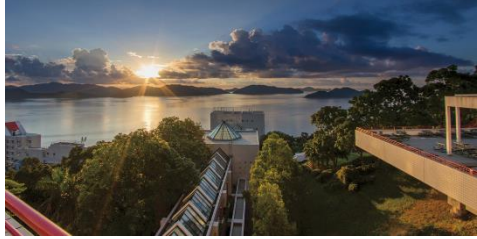

Sensitivity Assessment of the Ozone and Fine Particulate Matter Pollution Using a Regional-to-Local Coupling Model

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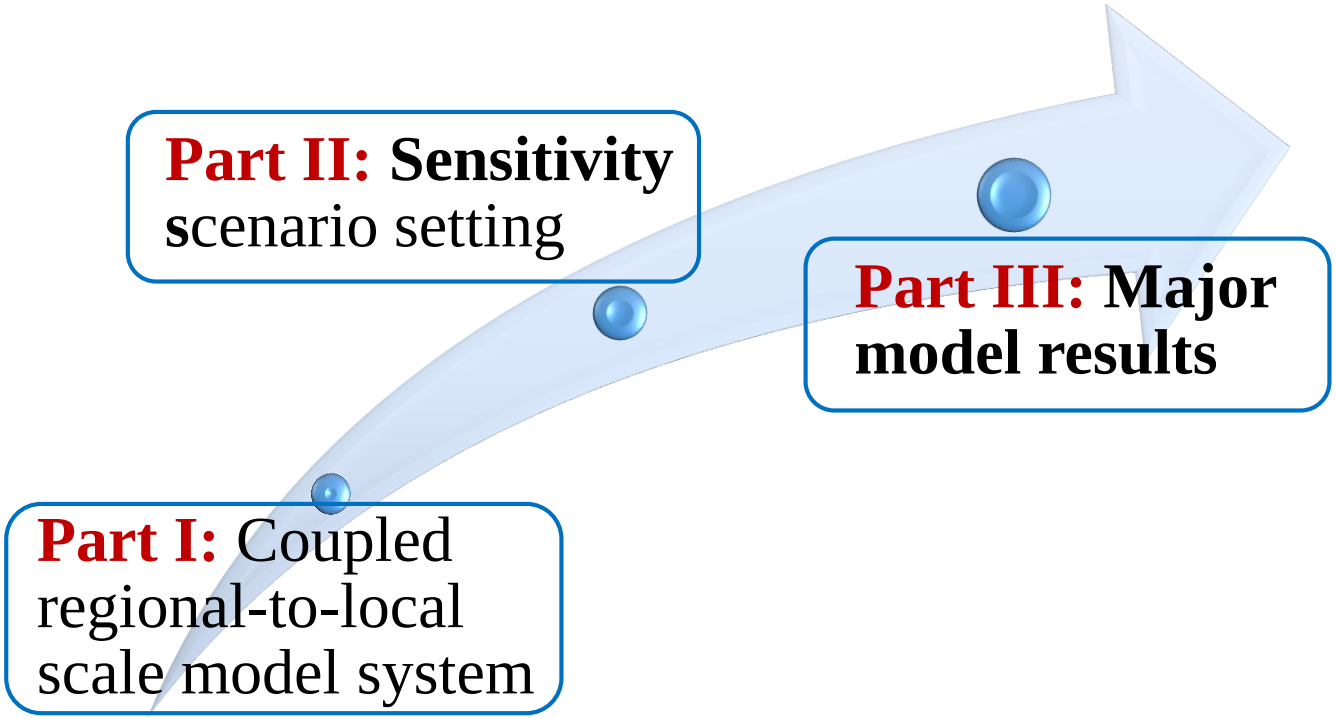
Outline

- **Research Motivation**

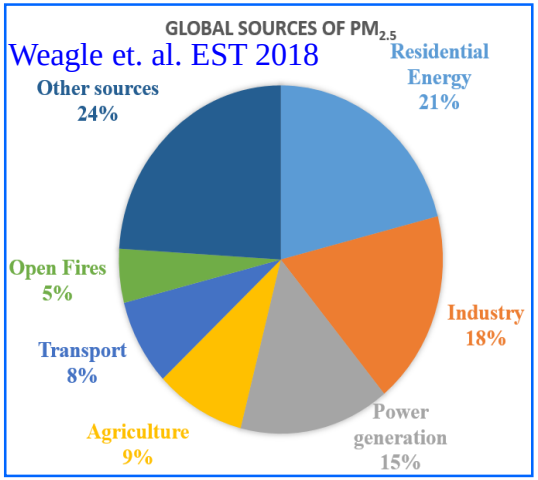


- **Conclusion**

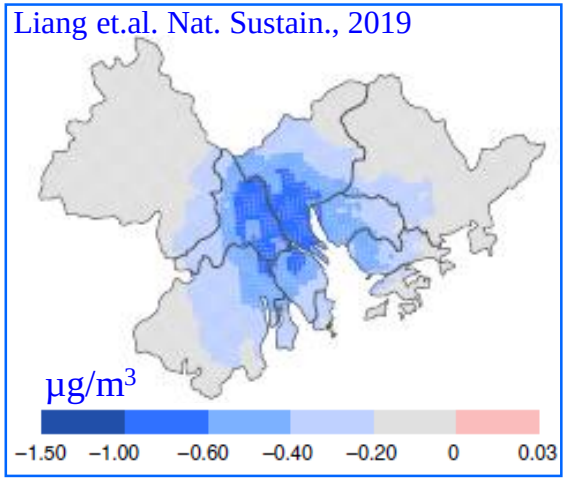
Research Motivation

- Air pollution is severe!!! Health, climate mitigation, policy-making (Zhang et. al. EP 2020).
- **Carbon Neutral** (30-60) Plan & **14th Five-Year-Plan** (2021-2025).
- **4.2 million deaths** in 2016 (attributable to $PM_{2.5}$). (WHO report 2021)
- **In 2019, >90% of global people** reside in the areas in which the WHO air quality guideline (annual mean of 10 μg/m^3) for $PM_{2.5}$ is exceeded. (WHO report 2021)
- High resolution modeling (ADMS-Urban) resolving the concentration gradient would be more accurate for health calculation.
- To implement a coupled model system (CMAQ-ADMS-Urban) and test the sensitivities are urgently needed in an urban area of GBA.

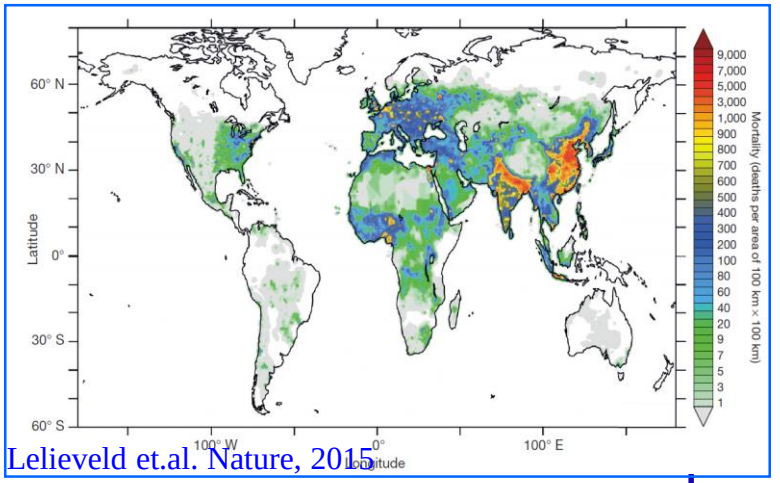
Source contribution



Policy Evaluation

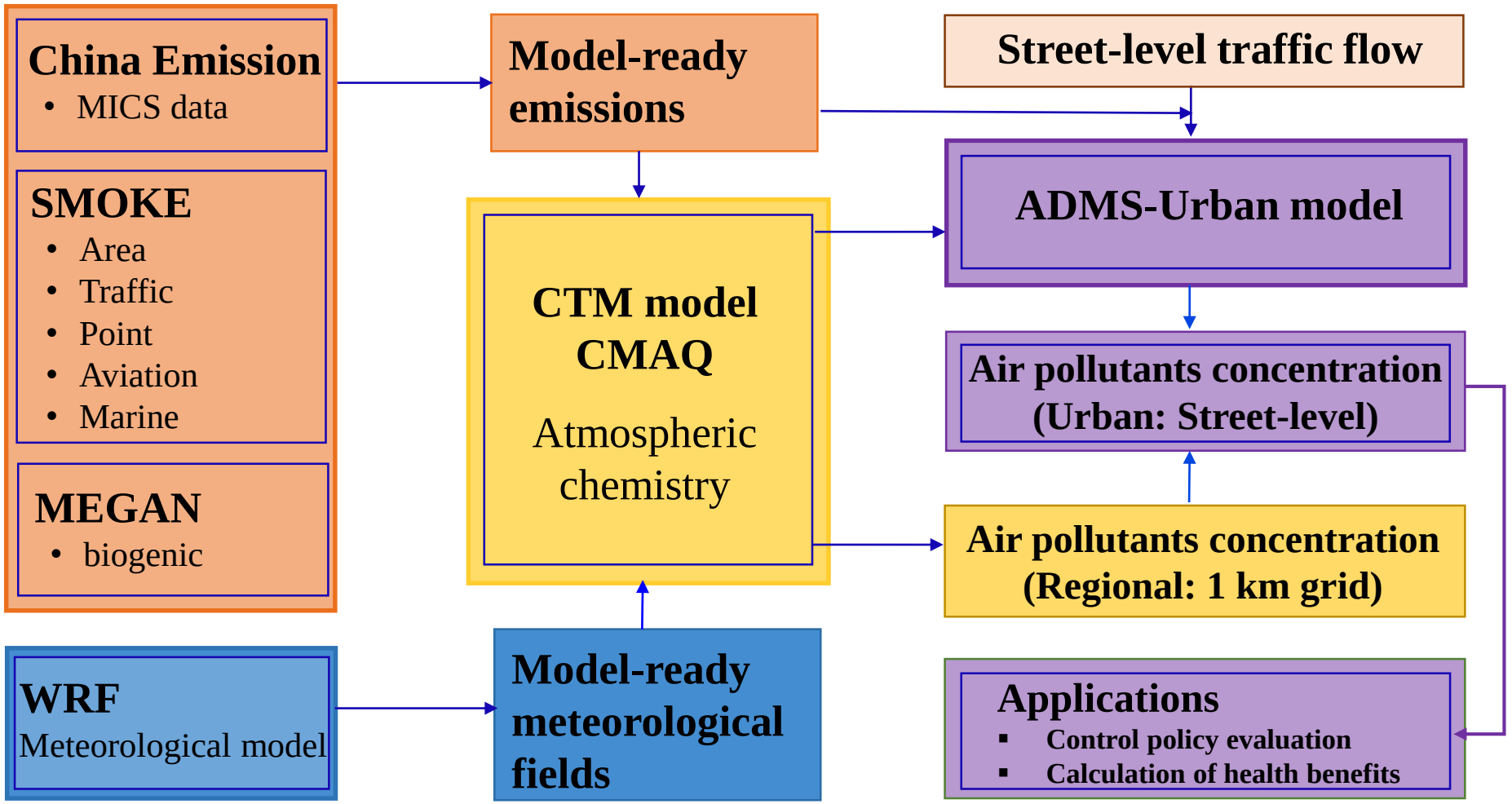


Health Risks

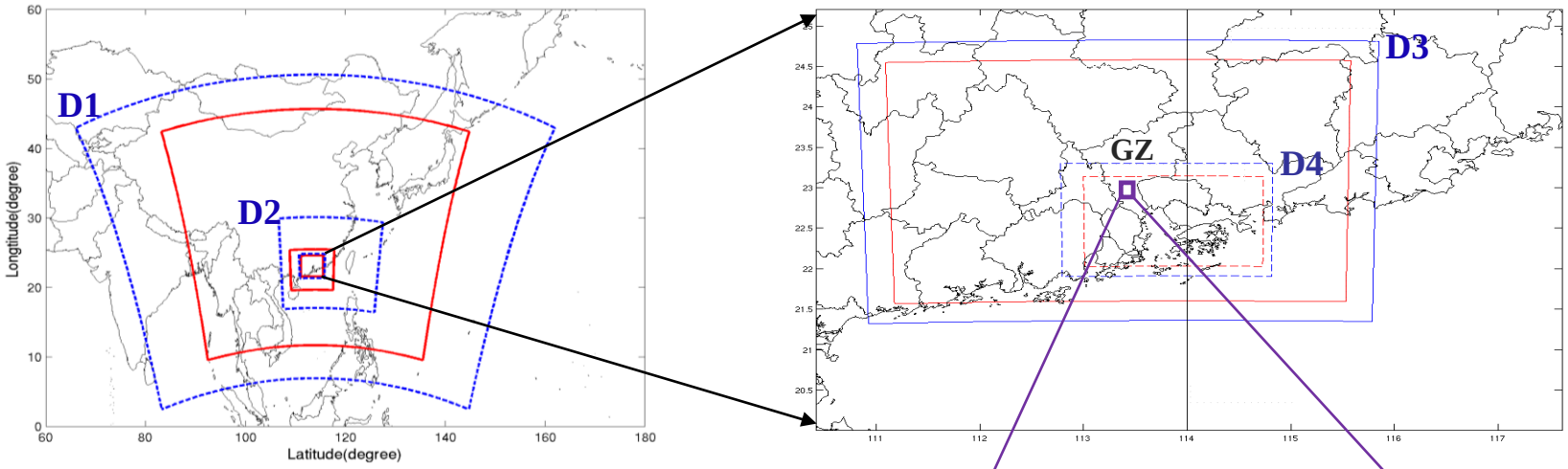


Lelieveld et.al. Nature, 2015

Part I: Research framework



Domain setting of coupled modeling system



- Larger **WRF domain** could minimize the boundary effects of meteorological parameters on **CMAQ grid.**
- The **ADMS-Urban domain** focuses on an urban area of Guangzhou.

Part II: Sensitivity scenario design

- Four sensitivity scenarios for the coupled model system.
- **Model running** period: April and May, 2019.
- Emission changes only focus on Guangdong province.
- Focusing on **traffic and industry sectors** since NO_x and VOC are two important precursors of O_3 formation and both sectors contribute substantially to $PM_{2.5}$ and O_3 from previous studies.

Scenarios	I. Base case	II. Half Traffic case	III. Half Industry VOC case	IV. Both Control case
Scenario description	Business As Usual (BAU)	50% reduction in traffic emissions	50% reduction in industrial VOC emissions	Scenarios II & III
Regional model emissions	BAU	50% emission reduction in Mobile sector (all pollutants)	50% emission reduction in VOC from Industrial sector	50% emission reduction in a) mobile sector (all pollutants) and b) VOC emissions from the industrial sector
Local model emissions	BAU	50% reduction in emissions from explicitly defined road traffic sources	BAU	50% reduction in emissions from explicitly defined road traffic sources

Part II: Emission changes for sensitivity scenarios

- The emissions changes are as same as expected.
- The maximum reduction for NOx is approximately 17% and for $PM_{2.5}$ is only 5%.
- For VOCs, which are impacted by both control measures, emissions are reduced by a much larger amount, 47%.

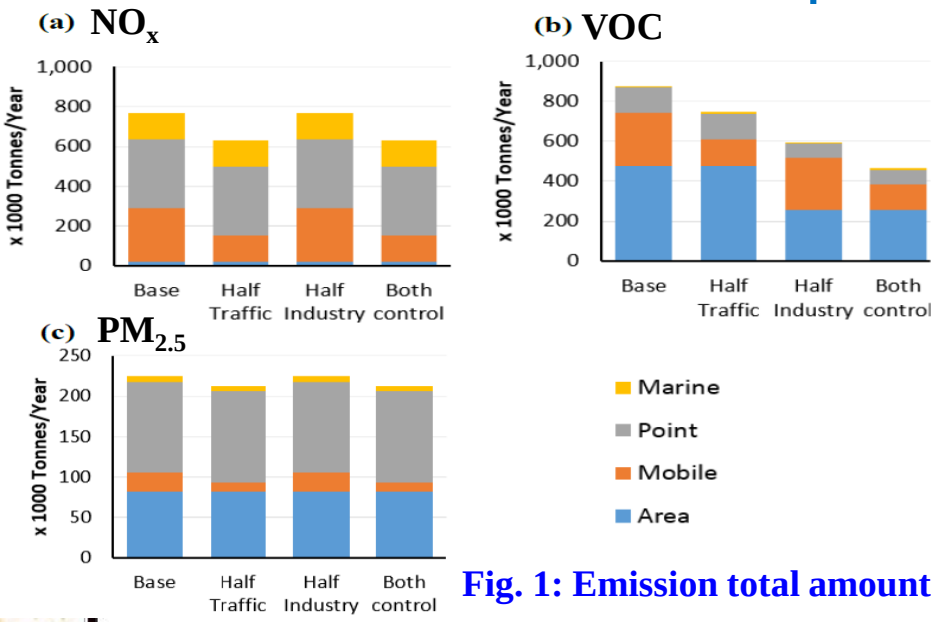


Fig. 1: Emission total amount

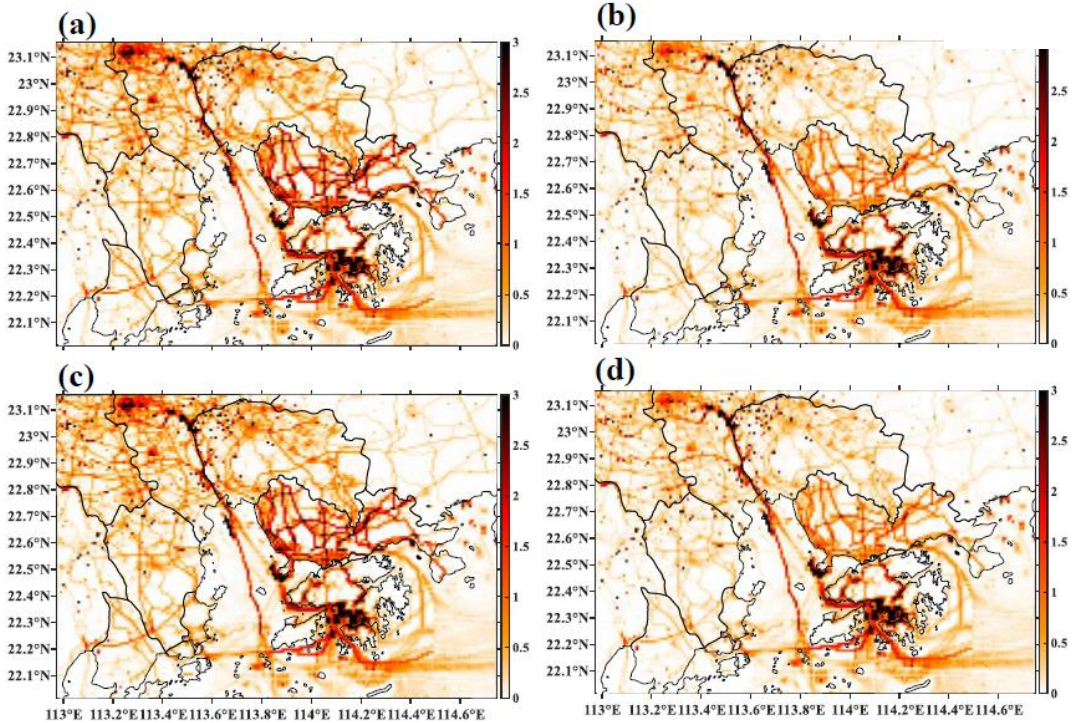
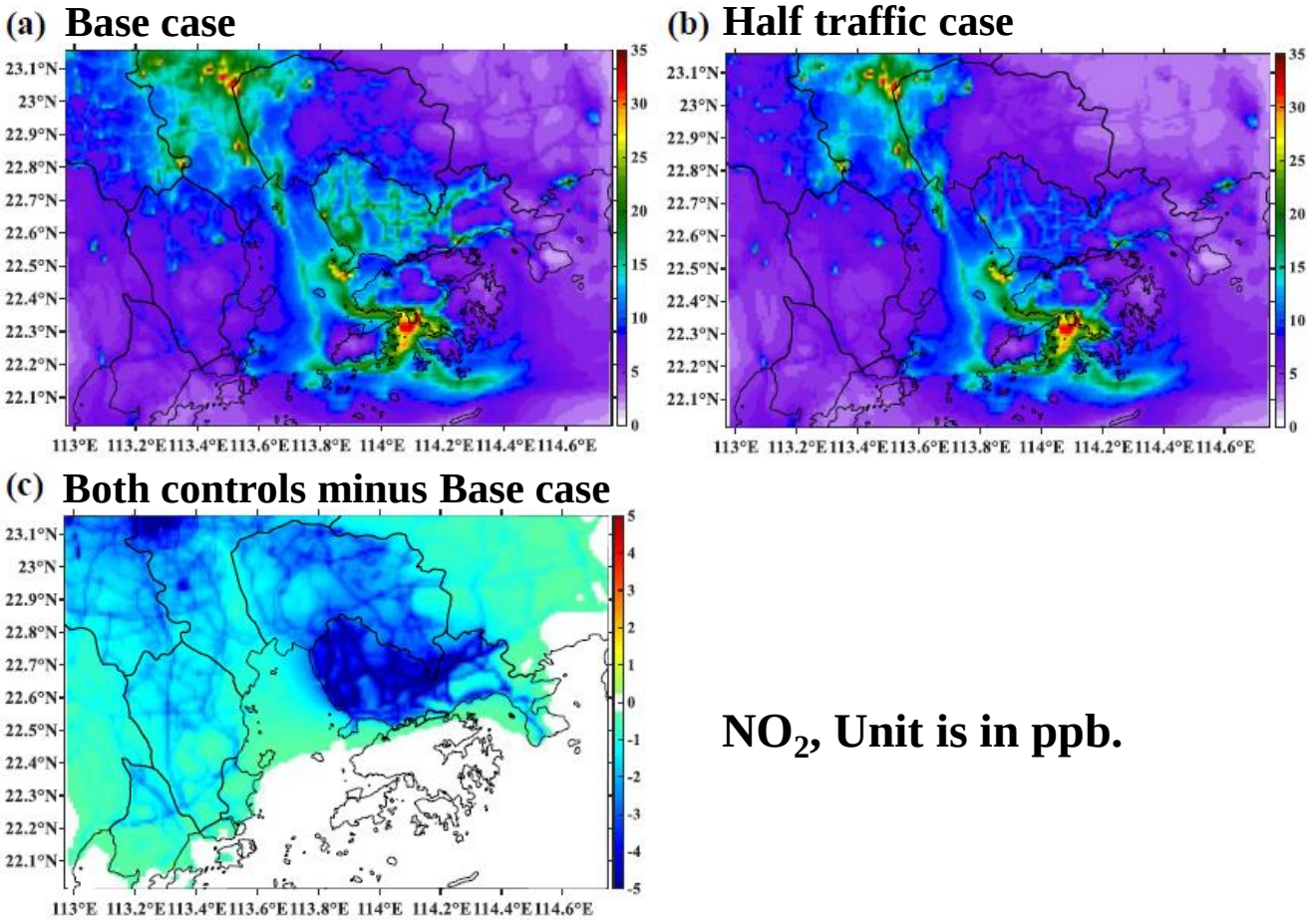


Fig. 2: Daily column emission comparison of anthropogenic NOx for (a) Base case, (b) Half Traffic case, (c) Half Industry VOC case, (4) Both control case. Unit: moles/s.

Part III: Regional model results-NO_2

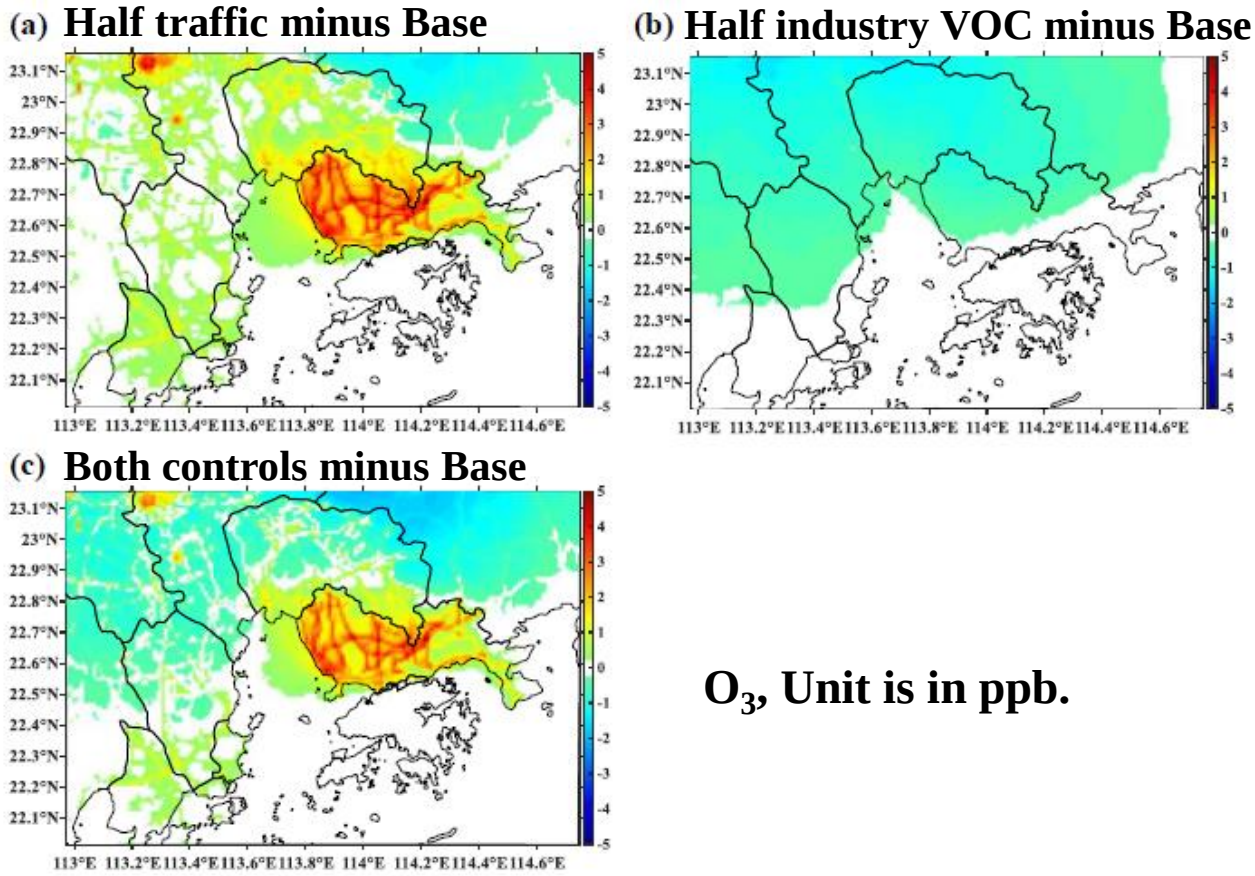
- Clear reduction is observed in Guangzhou and Shenzhen.
- NO_2 concentrations are substantially higher in the HK, and the industrial areas towards Guangzhou, and also along shipping lanes.
- Diff plot showed the reduction up to 5 ppb in central Guangzhou and Shenzhen.



NO_2, Unit is in ppb.

Part III: Regional model results-O_3

- **Half-traffic case**: the O_3 increases in the urban areas and decrease in the rural (upper right) areas, due to reduced NOx titration and lower oxidant emissions. It indicates a VOC-limited O_3 formation regime in urban.
- **Reduced VOC case**: O_3 is reduced throughout the domain because lower VOCs correspond to lower levels of reactive species, resulting in less oxidant (in this case, O_3) being generated.
- **Both controls**: O_3 increases in urban of Guangzhou and Shenzhen, but with a lower magnitude comparing with Fig. a, due to the reduced VOC case effects.

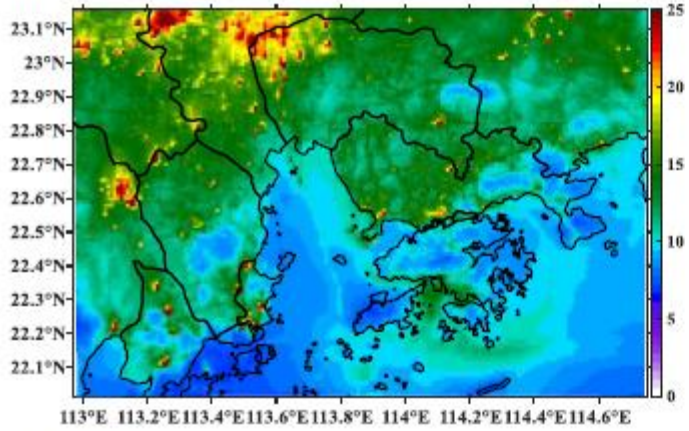


O_3, Unit is in ppb.

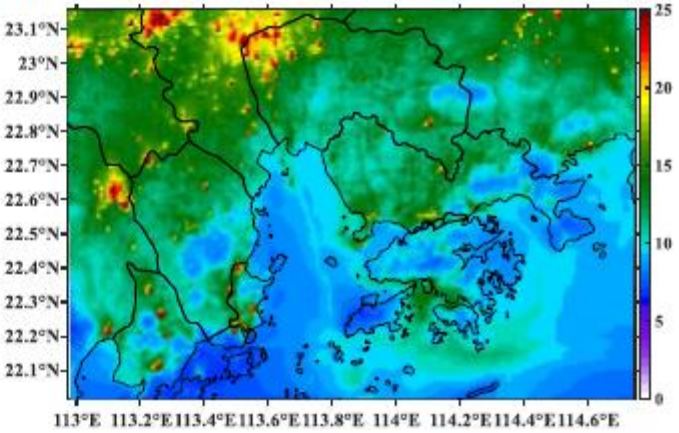
Part III: Regional model results-$PM_{2.5}$

- Period-average $PM_{2.5}$ concentrations for the PRD**.**
- **Half-traffic case** leads to a moderate decrease in $PM_{2.5}$ concentration.
- Considerable $PM_{2.5}$ concentration differences result from the traffic restrictions imposed in the urban areas (Up to 3 μg/m^3 in Shenzhen in **Both-control case).**

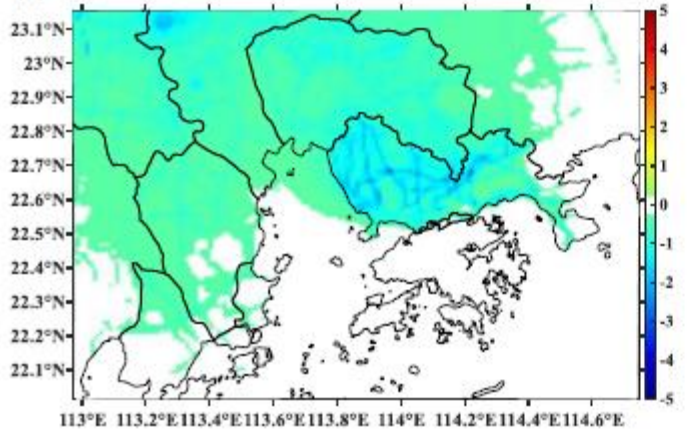
(a) Base case



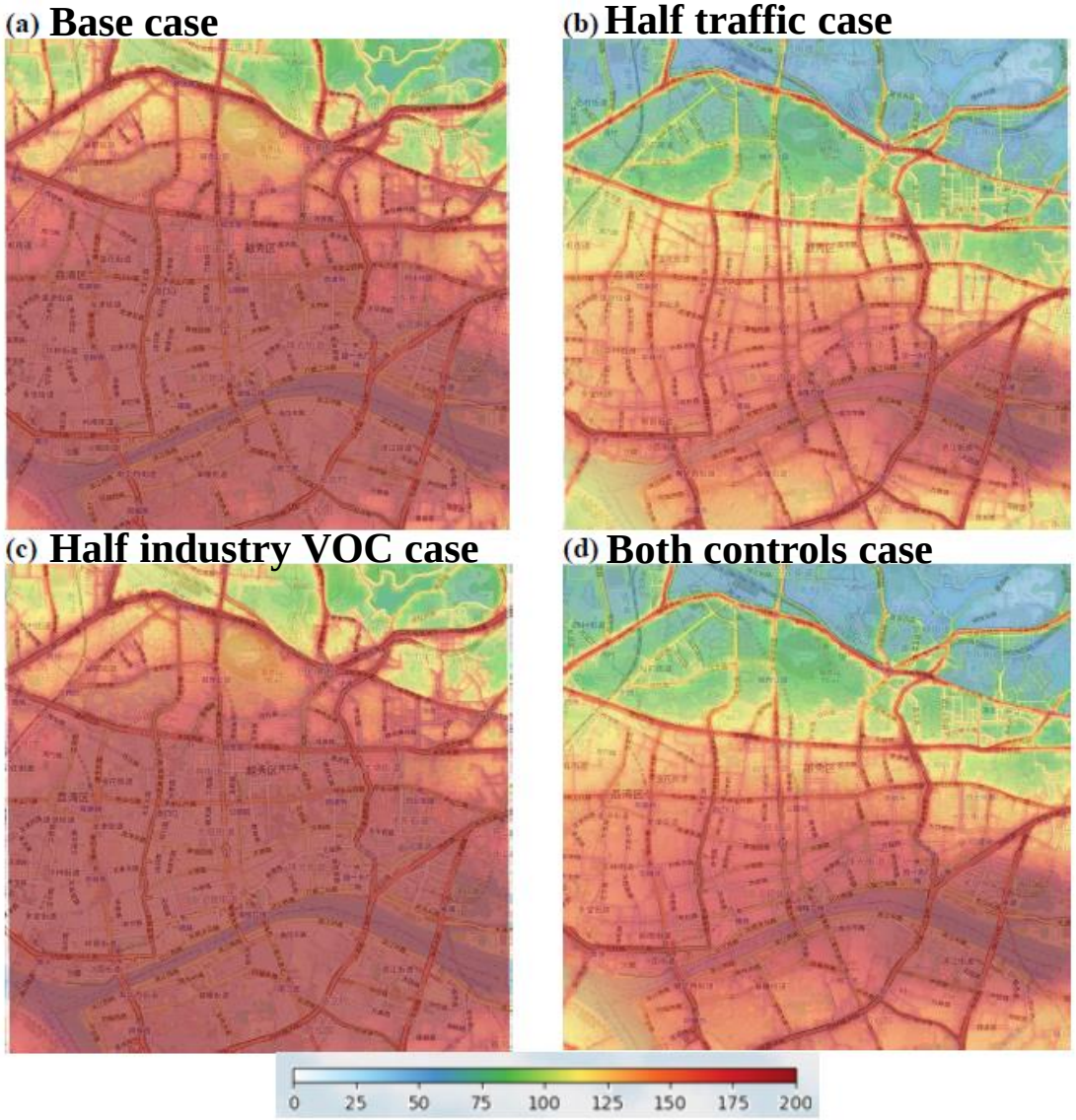
(b) Half traffic case



(c) Both controls minus Base case

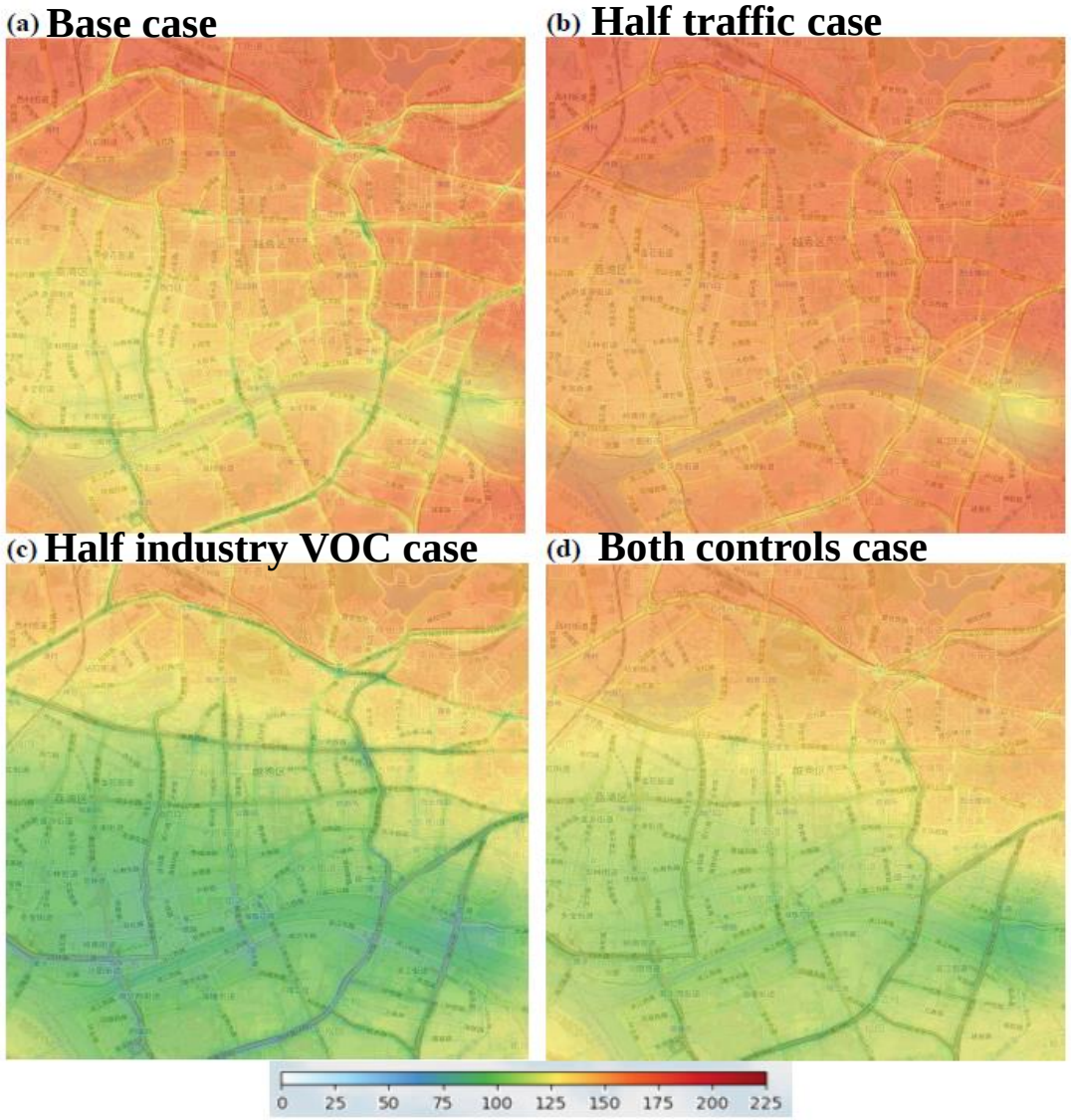


Part III: Coupled model results-NO_2



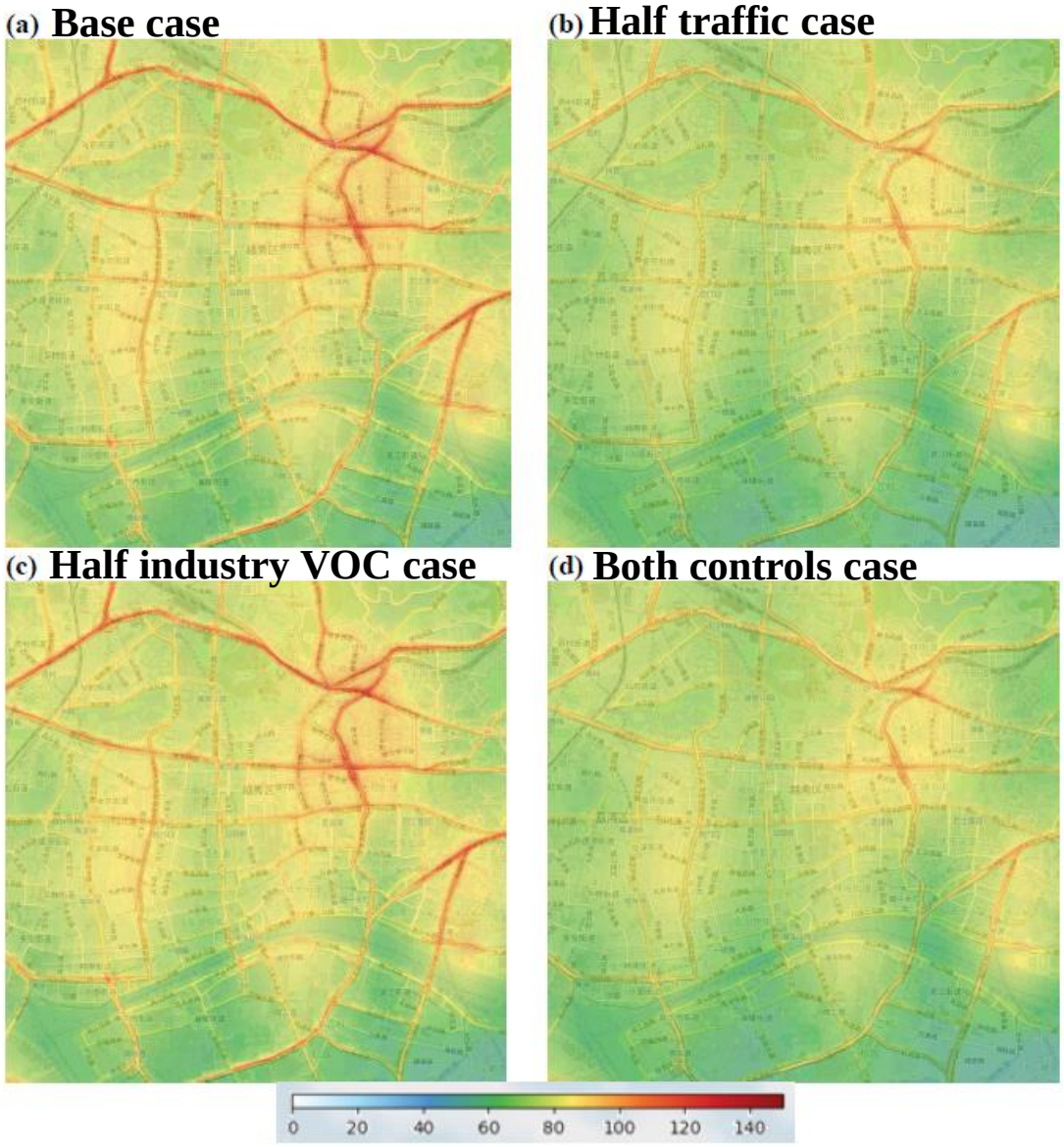
- Shows a case for the Guangzhou domain where NO_2 concentrations exceed the hourly limit value (200 µg/m^3) in the middle of the day during May.
- Figures b and d show that the area of exceedance of the limit value of 200 µg/m³ is significantly reduced when the traffic emissions are halved.
- Local NO_2 concentrations are not seen to change with variations in the VOC emissions (Figures c).

Part III: Coupled model results-O_3



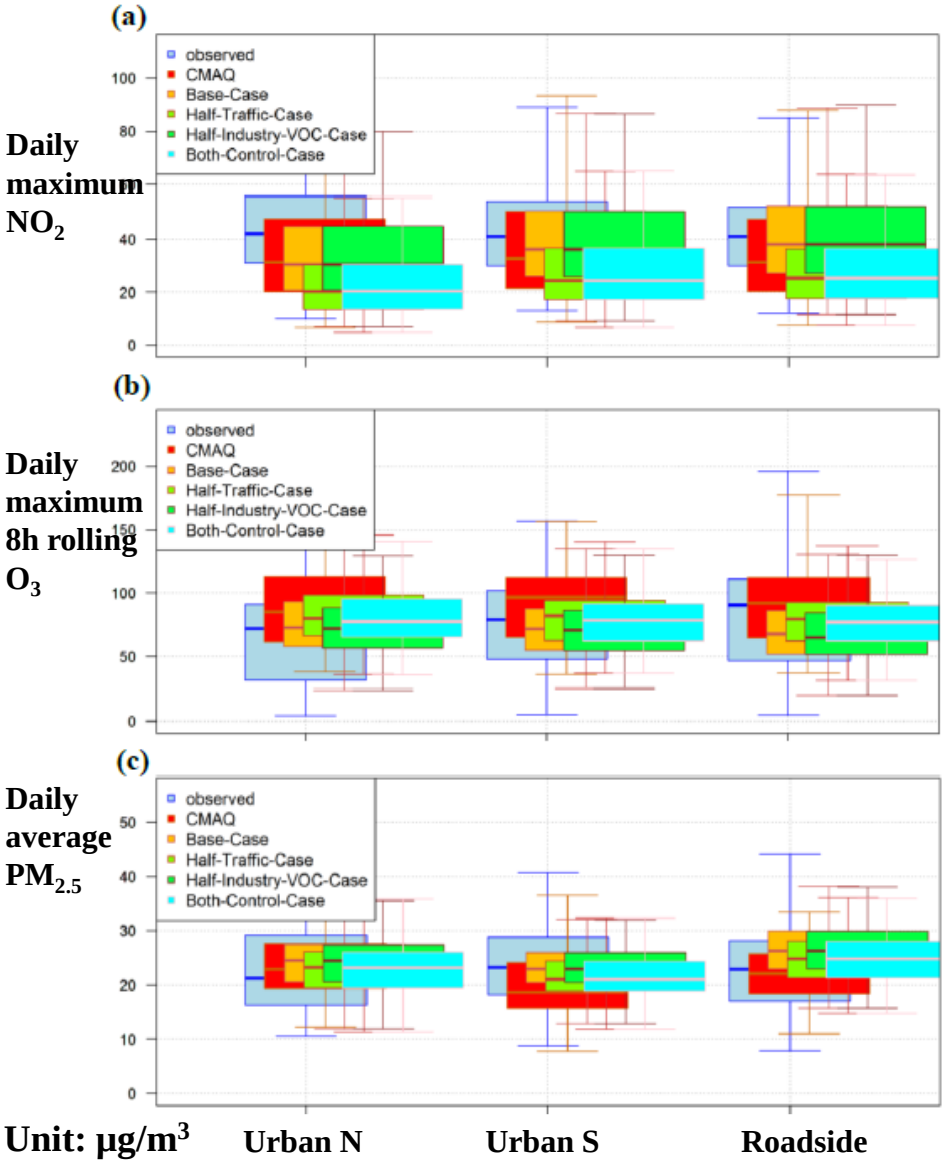
- O_3 concentrations in the Guangzhou domain during the same pollution episode.
- Reducing traffic emissions increases the spatial extent of the O_3 exceedances in urban areas due to reduced NOx titration of O_3.
- Conversely, reducing VOCs leads to a reduction in the area of O_3 exceedance within this local domain.
- When both controls are applied in the local area (comparing a and d), the net effect is a slight increase in near-road O_3 concentrations, but a decrease in concentrations elsewhere.

Part III: Coupled model results-$PM_{2.5}$



- Modelled concentrations for a different time are presented for $PM_{2.5}$, as the atmospheric conditions associated with $PM_{2.5}$ pollution episodes differ from those associated with O_3 and NO_2 episodes.
- Although there is a very small relative reduction in $PM_{2.5}$ emissions, the impact in urban areas is significant during this episode (compare a and b), as this emissions reduction relates to near-ground traffic sources.
- The change in VOC emissions has a negligible effect on $PM_{2.5}$ concentrations at this scale (7a and 7c), indicating the half-VOC strategy does not appear to be an effective control strategy for PM during the model period.

Part III: Coupled model results



- Modelled concentrations to the measurements recorded at three sites, for the base case and three coupled model scenarios in addition to the base case regional model.
- For NO_2 and $PM_{2.5}$ at the majority of sites, the coupled system predicts higher concentrations than the relatively coarse resolution regional model, and for O_3, the coupled system predicts lower concentrations.
- Fig. a shows that the NO_2 concentrations are dominantly contributed from the traffic sector.
- The NOx titration effects on the O_3 concentration in Fig. b drive up the O_3 concentration.
- Cutting the industry VOC emission sources is more effective for the O_3 control, revealing a VOC-limited regime in this region.

Conclusion

- The implemented coupled regional-to-local air quality model system allows a thorough assessment of the impact that NO_x and VOC emissions from traffic and industry have on ambient O_3 and $PM_{2.5}$, drawing a holistic pollution mitigation picture at a range of spatial resolutions.
- Half-traffic scenario leads to reductions of NO_2 and $PM_{2.5}$, but increases in O_3 concentrations in urban areas (and decreases in rural areas), revealing a VOC-limited O_3 formation regime.
- The reduced industrial VOC emissions scenario leads to reduced O_3 concentrations throughout the mitigation domain, suggesting more stringent VOC control measures in the industrial sector will substantially alleviate the worsening O_3 pollution.

Thank you!

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