Recent trends of global ozone derived from ground-based and ozonesonde measurements

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The purpose of this study is to investigate the factors on the trend of ozone and regional differences using ground-based and ozonesonde measurements while taking into account known natural variability using the Multiple Linear Regression (MLR) model. In this study, I used ozone data from WOUDC. I selected stations at various latitudes with few missing periods (58 total ozone stations and 13 ozonesonde stations). I investigated trends for 22 years after 2000 using the MLR model provided by the LOTUS group to consider the known proxies. The proxies considered were proxies for long-term variations in ozone (11-year solar cycle, ENSO, QBO, aerosols, AO/AAO, tropopause pressure (TP) and Eddy heat flux (EHF)) and proxies for short-term variations in ozone (meteorological variables). I used the stepwise method so that only proxies with significant coefficients are kept in the model. The ozone trend was derived from the linear trend term. Since I did not aim to include ODSs as proxies this time, I assume that the trend indicates the ozone change due to ODSs.
For total ozone, the average value of adjusted R^2, an indicator of the goodness of fitting of the MLR model, at 58 stations shows a high value, 0.58. This indicates that it can explain the ozone variability to some extent and each proxy could be separated to some extent. When using the MLR to take into account known natural variability, the global trend for total ozone was shifted upward than when only seasonal variability was taken into account without the MLR. This indicates that the ozone trend due to ODSs could be separated from other factors to some extent. But I can still find some downward trend, especially in Europe and East Asia. The detection of regions with a downward trend qualitatively agrees with previous study by Coldewey-Egbers et al. (2022).
I discussed the impact of the proxies used in this study on ozone trends. First, I discussed the impact of AOD. I compared the adjusted R^2 with/without AOD and found that the adjusted R^2 has not down so much even without AOD for both total and partial columns of ozone. Furthermore, the trend of ODSs is not masked by AOD, as the average for the case without AOD did not shift upward. I concluded that AOD is not needed for the trend analysis between 2000 and 2021. Second, I discussed the impact of meteorological variables. The meteorological-variable-corrected trend ($trend_m$) was defined as the contribution of the trend of the meteorological variable transferred to the trend term. The average of the trends at all stations shows that there was no significant difference between "$trend_m$" and the original “trend” term for both total and partial columns of ozone. I concluded that the impact of meteorological variables on the ozone trend was small.
Next, I discussed the factors on the trend of ozone. I investigated the factor of the trend in Europe and East Asia, where a downward trend in total ozone was found. However, no common factors of trend were found in both Europe and East Asia.
Since almost no factor considered in this study could explain the downward trend in total ozone, I tried to include other proxies in the MLR model. First, I investigated the impact of atmospheric circulation over several consecutive years on total ozone, which is difficult to detect with the EHF used as proxies in this study (HCl time series were used). However, including HCl in the proxies instead of EHF did not change the adjusted R^2. There was no advantage to include HCl in proxies instead of EHF in this analysis. Second, to investigate whether there were other proxies that could explain the ozone variability in troposphere, I tried to use the Clean aIr Index (CII), an indicator of air pollution but it could not explain tropospheric ozone variability at Tsukuba.

Finally, no factor that can explain the downward trend in total ozone was found. Therefore, another factor should be considered. One of the candidates is very short-lived halogenated substances.

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