# Impacts of Emission Changes and Meteorology on the Long-term (2013-2020) Ozone Trend in a Megacity (Chengdu), China

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**Abstract**

Elevated ozone (O3) pollution in the warm season is an emerging environmental concern affecting global highly urbanized megacities. In southwestern China, full characterization of causes for O3 pollution has been stymied by limited observations and the dominant factors that influence O3 variability on a long-term basis still lack understanding. Herein, we identified O3 variations and inferred trends in precursor emissions in Chengdu over 2013–2020 based on extensive ambient measurements, emission inventory, and satellite data. Numerical models were used to investigate the changes in meteorological variability and biogenic emissions. Trends of O3 in urban areas show deterioration (+14.0% yr-1) between 2013 and 2016 followed by a slight decrease over 2017–2020, while O3 levels in rural areas generally show a downward trend (-2.9% yr-1) during 2014–2020. Both emission inventory (-3.7% yr-1) and OMI satellite columns (-4.5% yr-1) depict strong decline trends in NOx emissions, while satellite HCHO columns exhibit a flattened downward trend of VOC emissions (-1.8% yr-1), which caused rural areas shifted from VOCs-limited to transitional or NOx-limited regime since 2016. Considering metropolitan Chengdu remains VOCs-limited regime over time, the existing regulatory framework involving simultaneous NOx and VOCs control would result in evident O3 improvements in the near future. Despite benefits from anthropogenic emission reductions, we demonstrate that meteorological conditions and enhanced biogenic emissions over the warm season could partially or even fully offset effects attributed to emission changes, making the net effects obscure. This finding provides robust evidence of reductions in NOx and VOCs emission and informs effective O3 mitigation policies for megacities which undergo similar emission pathways in Chengdu.

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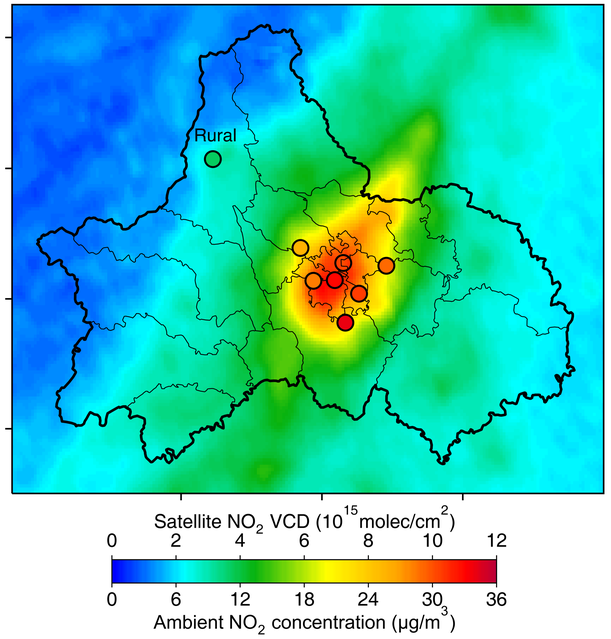
## Highlights



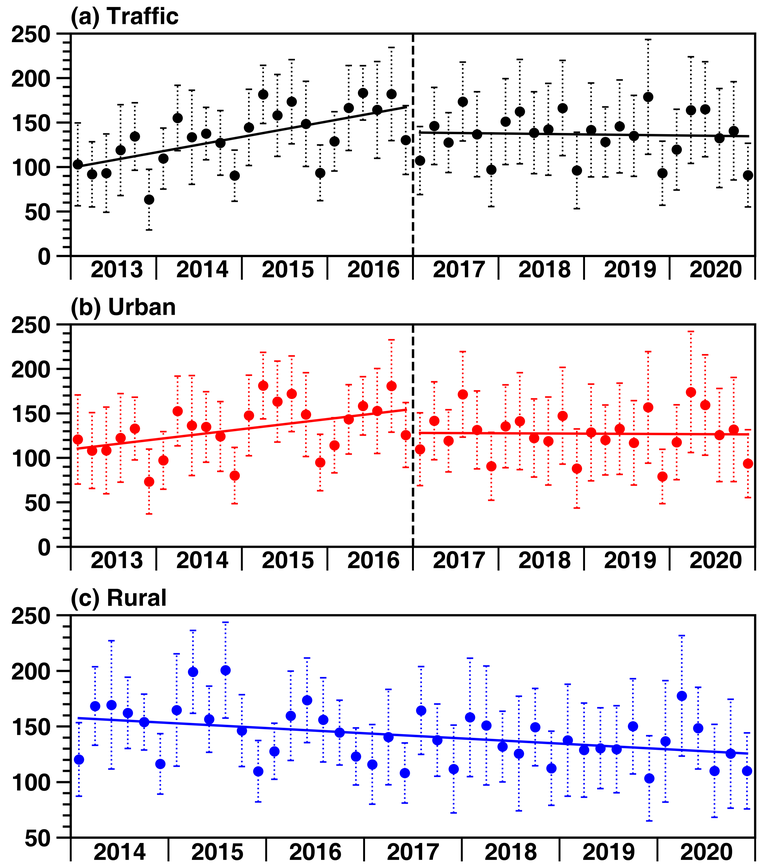

*TROPOMI $NO_2$ columns and ambient $NO_2$ concentrations over Chengdu in 2020*

- This work presents long-term ambient $O_3$ and precursor emissions trends in Chengdu.
- $O_3$-VOCs-$NO_x$ sensitivity is inferred from OMI $NO_2$ and HCHO columns.
- The anthropogenic and natural effects on $O_3$ trends are identified.

## Reference

- Wang, Y., Yang, X., Wu, K., et al., 2022. Long-term trends of ozone and precursors from 2013 to 2020 in a megacity (Chengdu), China: Evidence of changing emissions and chemistry. Atmospheric Research, 278, 106309.
- Zheng, B., Tong, D., Li, M., et al., 2018. Trends in China's anthropogenic emissions since 2010 as the consequence of clean air actions. Atmos. Chem. Phys. 18, 14095–14111.
- Deng, Y., Li, J., Li, Y., et al., 2019. Characteristics of volatile organic compounds, NO2, and effects on ozone formation at a site with high ozone level in Chengdu. J. Environ. Sci. 75, 334–345.
- Tan, Z., Lu, K., Jiang, M., et al., 2018. Exploring ozone pollution in Chengdu, southwestern China: a case study from radical chemistry to O3-VOC-NOx sensitivity. Sci. Total Environ. 636, 775–786.

## Long-term ozone trends

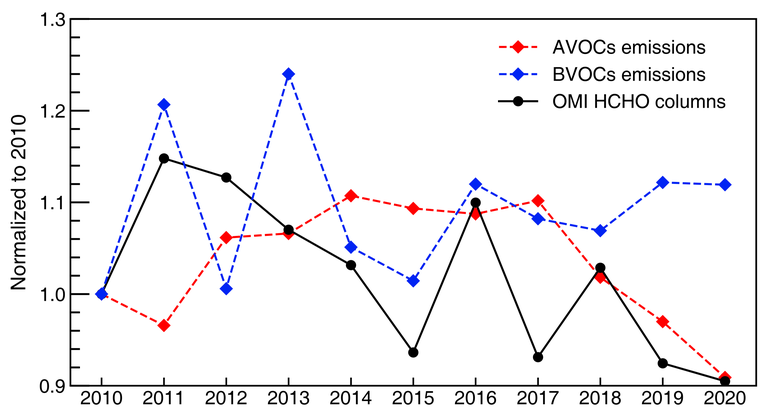



*Long-term ambient $O_3$ trends over Chengdu (unit: μg/m³)*

**Urban ↑ (2013-2016)** **Traffic ↑ (2013-2016)** **Rural ↓ (2014-2020)**

**Urban — (2017-2020)** **Traffic — (2017-2020)**

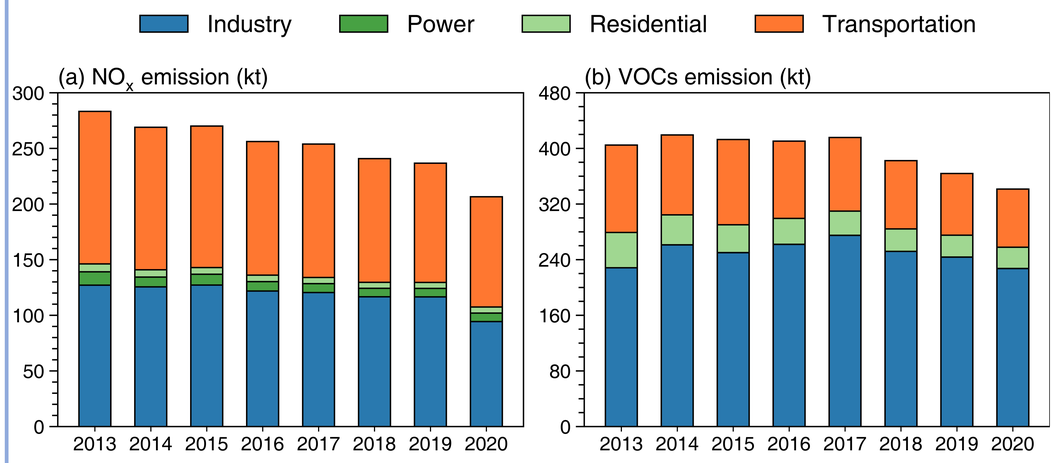
## Natural effects




*Trends of anthropogenic and biogenic VOCs emissions, and OMI HCHO columns*

- Both biogenic and anthropogenic VOC emissions contribute to the changes in HCHO levels.

## Anthropogenic effects



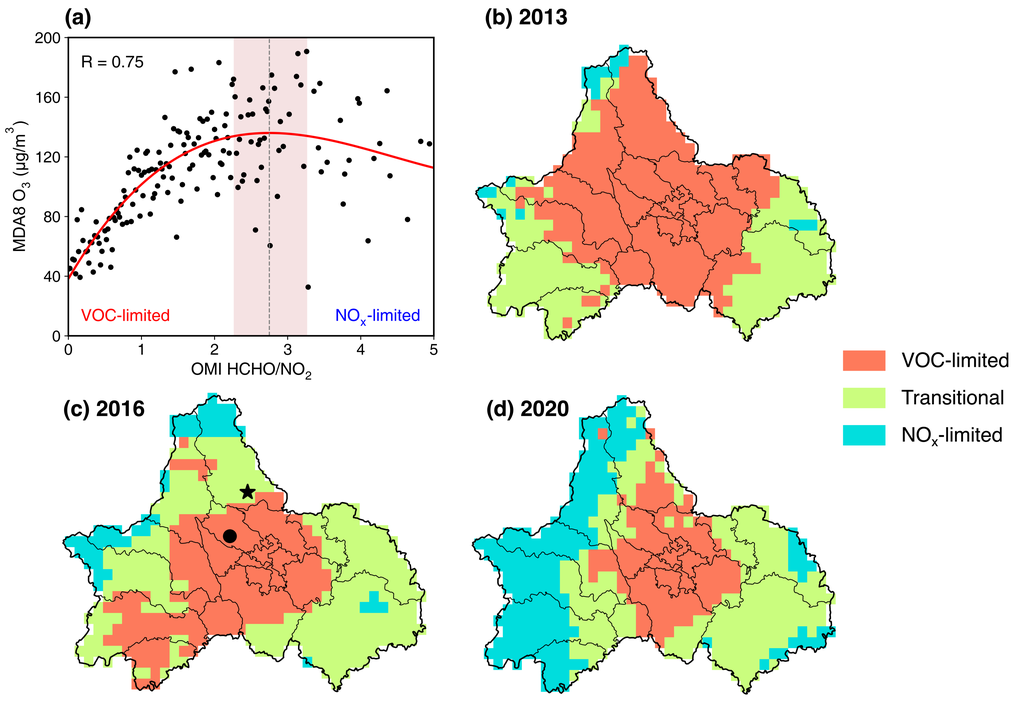

*Anthropogenic $NO_x$ and VOCs emissions in Chengdu from MEIC (Zheng et al., 2018)*

**$NO_x$ ↓ (2013-2020)**

**VOCs ↑ (2013-2017)**

**VOCs ↓ (2017-2020)**

## $O_3$-VOCs-$NO_x$ sensitivity




*(a) $O_3$ concentrations vs OMI $HCHO/NO_2$* *(b-d) $O_3$-VOCs-$NO_x$ sensitivity over Chengdu*

- The extent of the VOC-limited regime gradually shrinks in Chengdu.
- In 2016, the black circle site is reported in VOC-limited regime (Deng et al., 2019), while the pentagram is in transitional regime (Tan et al., 2018).