General Comments: (Reviewer 2)

The authors use total column ozone data to determine the specific date at which the zonally averaged ozone stopped declining (referred to as $T_A(\theta)$), which holds significance for atmospheric models. Subsequently, the trends of column ozone were calculated using MLR and linear regression, both before and after $T_A(\theta)$. The findings indicate that there has been only a minor recovery in the Southern Hemisphere towards the ozone levels observed in 1979, with virtually no recovery in the Northern Hemisphere, except for the Antarctic region. While these results present new insights, the robustness and interpretation of the findings require further reinforcement. Thus, significant revisions are necessary before considering the publication of this article.

All changes to the manuscript including those requested by the reviewers are marked in Green or Yellow (Reviewer #2).

Specific Comments:

Lines 83-86: The two trend research methods have distinct study areas, and it is important to explain why the MLR method might be affected by the polar night, potentially due to the solar cycle. Additionally, it might be more appropriate to include this discussion about the different study areas and the potential impact of the polar night on the MLR method within the introduction section of the methodology.

Inclusion of the polar night region introduces extra frequency components that are not always physical, especially near the Arctic and Antarctic circles. This could have been considered in the generalized MLR method with additional terms of varying periods depending on latitude for latitudes greater than 70 degrees. The annual average method does not have these complications.

The MLR method (Eqns. 1 and 2) are not applied poleward of the Arctic and Antarctic circles where latitude dependent extended winter night periods occur**.** Additional latitude dependent terms of varying periods would be needed for latitudes greater than 70^{O}. The annual average method does not have these complications.

Lines 124-129: It would be better to provide more description for the Fourier-based MLR to clarify its difference from the generalized multivariate linear regression (MLR) discussed in the next paragraph.

The MLR method is the generalized multivariate linear regression (MLR) discussed below. I have modified the sentence on page 4:

2) Fourier time series decomposition or generalized multivariate linear regression MLR (Ziemke et al., 2019) discussed below.

Fig. 2: In addition to the difference in the latitude range studied by the two methods, it is worth noting that they also differ in terms of latitude intervals.

Use of slightly different latitude intervals only in Figure 2 was done so that the error bars could be easily discerned between the two methods (larger for annual averages). The trend results are the same if identical intervals had been used in Fig. 2. In subsequent figures, identical intervals are used. Figure 2 is not physical as stated in the text, since it assumes a linear trend when in fact the time series is non-linear. It is just a mathematical exercise comparing the two methods and showing the difference in calculated trends even when making the erroneous linear assumption.

Although Fig. 3 demonstrates the fitting effects of different Lowess values (e.g., 0.05, 0.1, 0.3), it is necessary to provide a clear explanation as to why Lowess=0.3 was chosen as the optimal value in the final analysis.

Lowess(0.3) was chosen as the preferred value since it was the smallest value (f) that produced smooth curves with unique zero crossing dates in its derivative. Estimates for T_A have now been made for f = 0.1, which produce different noisy results in the derivative requiring averaging leading to an uncertainty estimate of 0.5 years. The uncertainty is now stated in the paper and in Fig. 6. Note: New figures have been added, Fig. 3, discussing volcanic effects.

The result mentioned in lines 176-177 lacks an accompanying visual display.

I added a small section and figure on the volcanic influence on ozone at the equator.

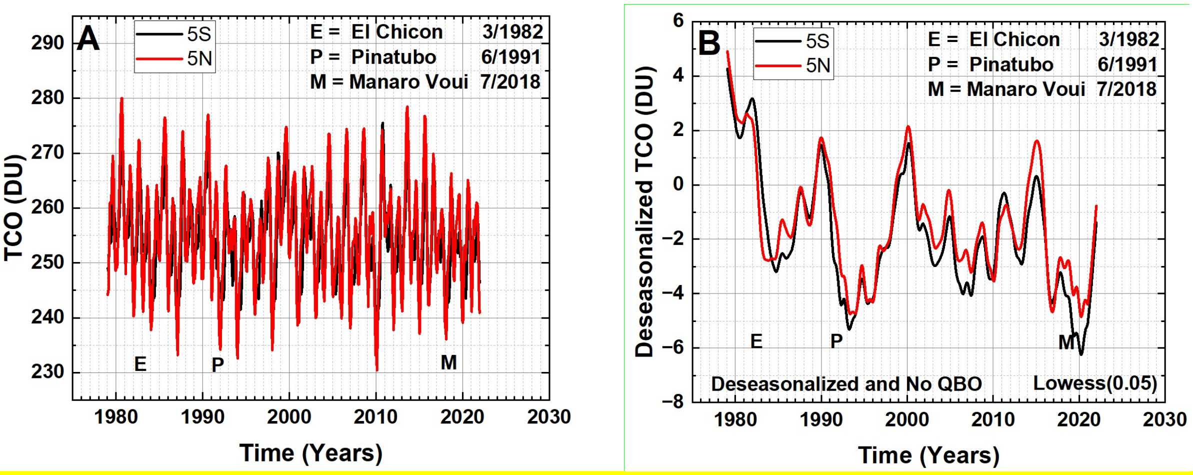

Fig. 3. A. TCO time series for θ = 5^{O}N and 5^{O}S. B. The deseasonalized TCO time series for θ = 5^{O}N and 5^{O}S with QBO effects subtracted (Eq. 1). The approximate dates are shown of volcanic eruptions that injected large amounts of SO_2 into the stratosphere leading to minima approximately 1 year later.

Some volcanos inject significant amounts of SO_2 into the lower stratosphere leading to the formation of aerosols that reduce UV light and the production of ozone, especially in the equatorial region. Figure 3A shows the $\Omega_{MOD}(t,\theta=5)$ time series for TCO in which volcanic SO_2 injection effects from El Chicon March 1982, Mt. Pinatubo June 1991, and Manaro Voui July 2018 are not obvious. After removal of both deseasonalized and the QBO effects from Eq. 1, the reduced ozone effects from three volcanic eruptions, El Chichon, Mt. Pinatubo, and Manaro Voui are shown in Fig. 3B.

Fig. 4-5: Fig. 4 shows decrease in TCO after 2010 in North Hemisphere, and the authors indicated that “the apparent downturn in the Lowess(0.3) fit to MOD after 2010 is not yet statistically significant as an indicator of long-term decrease”. However, do the “Turnaround dates” (Fig. 5) calculated based on Fig. 4 in the North Hemisphere make sense statistically?

The values of T_A are statistically significant with the ±0.5 years uncertainty. The decrease in TCO at the end of the record is not long enough for the trend to be statistically significant. If it continues at the present rate of decrease for a few more years, the trend will be statistically significant.

Fig. 5: The reason for the near symmetry in the early turnaround dates of the Brewer-Dobson ozone upwelling region (±25°) warrants further investigation. It is important to consider that there is considerably more longitudinal asymmetry in topography, land, and ocean distribution in the Northern Hemisphere (NH) compared to the Southern Hemisphere (SH). Consequently, the planetary wave drag may differ between the two hemispheres, which could contribute to the observed differences in ozone recovery patterns.

I agree that the differing topography is a contributing factor to hemispheric asymmetry especially the effect of NH topography preventing the formation of a persistent Arctic vortex wind. The delayed Antarctic ozone hole recovery and the mixing of mid-latitude ozone rich air with the Antarctic ozone poor air is also part of the delay in the SH. Researchers using models that include the topographic drag effect along with volcanic eruptions and all the atmospheric chemistry and dynamics should be able to see this asymmetry.

In lines 194-195, it is mentioned that the Spring Antarctic Ozone Hole and polar vortex winds led to a delay in high latitudes in the Southern Hemisphere (SH) until 1997. However, it is important to note that these phenomena should occur every year. Therefore, additional evidence, such as models or observations, is required to support the author's claim and provide a more robust explanation for the observed delay in high SH latitudes until 1997.

The following has been added on page 10: The T_A delay to 1997 for latitudes 35^{O}S – 65^{O}S follows the delayed recovery of ozone depletion within the Spring Antarctic Ozone Hole (Stone et al., 2021, their Fig. 3; Bodeker and Kremser, 2021, their Figs. 6 and 9) and backfilling (air exchange with lower latitude ozone-rich air) during the summer months after the polar vortex winds break down in October - November.

This paper's conclusions are not entirely consistent with those of Weber et al. (2022), despite utilizing similar data and methods. To explain the differences between the two studies, further analysis and investigation are needed. Possible factors contributing to the disparities could include variations in the data preprocessing techniques, differences in model configurations, or the incorporation of additional variables in one study compared to the other. A thorough comparison and evaluation of these factors may shed light on the discrepancies observed between the two studies.

The trends in this paper and Weber et al. are consistent within the error bars (their Fig. 3). However, Weber et al. included specific Pinatubo and El Chicon terms in their MLR method, which was not done here since we wanted to include volcanic effects not just ODSs. This leads to differences in the calculated trends. The trend calculations are only weakly dependent on T_A as noted by Weber on their page 6849. Weber et al. uses a fixed T_A (1995) with their trend figures (Fig. 2) suggesting a considerable uncertainty in defining T_A. The importance of latitude dependent T_A is for models to be able to reproduce the shape of the hemispherical asymmetry, including volcanic effects, while maintaining the equatorial symmetry associated with the Brewer-Dobson circulation.

Technical Comments

The abbreviation "TCO" should be defined and explained in line 53 rather than line 64.

Done

The legend of Figure 4 (e.g., 35°N) should be revised. **Fixed**

In lines 216-218, the text presentation and punctuation should be adjusted for clarity and accuracy. **Fixed**

Reply