observational and modelling studies (Steinbrecht et al., 2021; Christofanelli et al., 2021; Weber et al., 2020; Bouarar et al., 2021; Miyazaki et al., 2021).

I think the manuscript has major flaws, needs very fundamental revisions, and especially additional data, before it might become acceptable as an ACP paper.

- The "conventional wisdom", that tropospheric background ozone showed a large increase from the 1960s until around 2000, but has been consistently decreasing since sometime after 2000 is held only by the authors themselves. In particular, the claim that their reported ozone decrease by about -4 ppbV per decade since about 2005 (Parrish et al. 2020) is significant and representatative, is in clear contrast to many other current studies, which generally indicate small and often non-significant mixed positive and negative trends with small magnitudes (typically +-1 ppbV per decade or less, e.g. Cooper at al., 2021; Chang et al., 2022).
- The authors' parabolic trend is the only estimate that results in very low expected "background" ozone in 2020. Almost all other authors / studies have used a constant climatology, or a linear trend to estimate "background" ozone in 2020. These more conservative estimates provide substantially higher "background" ozone for 2020, and

they all point to unusually low tropospheric ozone in 2020 (with the explanations provided by e.g. Weber et al., 2020; Bouarar et al., 2021; Miyazaki et al., 2021).

- The authors' parabolic trend fit has no degree of freedom that would allow a different behaviour of long-term ozone changes before the maximum around 2005 and after the maximum, since 2005. Essentially the authors are assuming that since about 2005 ozone MUST be going down in the same way, as it has been going up before 2005. Clearly this is a very strong assumption, and completely ignores the very different economic and societal circumstances that have been driving the observed very large ozone increases from the 1960s to about 2000, and are now driving small possible ozone changes since 2005 (with regional differences and many more complications, e.g. Cooper at al., 2021; Chang et al., 2022).
- The authors use no data after 2018. There is no constraint for "background" ozone just before 2020, and also no constraint for "background" ozone after the 2020 anomaly. Without data from these important additional years, the authors' claim that the 2020 ozone anomaly was not an anomaly but instead was normal, has no physical basis at all!!

I summarize my critique by providing two alternative versions of Fig. 1 of the manuscript (having digitized the data points).

My Fig. 1 is essentially the same as Fig. 1 of the Parrish et al. manuscript. It shows the 2 year average background ozone data (blue circles and line), along with three fits:

- mean after 2000, cyan line;
- linear fit using data after 1994, magenta line and confidence interval;
- parabolic fit, black line with grey confidence interval (same as used in manuscript)

The 2020 anomaly observed by Steinbrecht et al., 2021 (brown square), and the parabolic "background" extrapolation to 2020 by Parrish et al. (green circle) are shown as well. As in Parrish et al., the fitted parabola here gives the same extrapolated green circle for 2020, which is close to the observed 2020 anomaly (brown square) of Steinbrecht et al. (2021). However, the (grey) 95% confidence interval derived here (by Monte-Carlo bootstrap) is wider than the green uncertainty bar given by Parrish et al. The confidence interval is also not symmetric around the extrapolated 2020 value, and reaches closer to zero. As in Parrish et al., the 2020 observed value (brown square) lies far below the mean since 2000, and far below the linear trend since 1994. It also lies at the bottom of the confidence interval of the extrapolated parabola (green circle).

My Fig. 2 shows the same data as Fig. 1, but now an additional "hypothetical" data point is added for 2019. I chose zero anomaly for this data point - inline with e.g. Fig. 4 of Steinbrecht et al. 2021, which shows slightly higher tropospheric ozone in 2019 compared to previous years. The addition of this one data point changes both the parabolic fit (black line, grey confidence interval), and the linear fit (magenta line and confidence interval). Now, the parabola predicts higher "background ozone" in 2020 than Fig. 1, and the observed anomaly (brown square) lies outside of the 95% confidence interval. The linear

fit has changed very little. It still predicts "background ozone" close to zero for 2020. In addition, Fig. 2 has a cubic fit added to the 2 year anomaly data (red dashed lines). Importantly, this fit has an additional degree of freedom, which allows for different trends before and after 2005. This cubic fit also predicts "background ozone" close to zero for 2020 (but with large uncertainties for values after 2015 and before 1985, reflected in the wide confidence interval). So all background estimations, with the notable exception of the Parrish et al. parabola, give close to zero "background ozone" in 2020, and indicate a large negative observed anomaly for 2020 - consistent with many other studies, as mentioned above.

Hopefully, my two Figures demonstrate clearly the very problematic use of the Parrish et al. parabolic fit for an extrapolation of "background ozone" to 2020. Given this and other important flaws, I feel that the manuscript is not acceptable as an ACP paper. In fact it is quite misleading, and should be definitely by rejected in anything resembling its current content. (This was the case for a previous version of the manuscript, which was rejected by Geophysical Research Letters). I suggest that the authors wait for a number of additional years of data, including 2022 and 2023 (as 2021 may still be affected by ongoing COVID related emission reductions, for example due to still reduced air traffic), and then redo their analysis. I also strongly suggest to use a trend estimator that allows different trends before and after the years around 2005, and to better consider the large uncertainties of trend estimators, e.g. for the year 2020.

Without new data and new information, the present manuscript is just a rehash of Parrish et al. (2020). It does not report "substantial new results and conclusions", and does not provide the "substantial advances and general implications for the scientific understanding", which are required for an ACP research article.

Figures:

Figure 1, same as Fig. 1 of the Parrish et al. manuscript: 2 year average baseline / background ozone, along with three fits to estimate background ozone after 2000: Mean since 2000 (here cyan line), linear trend since 1994 (magenta line and 95% confidence interval), parabola (black line and grey 95% confidence interval). The green circle gives the value of the parabola extrapolated to 2020. The brown square gives the observed 2020 anomaly from Steinbrecht et al. (2021).

Figure 2: Same as Fig. 1, but including an additional (hypothetical) data point in 2019 (black circle), and including also a cubic fit (dashed red lines and 95% confidence interval).

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