Trends in surface ozone and its precursors in Saxony, Germany

Yaru Wang, Dominik van Pinxteren, Hartmut Herrmann

TROPOS
Leibniz Institute for Tropospheric Research

Leibniz Association

Atmospheric Chemistry Department (ACD), Leibniz-Institut für Troposphärenforschung (TROPOS), Permoserstr. 15, 04318 Leipzig, Germany

contact: yaru.wang@tropos.de

Motivation

Tropospheric surface ozone (O_3) is a hazardous air pollutant abundant on a regional to global scale. Besides its effects on human health and plant growth, O_3 has long been recognized to play key roles in altering climate as a greenhouse gas.

Given the importance of surface O_3, the long-term trends of O_3 concentrations in the federal state of Saxony, Germany, are presented, based on the measurements from 16 stations with long-term O_3 data (>10 years).

The trends of meteorological factors and anthropogenic emissions are also investigated, which provide further insight into the potential causes of the observed trend of surface O_3.

O_3 measurements

- Fig.1 and Table 1 inform on the O_3 monitoring in Saxony.
- Some of the stations (C-Mitte, DD-Herzoging, Plauen-DWD, L-Thekla) were not operating continuously until 12/31/2020.
- 16 sites with >10 years of data and running until 2020 were selected for trend analyses.
- Missing pecentage of O_3 data was < 5% at any given station.

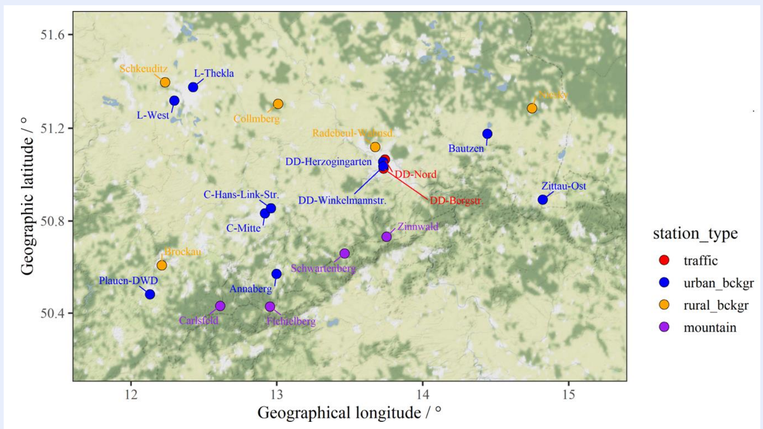

Fig. 1: Map of all O_3 measuring stations

Table 1: O_3 measurments in Saxony - data availability per station

station	station_type	O3 starting date	O_3 ending date	O_3 period/year
DD-Nord	Traffic	1/1/1997 00:00	12/31/2020 23:00	24
DD-Bergstr.	Traffic	6/14/2016 00:00	12/31/2020 23:00	4.6
Annaberg	Urban	1/2/1997 00:00	12/31/2020 23:00	24
Bautzen	Urban	1/1/2005 00:00	12/31/2020 23:00	16
C-Hans-Link-Str.	Urban	1/1/2017 00:00	12/31/2020 23:00	4
C-Mitte	Urban	1/1/1997 00:00	12/31/2016 23:00	20
DD-Herzogingarten	Urban	12/20/2005 16:00	6/16/2008 07:00	2.5
DD-Winkelmannstr.	Urban	6/19/2008 23:00	12/31/2020 23:00	12.5
L-Thekla	Urban	4/2/2004 00:00	4/29/2020 18:00	16.1
L-West	Urban	1/1/2000 00:00	12/31/2020 23:00	21
Plauen-DWD	Urban	11/20/2003 13:00	7/14/2020 08:00	16.7
Zittau-Ost	Urban	1/10/1997 12:00	12/31/2020 23:00	24
Brockau	Rural	10/1/2020 00:00	12/31/2020 23:00	0.3
Collmberg	Rural	9/30/1998 11:00	12/31/2020 23:00	22.3
Niesky	Rural	5/5/2003 15:00	12/31/2020 23:00	17.7
Radebeul-Wahnsd.	Rural	1/1/1974 00:00	12/31/2020 23:00	47
Schkeuditz	Rural	6/6/2003 13:00	12/31/2020 23:00	17.6
Carlsfeld	Mountain	1/1/1997 00:00	12/31/2020 23:00	24
Fichtelberg	Mountain	1/1/2002 00:00	12/31/2020 23:00	19
Schwartenberg	Mountain	2/11/1998 14:00	12/31/2020 23:00	22.9
Zinnwald	Mountain	1/2/1997 09:00	12/31/2020 23:00	24

1. Basic overview of O_3 measurements

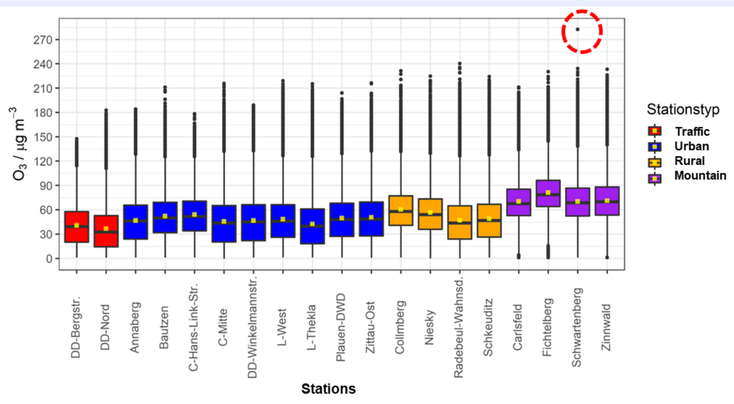

Fig. 2: Distribution of hourly O_3 conc. at each station

O_3 mean levels change with station type:

- Ore Mountain:~ 70 - 80 µg m^{-3}, Max. @ Schwartenberg: 282 µg m^{-3}
- Rural : two level (~ 55 - 60 and ~ 45 - 50 µg m^{-3}
- Urban: ~ 40 - 55 µg m^{-3}
- Traffic: ~ 35 - 40 µg m^{-3}

2. O_3 Trend analyses per station type

Experimental method

Theil-Sen estimator: Calculates mean concentration change per year and its statistical significance, based on de-seasoned monthly means. It is part of the R package Openair (Carslaw and Ropkins, 2012).

Robust for extreme & missing values, and more robust than linear regression.

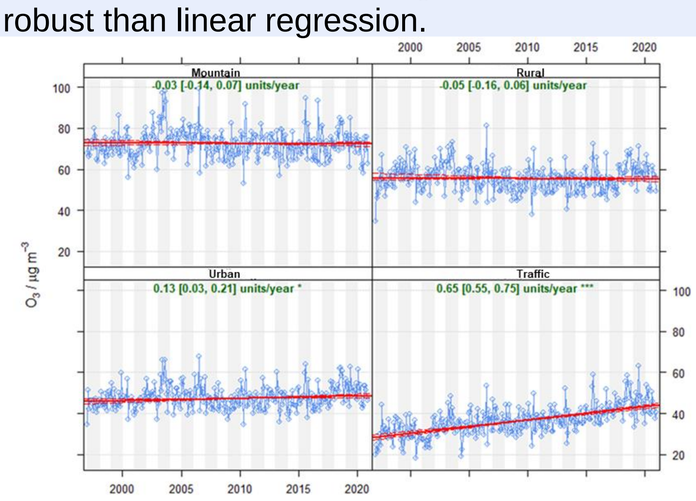

Fig. 3: Theil-Sen O_3 trend for each station type from 1997 to 2020 using seasonally adjusted monthly means and stations with more than ten years of data coverage.

Trend results for each station type

For the stations of the Ore Mountains ridge and in the rural background, no statistically significant trend is found for this respective total data set within one station type.

In the urban background, the long-term trend is calculated with 0.13 µg m^{-3} $year^{-1}$ statistically significant with $p < 0.05$.

At the traffic station (DD-North only) a clearly increasing and statistically significant trend is found with 0.65 µg m^{-3} $year^{-1}$.

3. Trends in mean O_3 and its precursors

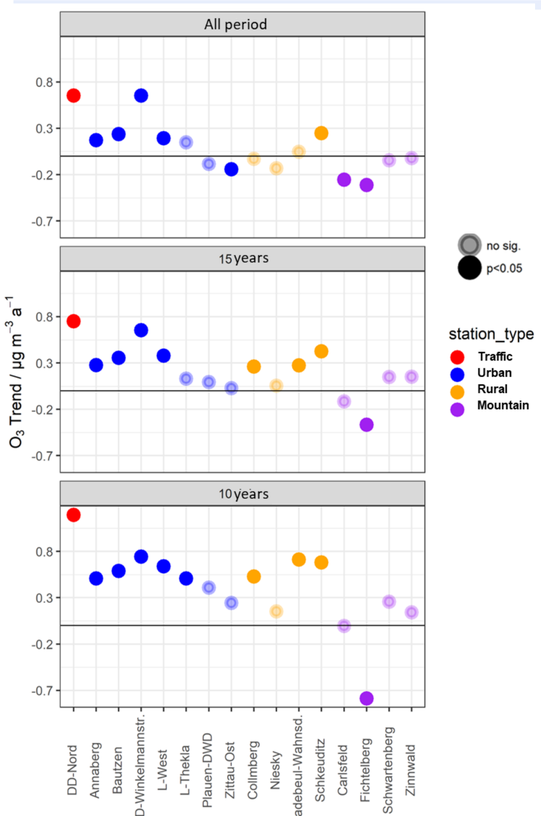

Fig. 4: Comparison of Theil-Sen O_3 trends covering three time spans (all available period, 15 years (2006-2020), and 10 years (2011-2020) for each station with more than ten years of data coverage and after 1997. The solid circle marks indicate that the rate of O_3 growth is statistically significant.

O_3 trends during three time spans

- Traffic and almost all urban sites with clearly increasing rates (0.18 - 0.65 µg m^{-3} $year^{-1}$, $p<0.05$) over periods of typically recent 15 - 20 years.
- In contrast, rural background and elevated mountain stations display mixed patterns with partially decreasing, stagnant or increasing trends.
- Faster growth or slower reduction trends across almost sites were seen during recent 10 years (2011-2020) than those obtained for longer periods (recent 15 years or 1997-2020).

Relationship between O_3 trend and other precursors trends

- Only traffic station (DD- North) with faster decrease in NO_x trend in recent 10 years as compared with ones during all period and recent 15 years.
- The temperature increases faster during recent 15 or 10 years as compared to longer periods.

Decreasing NO_x accompanied by rising temperature would promote further O_3 increase, at least in urban areas.

Possible reasons

- Higher temperature increase biogenic emission, which leads to more ozone precursors. (Monks et al., 2015).
- NO_x largely affect the O_3, especially in urban sites. NO_x increase will result in more NO titration to O_3, then more O_3 decrease.

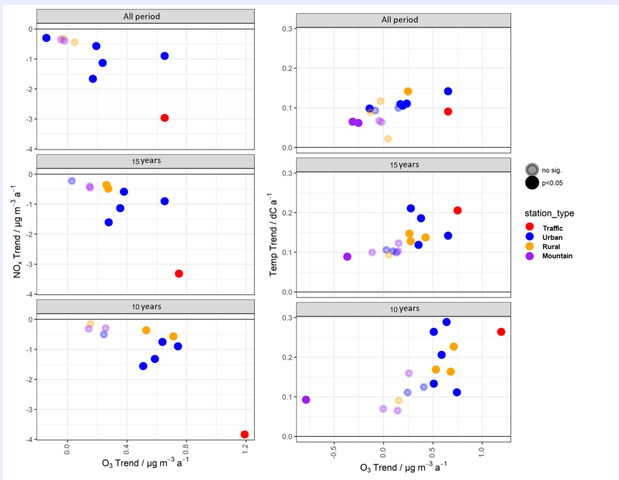

Fig. 5: Relationships between O_3 trend vs NO_X trend and temperature trend during three time spans.

4. Trends in different percentile of yearly O_3

- Stagnant or downward trends in the O_3 highest percentiles (90th, 95th, 99th, and maximum) at most of urban and rural stations and all mountain stations.
- Lower percentiles (minimum, 1th, 5th and 10th) increase across almost all stations with a trend ranging from 0.05 - 0.54 µg m^{-3} $year^{-1}$, $p<0.05$.

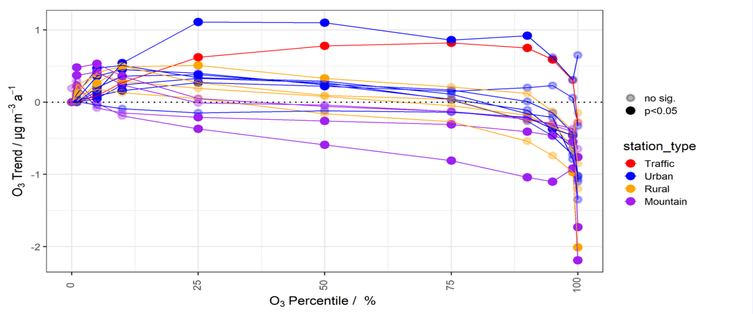

Fig. 6: T-S trends changes in different percentiles of O_3 conc.s at four station type. T-S trend value are calculated based on yearly percentile O_3, from minimum, 1, 5, 10, 25, 50, 75, 90, 95, 99, to maximum, during all available period (after 1997). The black dashed horizontal lines indicate the zero value for O_3 trend. Note the reason why trends of O_3 minimum for some stations approached zero is that the lowest available data is essentially near zero.

Conclusions

- Traffic and most urban stations showed clearly O_3 increasing trends over periods of typically recent 15 - 20 years with 0.18 - 0.65 µg m^{-3} $year^{-1}$, $p<0.05$. In contrast, no consistent trend is found for mountain and rural station.
- Faster growth or slower reduction O_3 trends across almost all sites were observed during recent 10 years (2011-2020) than those obtained for longer periods (e.g., 15 years (2006-2020) or ~20 years (1997-2020)).

Our findings not only provide evidence that Saxony is facing increased O_3 in current days, but also indicate the complex effects of reduced O_3 precursor emissions on O_3 trends, which need future modeling work to confirm.

Reference

Carslaw, D. C., and Ropkins, K.: Openair—an R package for air quality data analysis, Environmental Modelling & Software, 27, 52-61, 2012. **Monks, P. S.**, Archibald, A., Colette, A., Cooper, O., Coyle, M., Derwent, R., Fowler, D., Granier, C., Law, K. S., and Mills, G.: Tropospheric ozone and its precursors from the urban to the global scale from air quality to short-lived climate forcer, Atmospheric Chemistry and Physics, 15, 8889-8973, 2015.