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Comprehensive Insights Into O_3 Changes During the COVID-19 From O_3 Formation Regime and Atmospheric Oxidation Capacity

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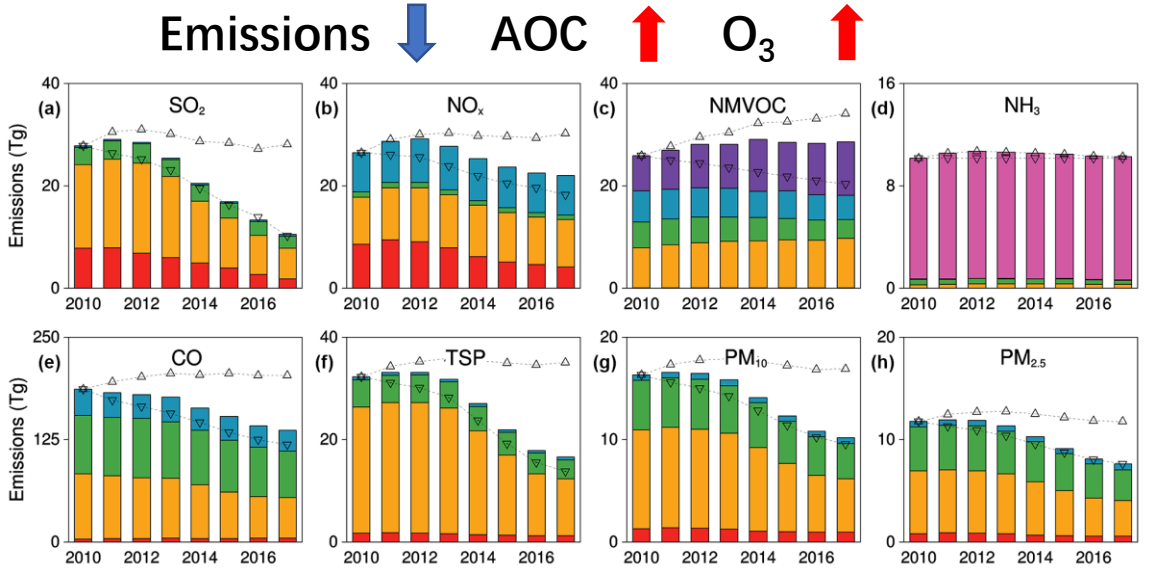
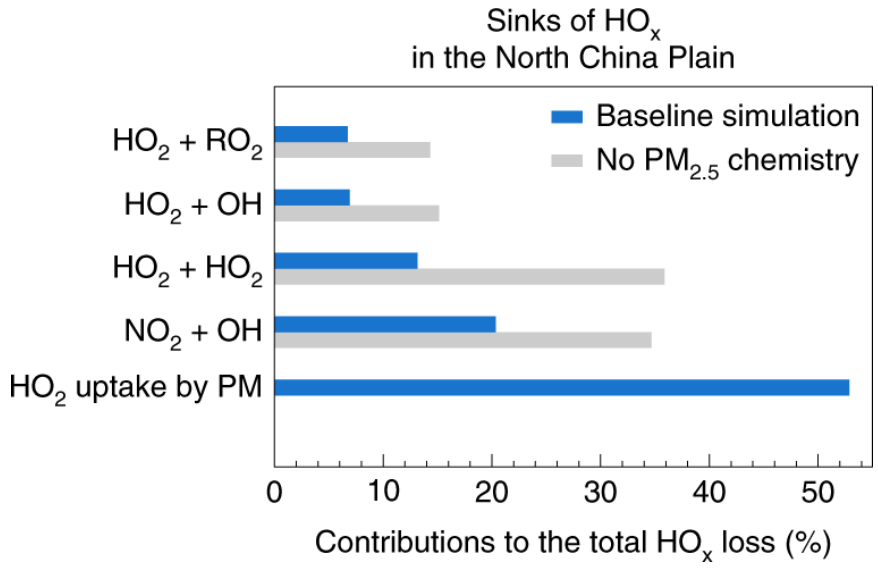
Background

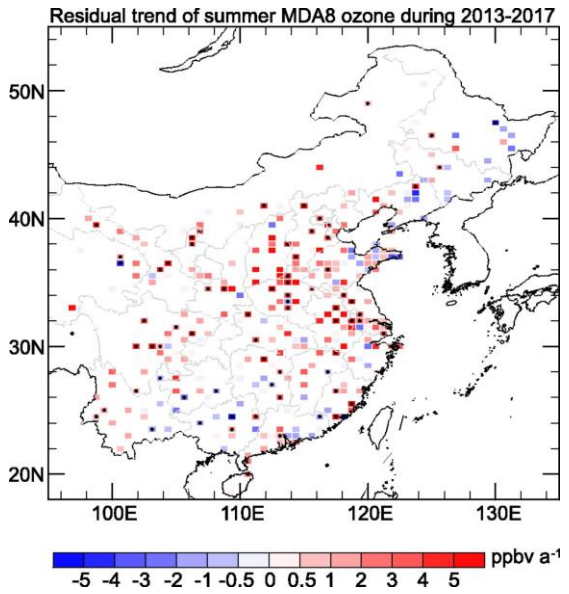
- Anthropogenic emissions decreased in China, but the AOC increased, leading to the elevated O_3 issue.
- The sink ($PM_{2.5}$) of NO_x and HO_2 radical reduced, leading to the elevated O_3 issue.
- Simultaneously, more VOCs reacted with the oxidants (e.g. OH radical), leading to the elevated O_3 issue.



Zheng, et al., ACP, 2018



Li, et al., NG, 2019



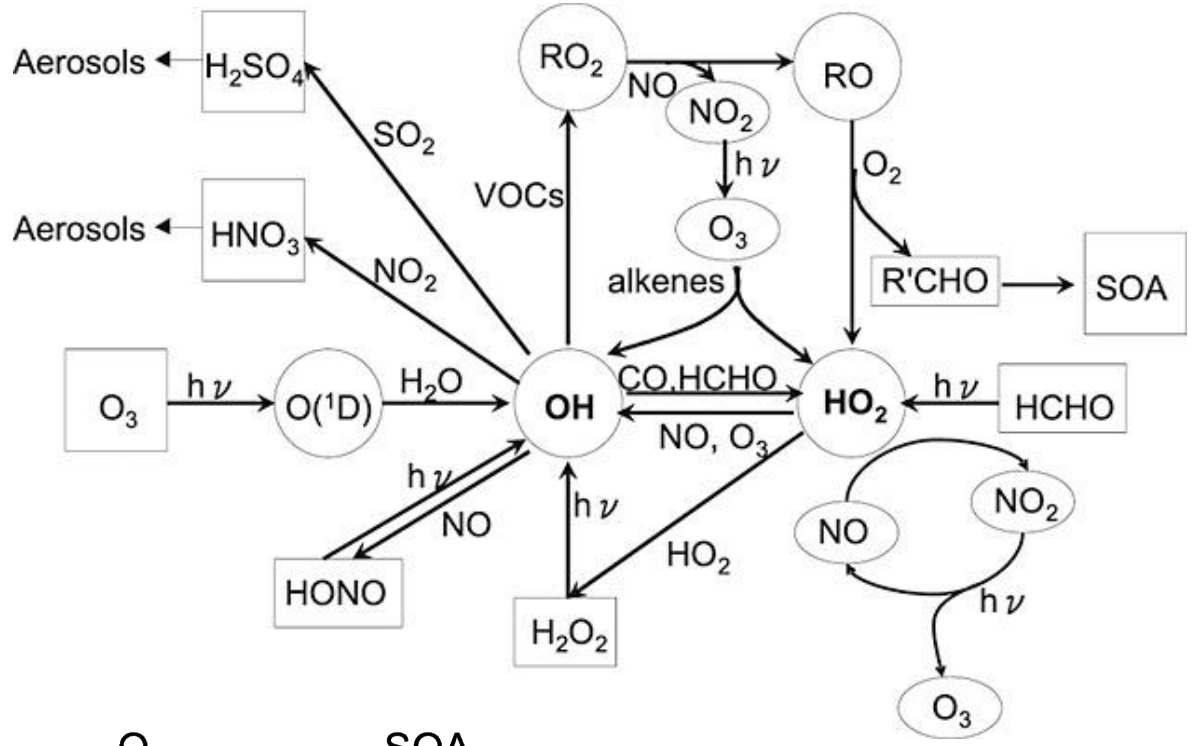
Li, et al., PNAS, 2018

What is AOC?

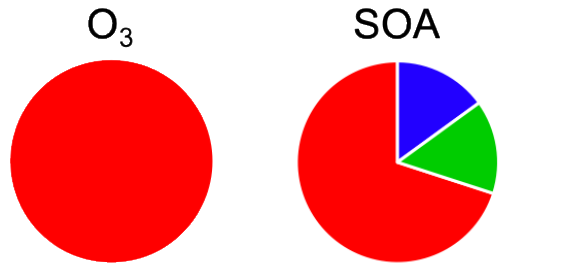
- AOC plays a key role in the secondary pollutants formation.
- AOC is defined as the sum of individual oxidation rates of primary pollutants (VOCs) by oxidants (HO_x and NO_3)
- These oxidants are regarded as indicators to assess AOC

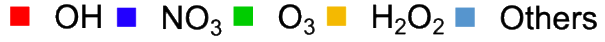
$$\mathbf{AOC = [OH]\times k_{OH} + [O_3]\times k_{O3} + [NO_3]\times k_{NO3} + \dots}$$

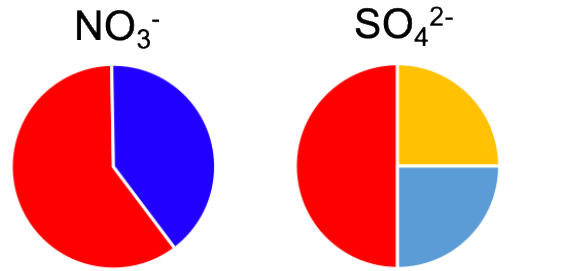
Major oxidation pathway



X. Ren, et al., JGR, 2013



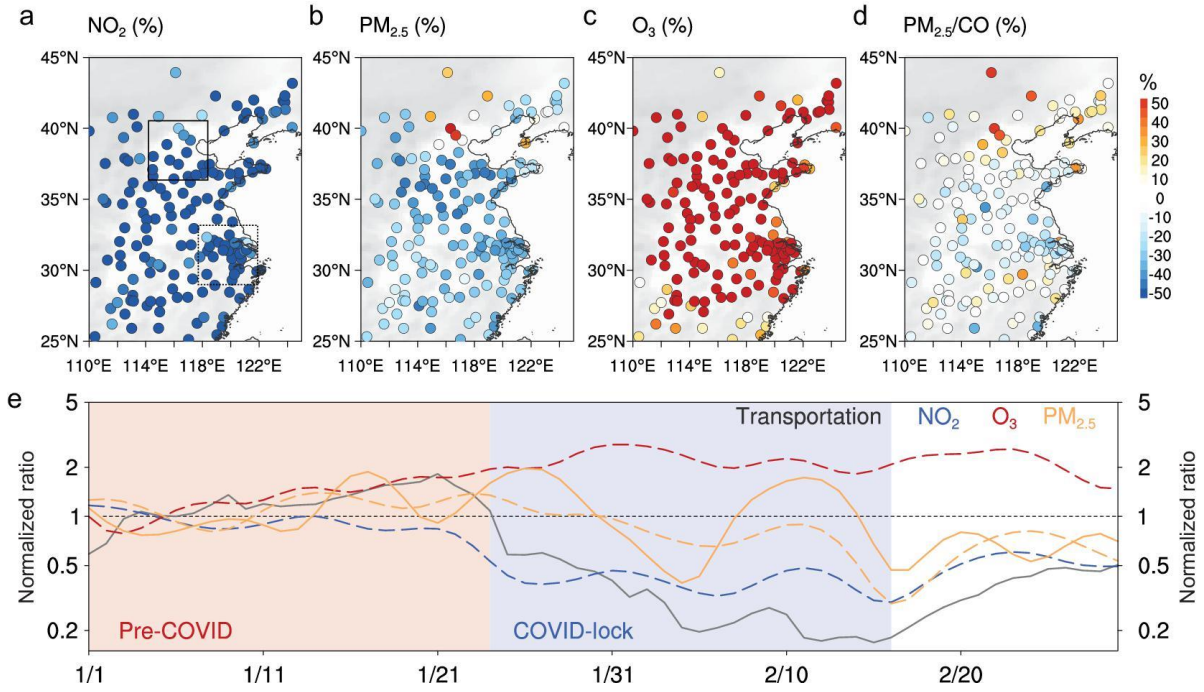


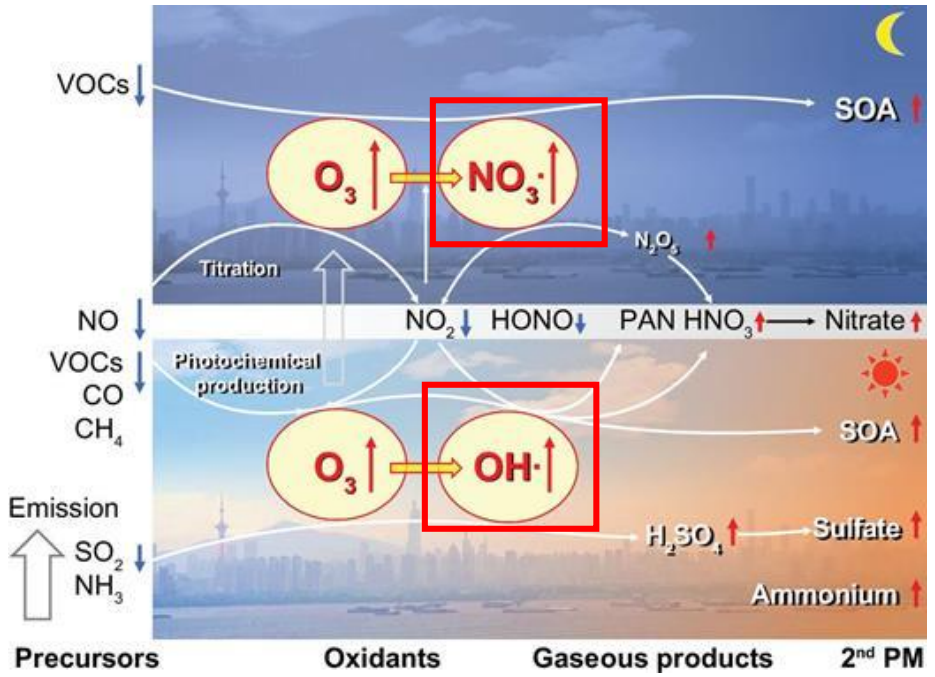


AOC in COVID-19

- During the lockdown period, most transportation and commercial activities were terminated which gives an important opportunity to investigate the changes in air quality due to drastic emissions reduction.

- $PM_{2.5}$ decreased but the O_3 increased in eastern China during the lock-down.



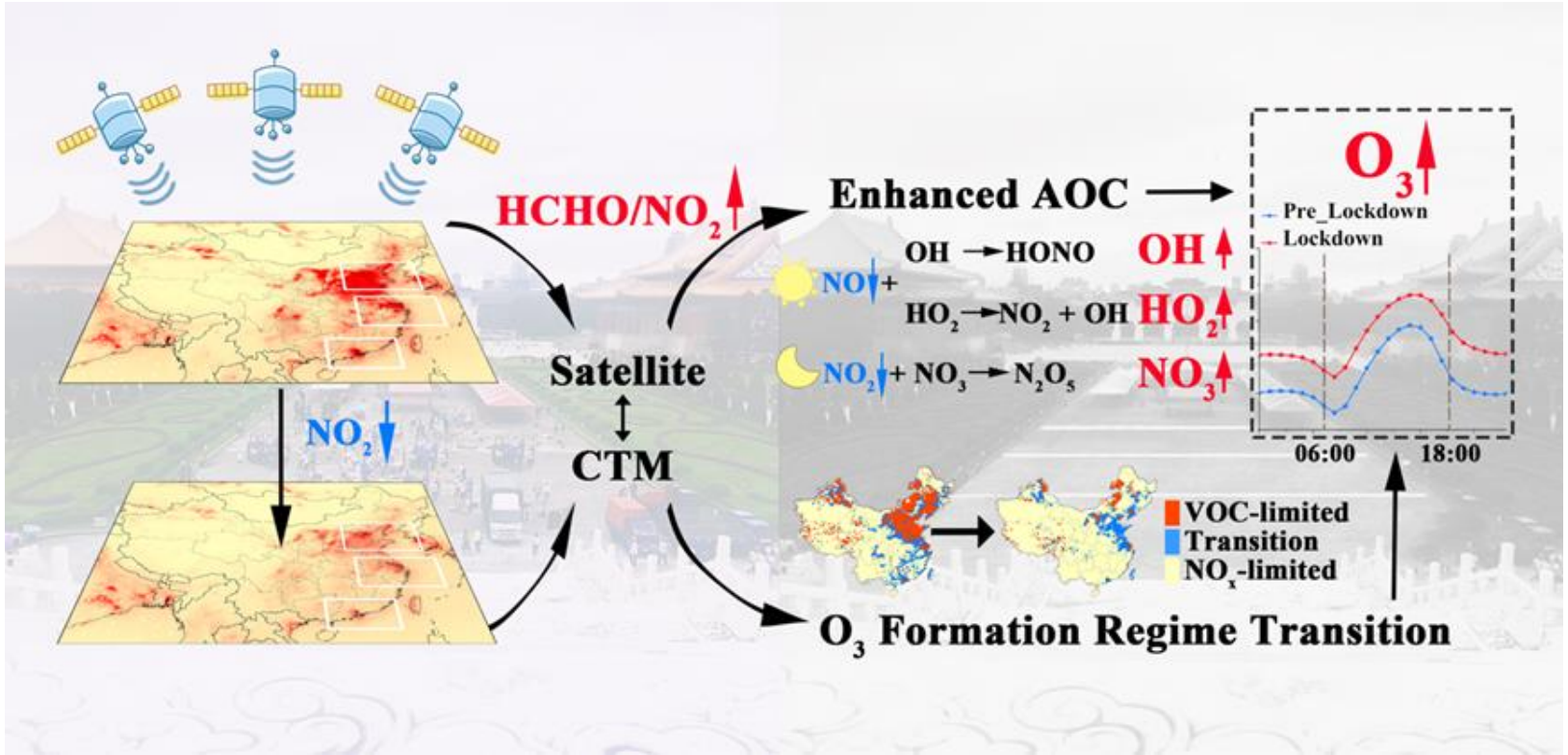


Huang, et al., NSR, 2020

AOC study

- We utilized comprehensive satellite, ground-level observations, and source-oriented chemical transport modeling to investigate the O_3 variations

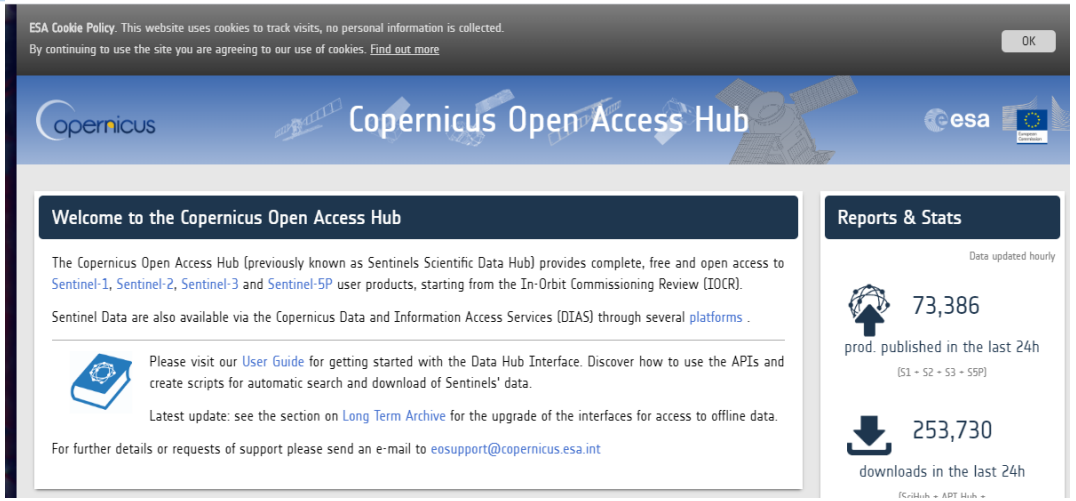
- Study periods： Pre-lockdown (Jan. 6-22)， Lockdown (Jan.23-Feb.29) and Post-lockdown (Mar.1-31)

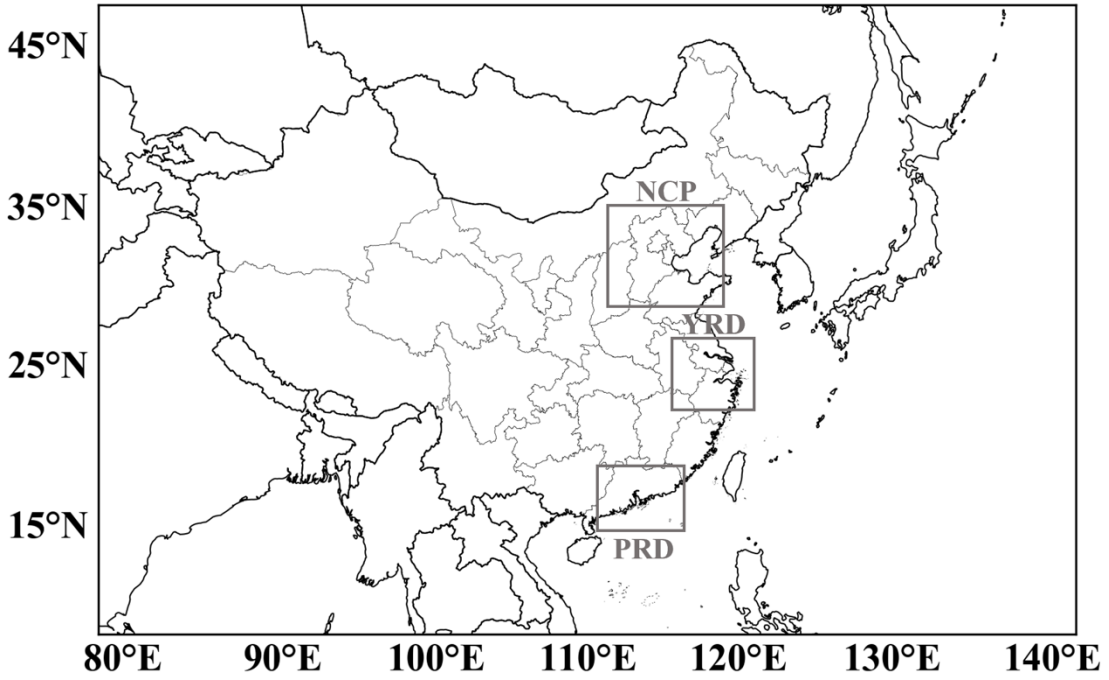


Zhu, et al., *2021, GRL.*

Model setup

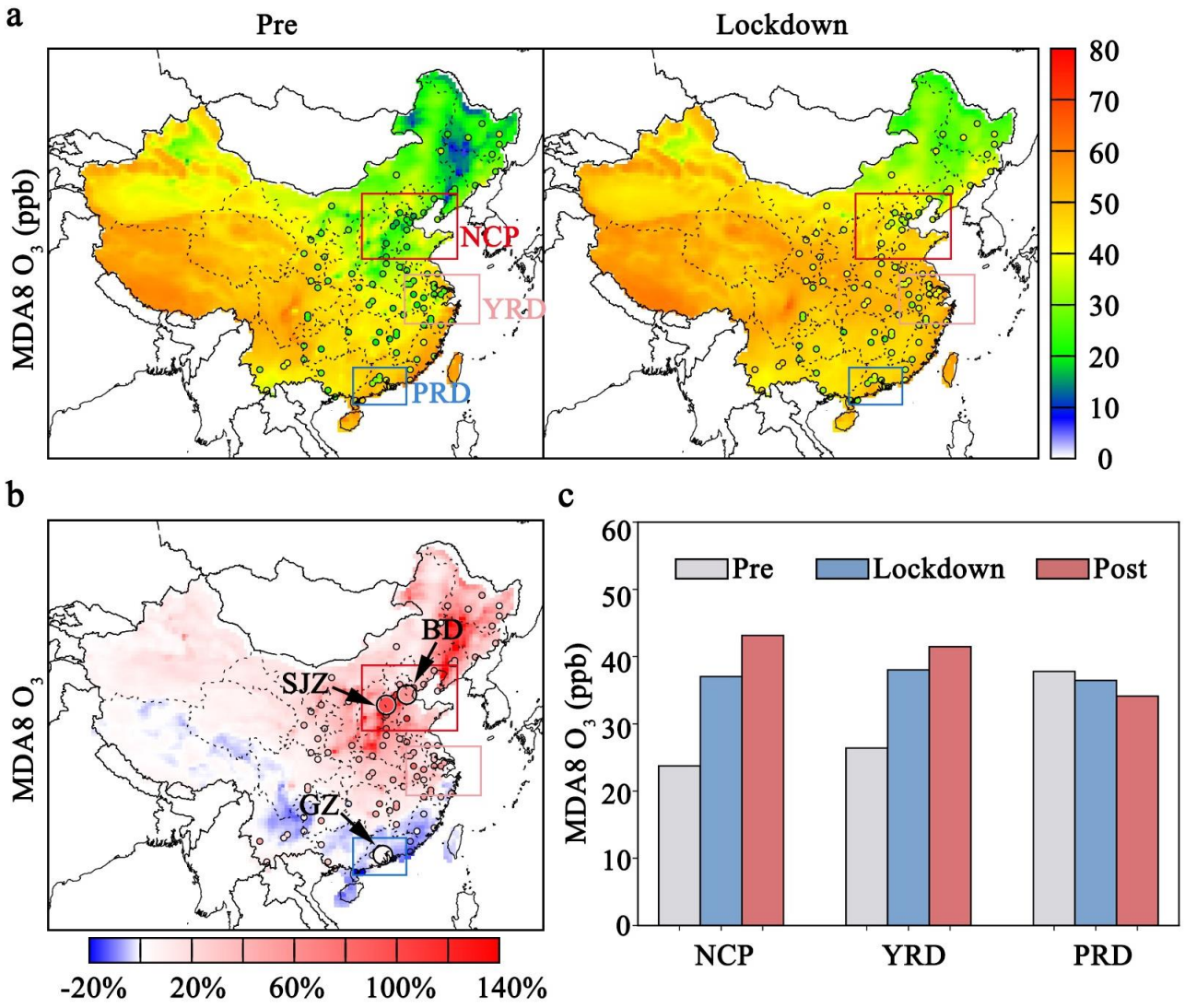
- Satellite: HCHO and NO_2 are from TROPOMI
- CTM: source-oriented CMAQ v5.0.2
- MET: WRF v4.2
- Emission: MEIC+MEGAN





O_3 observation

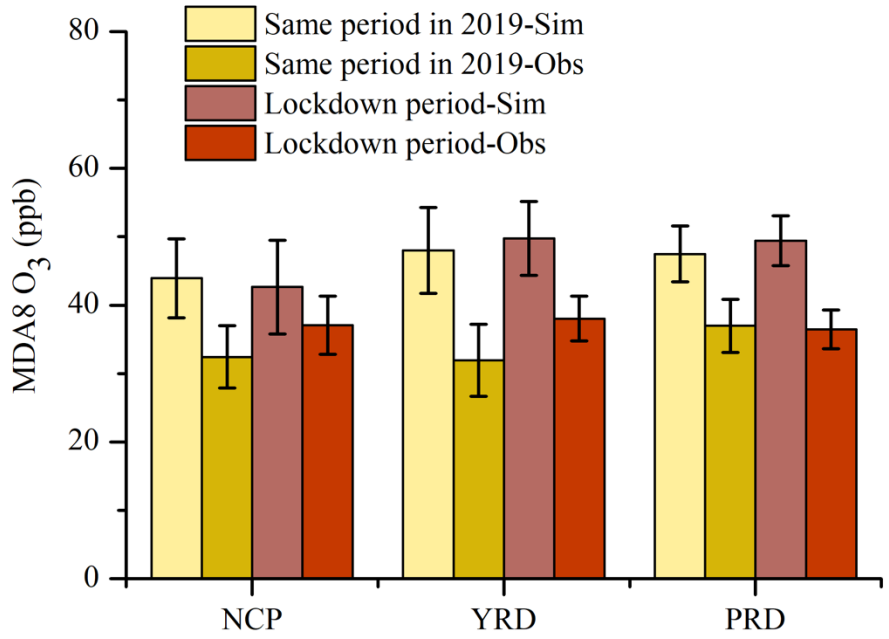
- O_3 increased across China during the Lockdown.
- Over 30% of O_3 increased in the NCP and YRD regions.
- During Post-lockdown, observed O_3 concentrations continued to increase in the NCP and YRD regions.

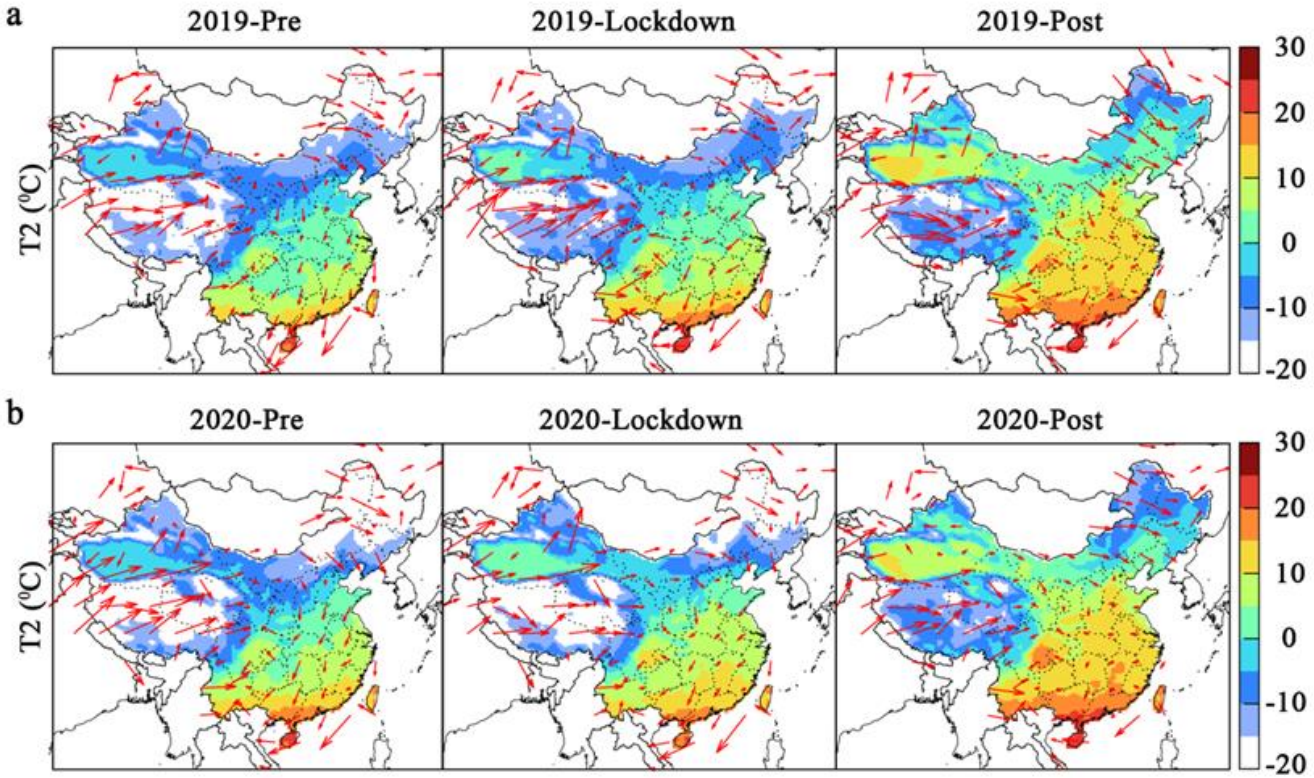


Zhu, et al., *2021, GRL.*

2019 O_3 vs 2020 O_3

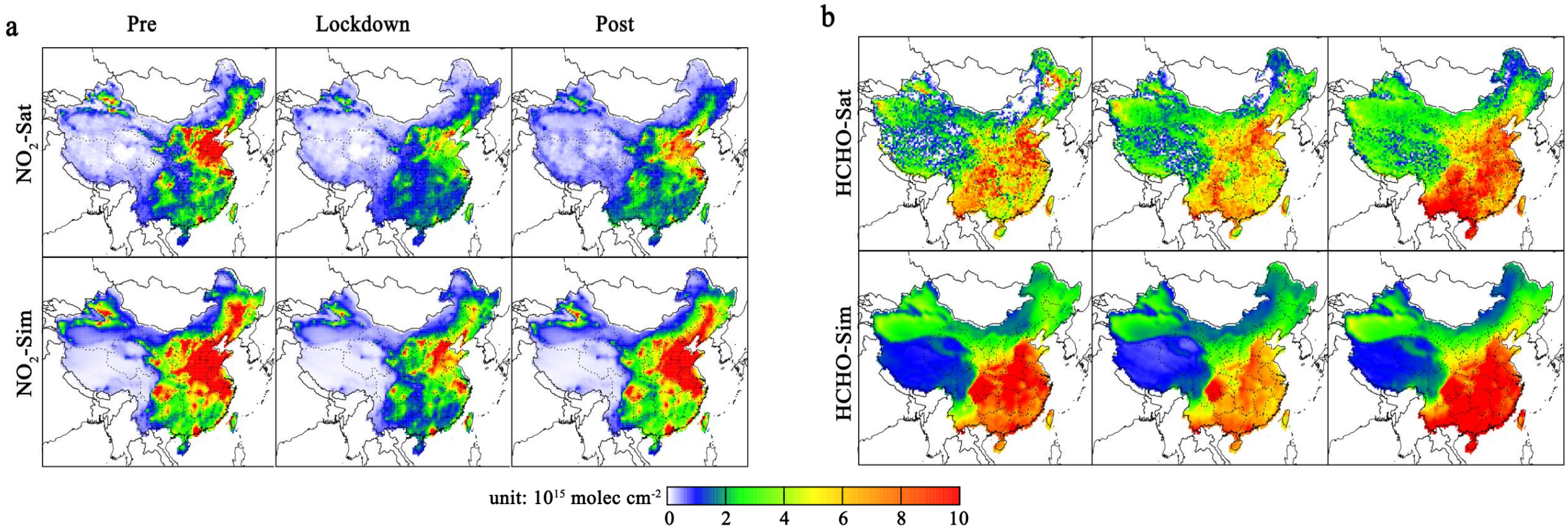
- the changes of O_3 levels between the same periods of Pre-lockdown and Lockdown in 2019 were not as obvious as in 2020.
- Both meteorology and emission reduction played important roles in O_3 elevation in NCP





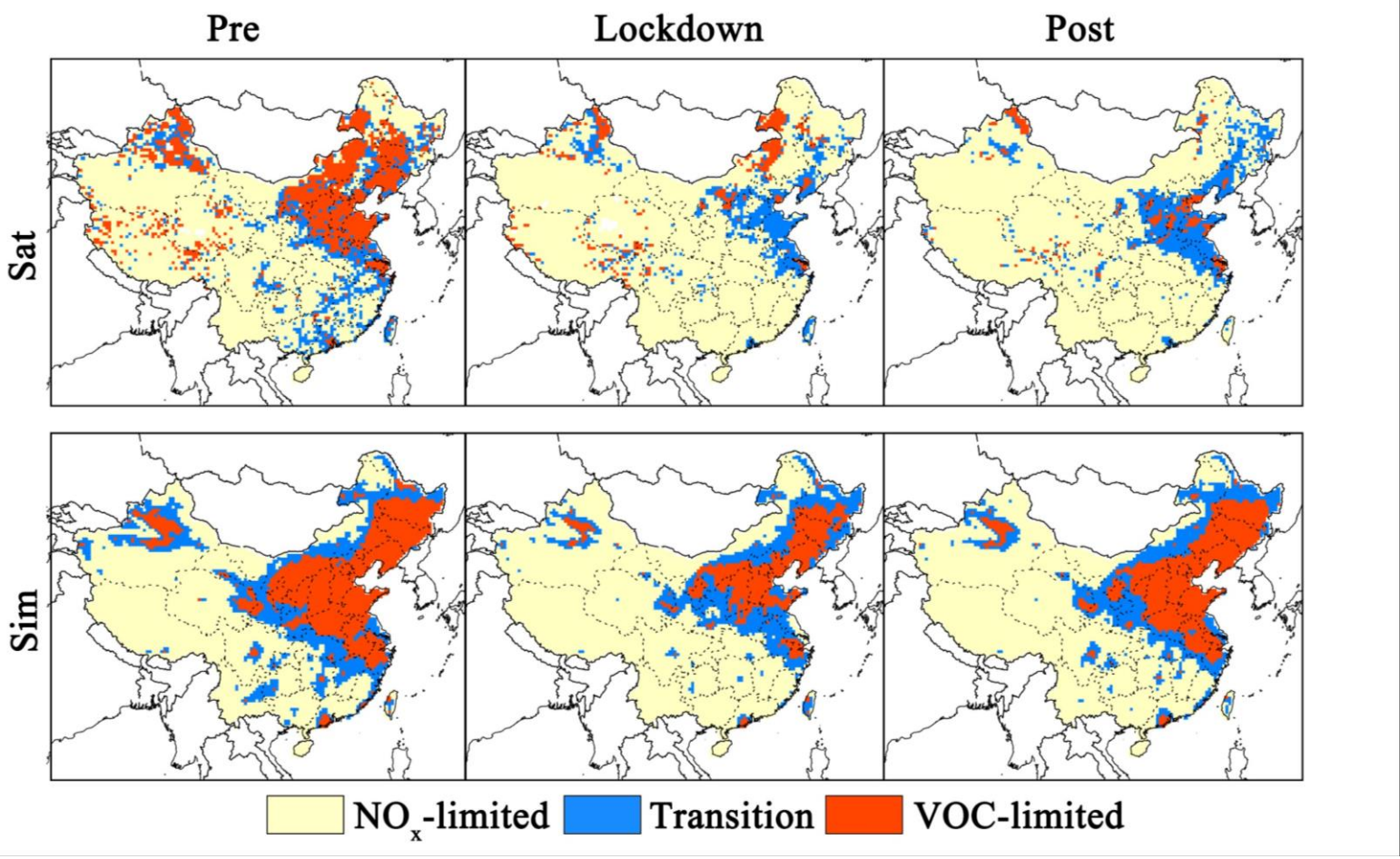
Precursors?

- Sat: TROPOMI data and Sim: CMAQ simulations
- NO_2 in the NCP, YRD, and PRD regions declined by 59.61%, 63.28%, and 44.03% during the Lockdown respectively.
- No noticeable changes were observed in the HCHO, indicating the stable/higher level of AOC.



Sensitivity Regime

- The changes of precursor lead to the shift of O_3 sensitivity regimes
- Regime Indicator = $HCHO/NO_2$
- During the Lockdown, VOC-limited regimes changed to NO_x-limited or transition regime.
- Investigated impacts of AOC on O_3 levels, which were associated closely with the shift of O_3 formation regime



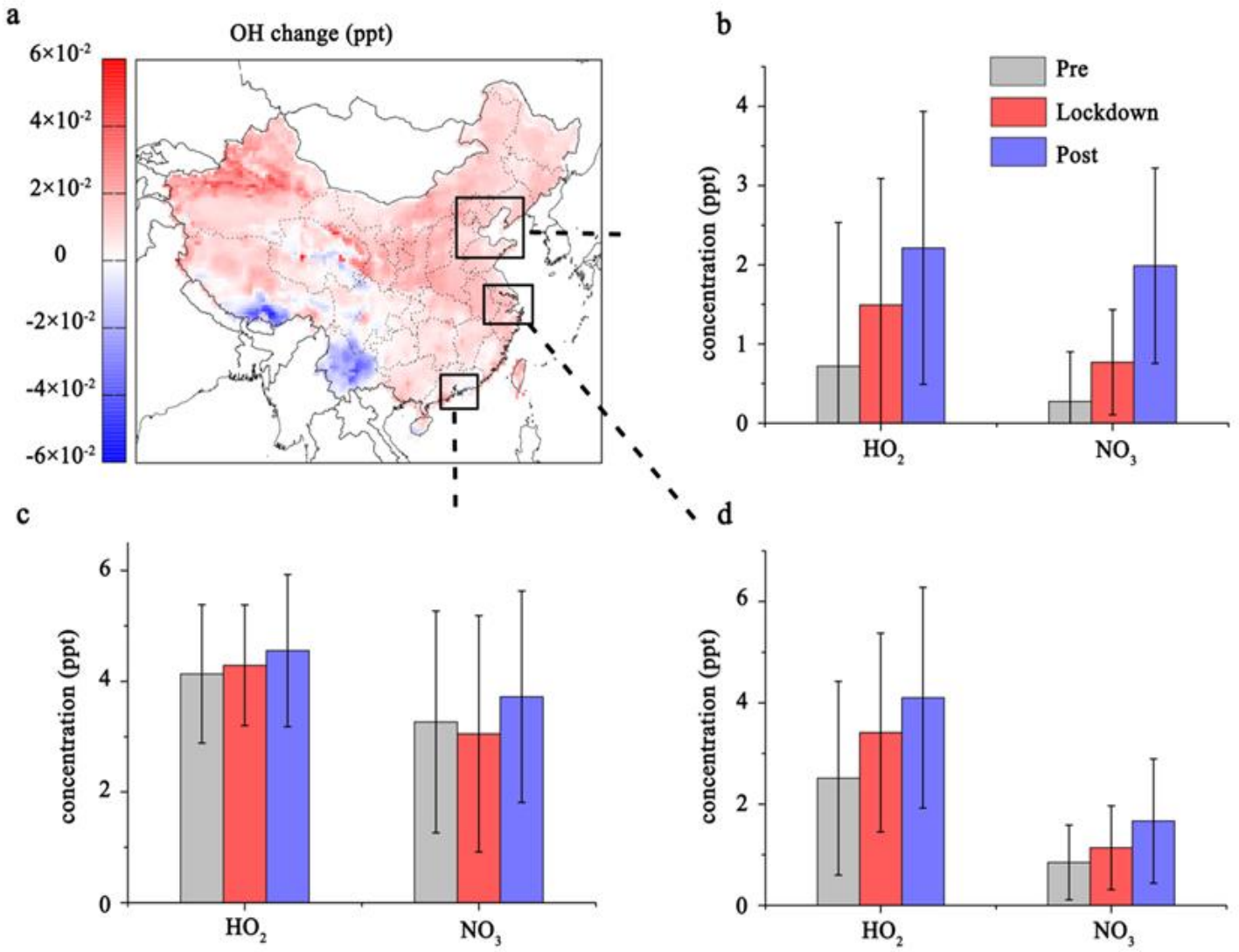
Sensitivity Regime

Pre				CMAQ		
	NO_x-limited	Transition	VOC-limited	NO_x-limited	Transition	VOC-limited
NCP	0.11	0.22	0.67	0.13	0.15	0.72
YRD	0.37	0.45	0.17	0.03	0.31	0.66
PRD	0.31	0.41	0.28	0.31	0.23	0.46
Lockdown	TROPOMI			CMAQ		
	NO_x-limited	Transition	VOC-limited	NO_x-limited	Transition	VOC-limited
NCP	0.56	0.36	0.08	0.20	0.28	0.52
YRD	0.65	0.33	0.02	0.29	0.55	0.16
PRD	0.69	0.31	0.0	0.44	0.28	0.28
Post	TROPOMI			CMAQ		
	NO_x-limited	Transition	VOC-limited	NO_x-limited	Transition	VOC-limited
NCP	0.48	0.36	0.16	0.09	0.26	0.65
YRD	0.57	0.38	0.05	0.09	0.39	0.51
PRD	0.74	0.0	0.26	0.28	0.36	0.36

In the NCP, the NOx-limited regime increased from **0.11 to 0.56** during the Lockdown.

Changes of AOC

- Significantly enhanced AOC in the NCP and YRD regions, which is consistent with the variation of O_3 concentrations.
- The NO_3 radical, the primary nighttime oxidant, has increased significantly in the NCP and YRD regions during the Lockdown



Conclusions

- AOC was enhanced significantly with the decline of NOx, which contributed to the O_3 elevation during Lockdown.

- O_3 formation regime has shifted from VOC-limited to NOx-limited with the impact of dramatic emission reduction during Lockdown

- The importance of balanced emission control policies has been emphasized

- We recommend that O_3 control policies of emission reduction utilize knowledge regarding the associations of O_3 formation regime, AOC variations, and O_3 levels.

Thanks!