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2025 DRAGON 6 SYMPOSIUM

14-18 JULY 2025

[PROJECT ID. 95381]

[AIR QUALITY MONITORING AND ANALYSIS IN POPULOUS AREAS IN CHINA (AQMAP)]





2025 Dragon 6 Symposium

<TUESDAY 15/JULY/2025 >

ID. 95381

PROJECT TITLE: AIR QUALITY MONITORING AND ANALYSIS IN POPULOUS AREAS IN CHINA (AQMAP)

PRINCIPAL INVESTIGATORS: JIEYING DING, WUKE WANG

CO-AUTHORS: RONALD VAN DER A, GERRIT DE LEEUW, QIANQIAN ZHANG, SELVIGA SINNATHAMBY, SARAH SAFIEDDINE, SERENA DI PEDE, YINGYING YAN, CHENG FAN

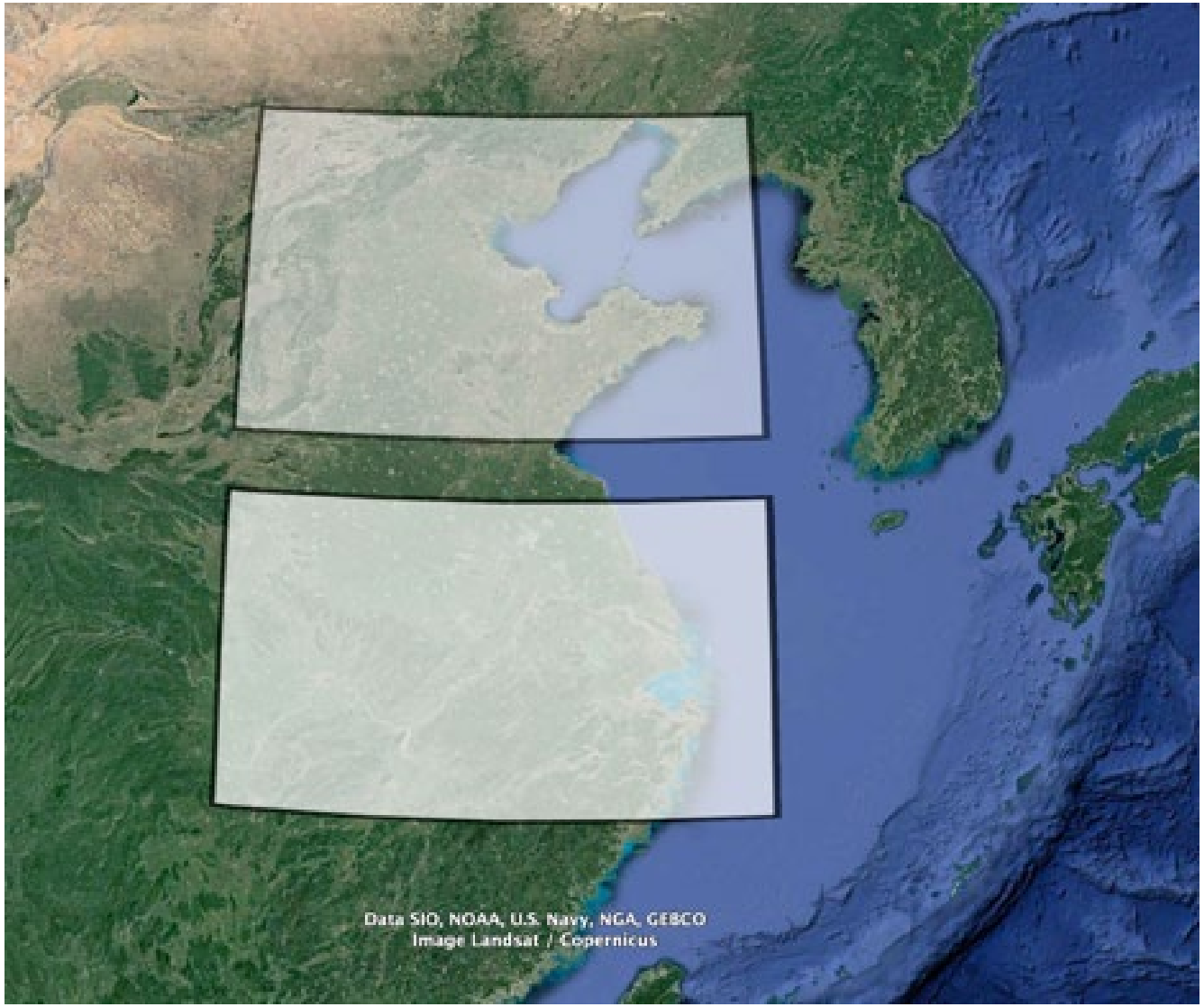
PRESENTED BY: JIEYING DING, WUKE WANG

1. Analyse emissions and concentrations of air pollutants derived from satellite observations
2. Identify new particle formation using satellite-derived proxies
3. Evaluate the emission products using chemical transport models.
4. Study the impact of shipping emissions on air quality.
5. Improve the forecast level of ozone and PM2.5 in Wuhan areas
6. Determine meteorological and anthropogenic effects on emission reduction policy.
7. Train young scientists in the field of remote sensing of air pollution

Work Packages

- WP1: Emissions, concentrations and trends of pollutants from satellite observations (KNMI, NSMC, LATMOS, WP leader: Ronald van der A)
  - Input: Satellite data from TROPOMI, IASI, Sentinel 5, EMI, GIIRS, GEMS
- WP2: Aerosols (AirCAS, KNMI, WP leader: Cheng Fan)
  - Input: UV satellite observations, HCHO, SO2, NO2 from TROPOMI and GEMS in WP1, AOD from MODIS. Ground-based remote sensing data of HCHO, SO2, NO2 and UV (PANDORA), AOD (Sunphotometer) and in-situ measurements of particle size distributions in the nm size range.
- WP3: Shipping emissions and its impact on air quality (CUG, KNMI, WP leader: Yingying Yan)
  - Input: AIS data, satellite-derived emissions from WP1
- WP4: Evaluation of satellite-derived emissions and study of air quality over East China (CUG: WP leader: Wuke Wang)
  - Input: satellite-derived emissions from WP1

Study domain



Dragon 6 Batch-2 EO Data Request

Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert “ftp”

ESA /Copernicus Missions	No. Scenes
1. OMI: 2010-2020	
2.TROPOMI: 2018-end of project	
3.	
4.	
5.	
6.	
Total:	
Issues:	

ESA Third Party Missions	*No. Scenes*
1. GEMS	
2. IASI	
3.	
4.	
5.	
6.	
Total:	
Issues:	

Chinese EO data	No. Scenes
1. AGRI-B	
2. GIIRS	
3.	
4.	
5.	
6.	
Total:	
Issues:	

European Young Scientists contributions in Dragon 6

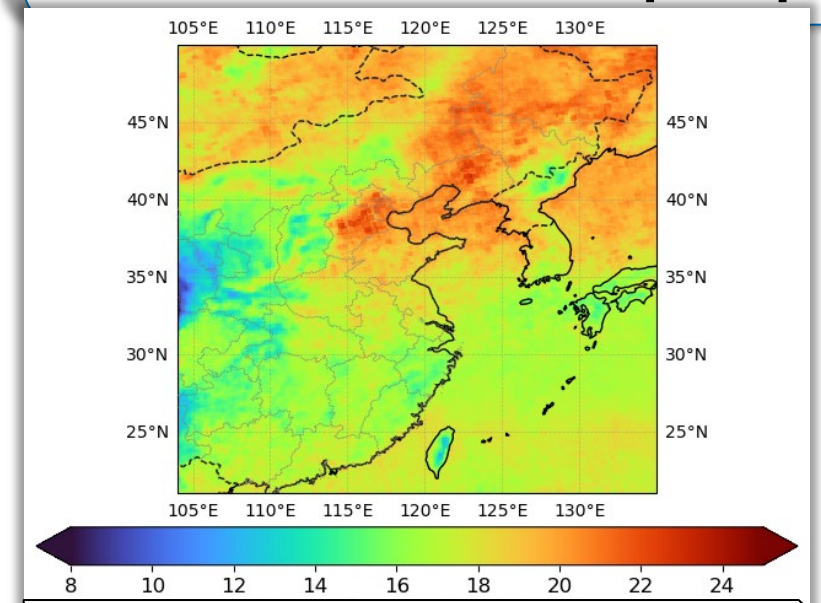
Name	Institution	Poster title	Contribution including period of research
Serena Di Pede	KNMI	**ID: 196** Improvements in the TROPOMI ozone profile retrieval to enhance tropospheric ozone detection sensitivity	

Chinese Young Scientists contributions in Dragon 6

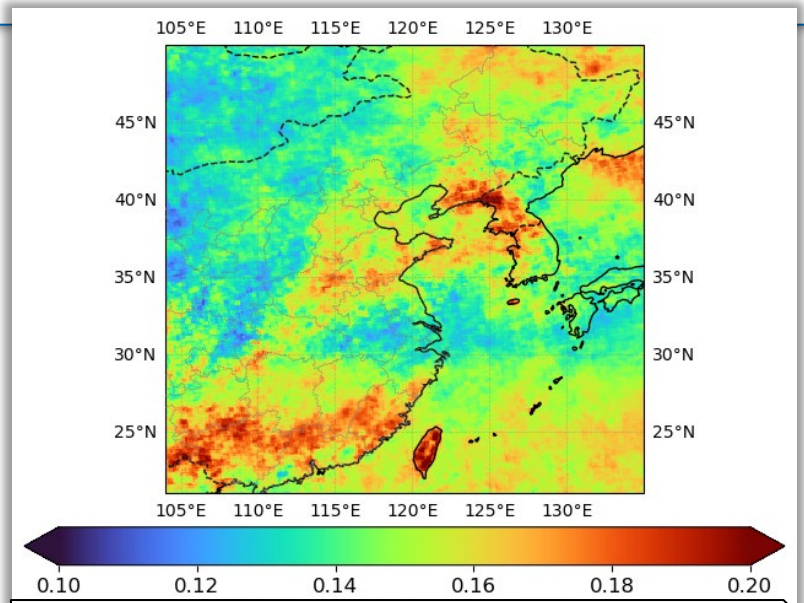
Name	Institution	Poster title	Contribution including period of research
Ouyang Liu	Aerospace Information Research Institute, Chinese Academy of Sciences	Aerosol optical depths retrieval study based on FY-4A AGRI instrument - A case study in East-South Asia	

Overview of European YSs research

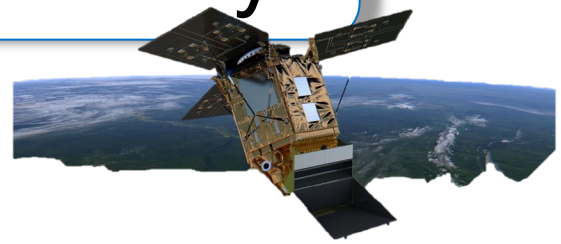
Improvements in the TROPOMI ozone profile retrieval to enhance tropospheric ozone detection sensitivity



Ozone in sub-column 0-6km [DU]



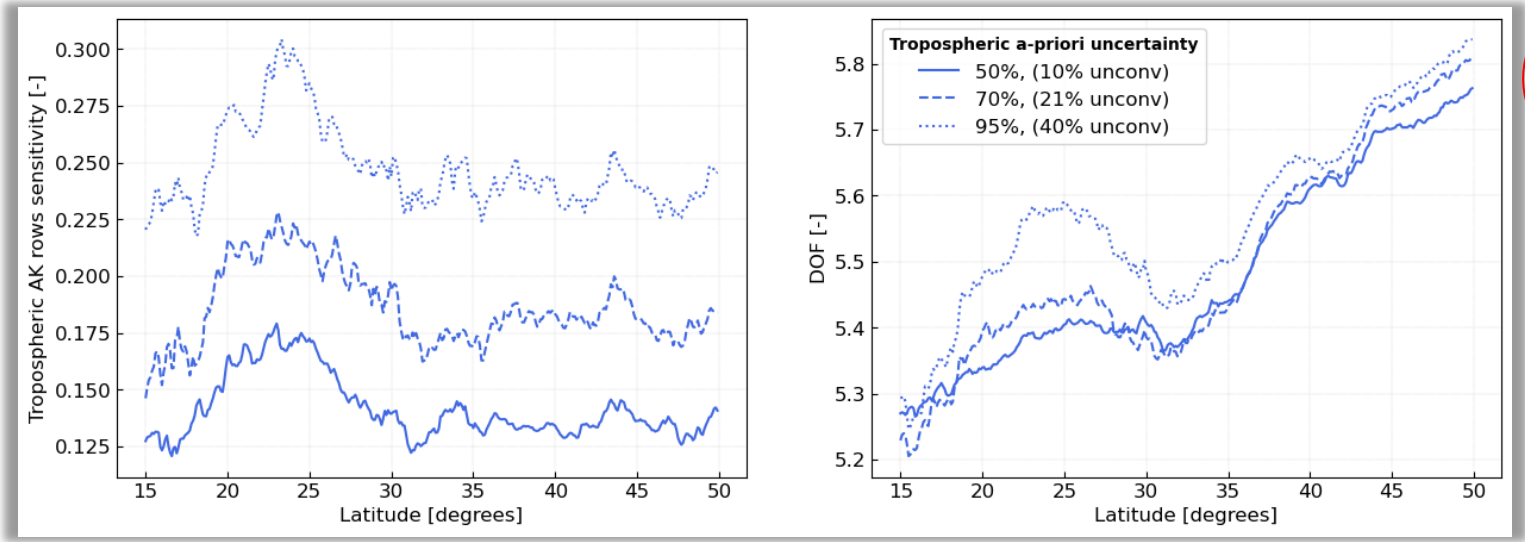
Tropospheric sensitivity (in troposphere) [-]



TROPOMI

Serena Di Pede

Dragon 6 Symposium
Qingdao, 14-17 July 2025



Want to know more?
Come to my poster for more details!

Atmosphere area, Back hall

Tuesday 15 July, 1600-1800

TU Delft
Delft University of Technology

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

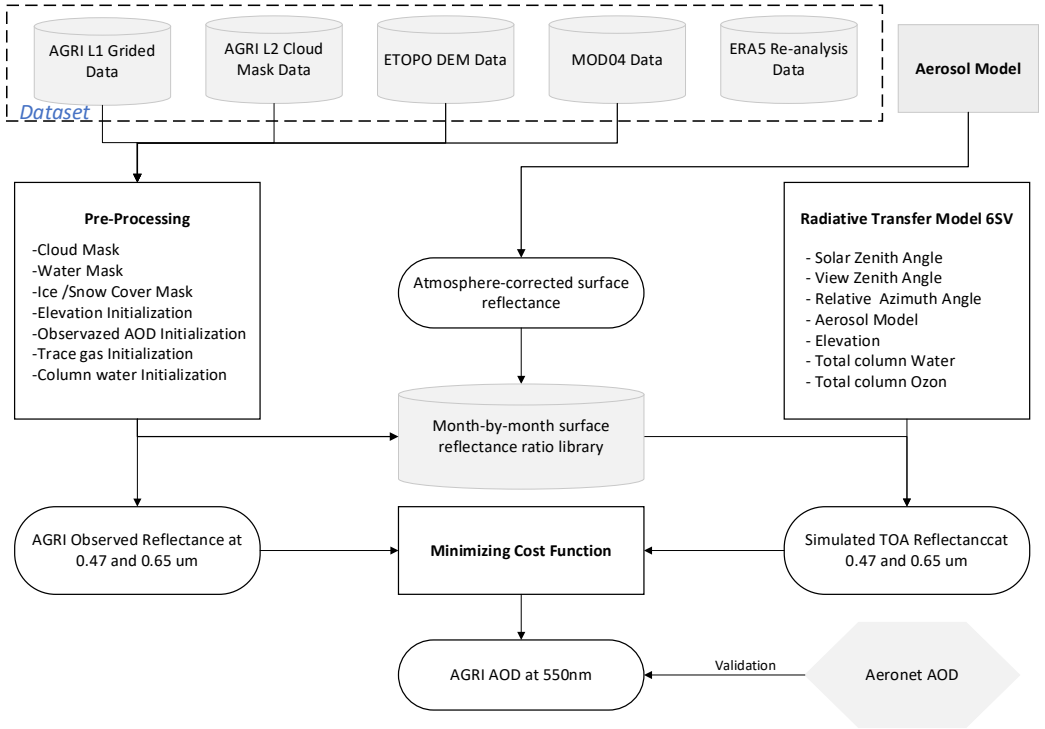
AOD retrieval of FY4-A AGRI over east Asia

(WP2: AIRCAS & KNMI) (YS)

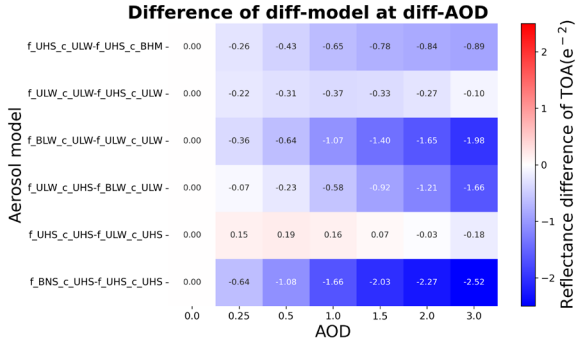
We find that:

- Li et al 2019 Aerosol Model developed from China Area is also applicable to the South Asian region.
- High AOD occurs in the New Delhi, Patna regions, eastern China and Taklimakan Desert area.
- AGRI can successfully capture the autumn and winter pollution events in North China, New Delhi and Patna region of North India, and provide support for air quality monitoring.

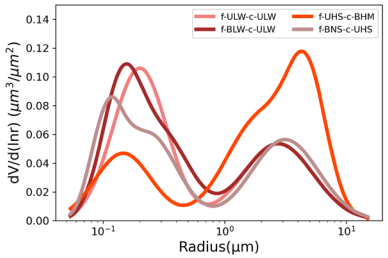
◆ Research method



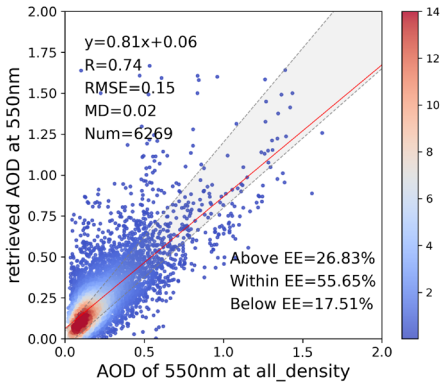
◆ Aerosol model picked

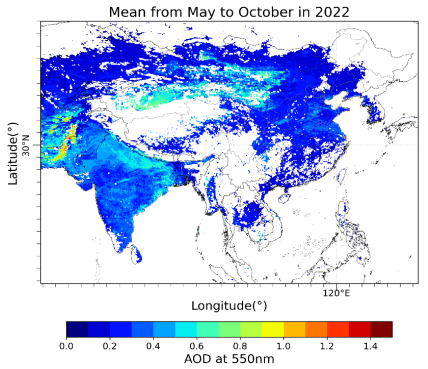


- Four aerosol model are picked finally (Size distribution)



◆ Validation





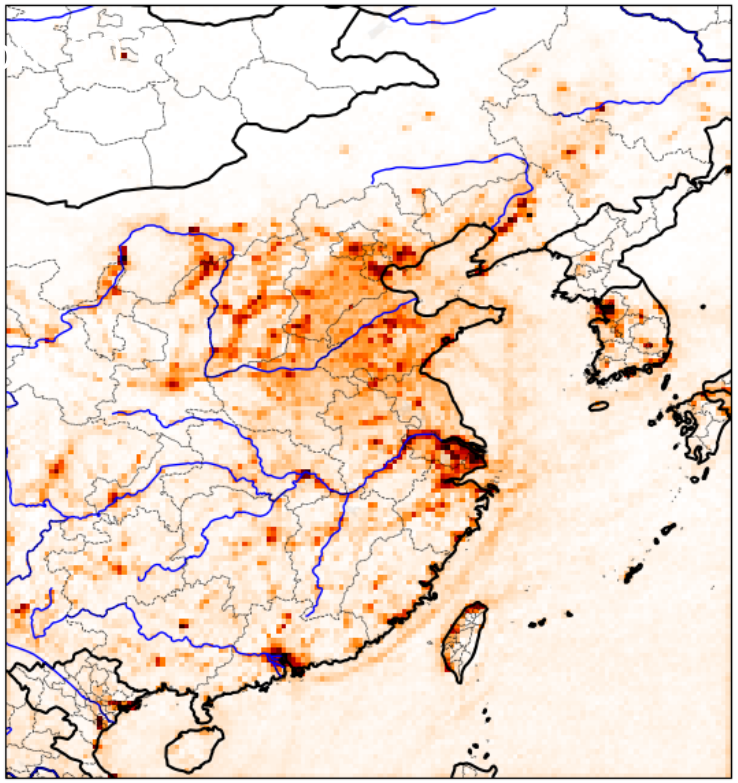
- Good agreement with ground Aeronet
- 55.65% data within ± (0.05 + 0.15 AOD_{Aeonet})
- High AOD distribution fit the real distribution.

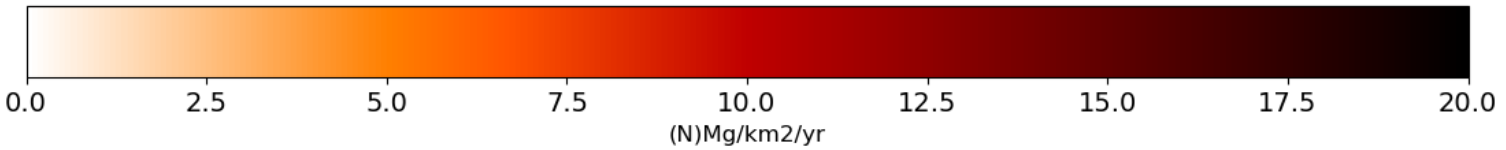
- **Liu O.**, Zhang Y., Li Z., de Leeuw G., Aerosol optical depth retrieval based on the FY-4A AGRI instrument - A case study in East-South Asia. Under submission.

WP 1 results

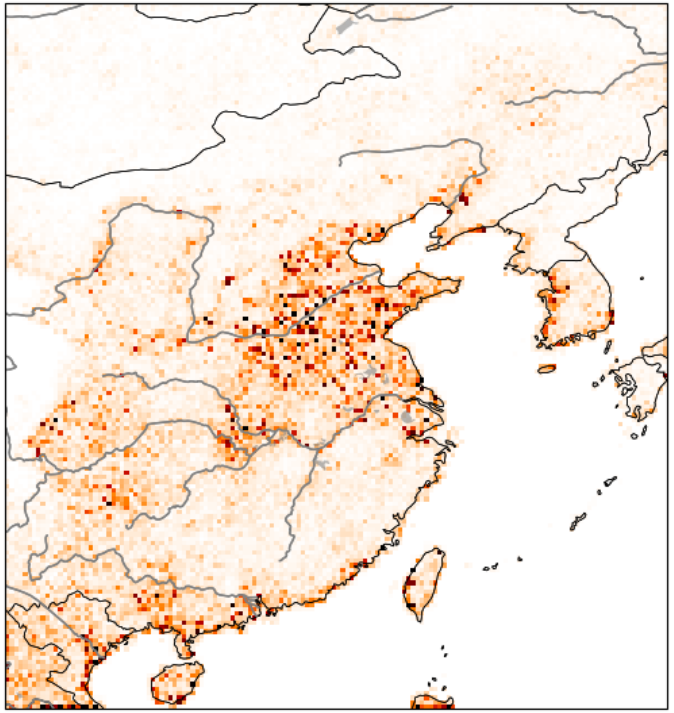
Annual Averaged NOx and NH3 emissions East China

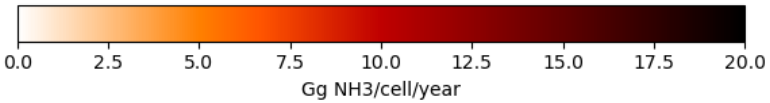
DECSO 2019





2020





KNMI

Yangtze River Delta: NOx emissions from TROPOMI observations

DECSO version 6.4 using observations from the TROPOMI NO2 retrieval v.2.x and CHIMERE (version 2020r3).

Spatial resolution: 10 km

Temporal resolution: daily

Year: 2019-2022

The NOx emissions are split into:

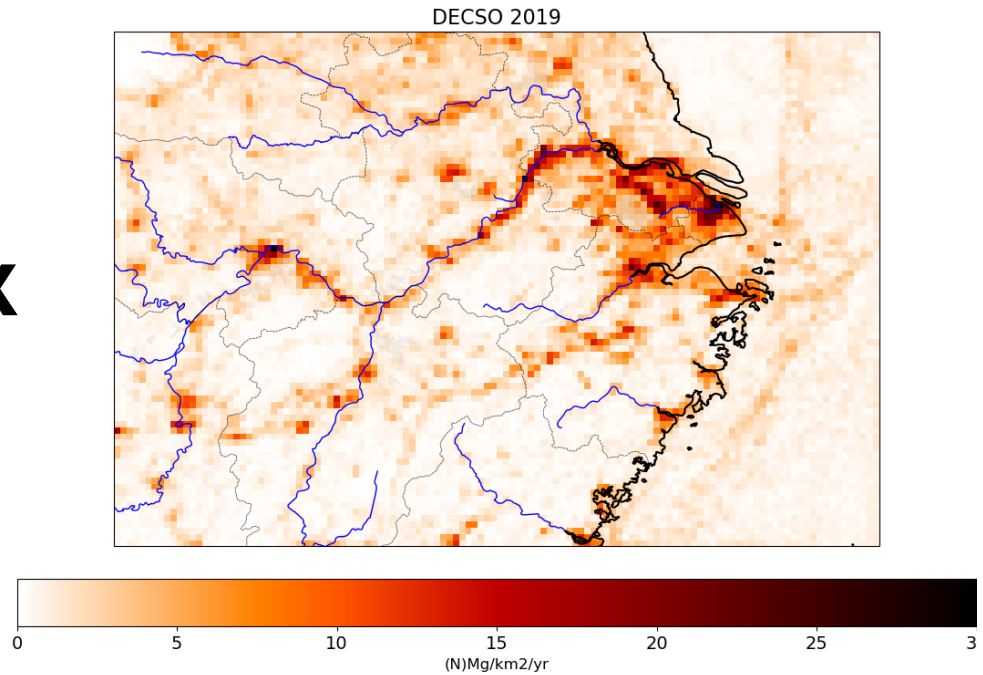
1) Anthropogenic NOx emissions (Combustion processes)

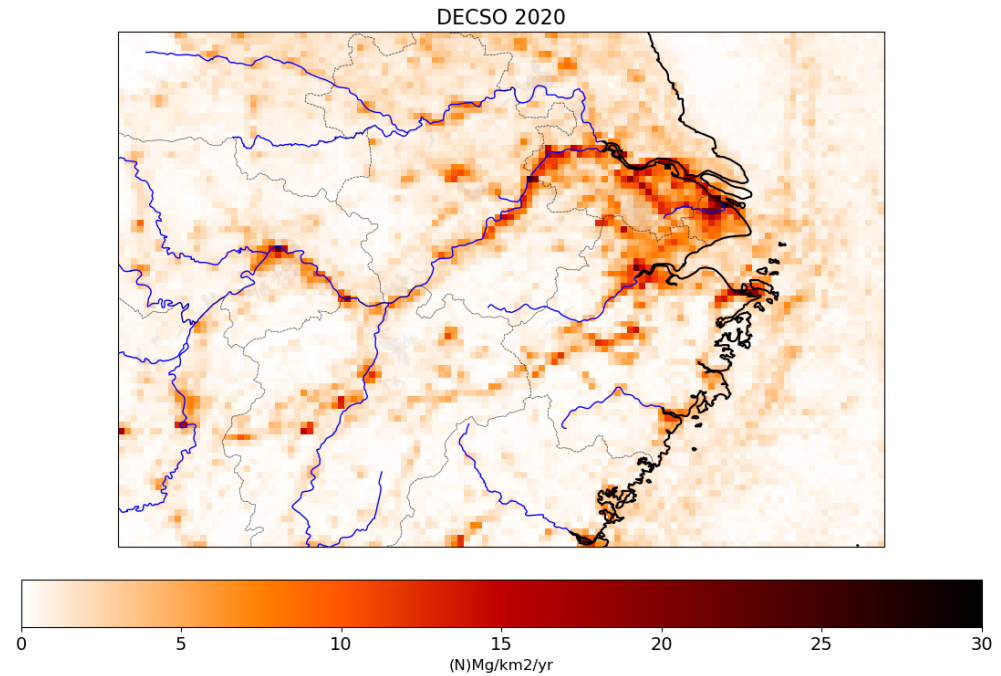
2) Soil NOx emissions (mostly agriculture, forestry)

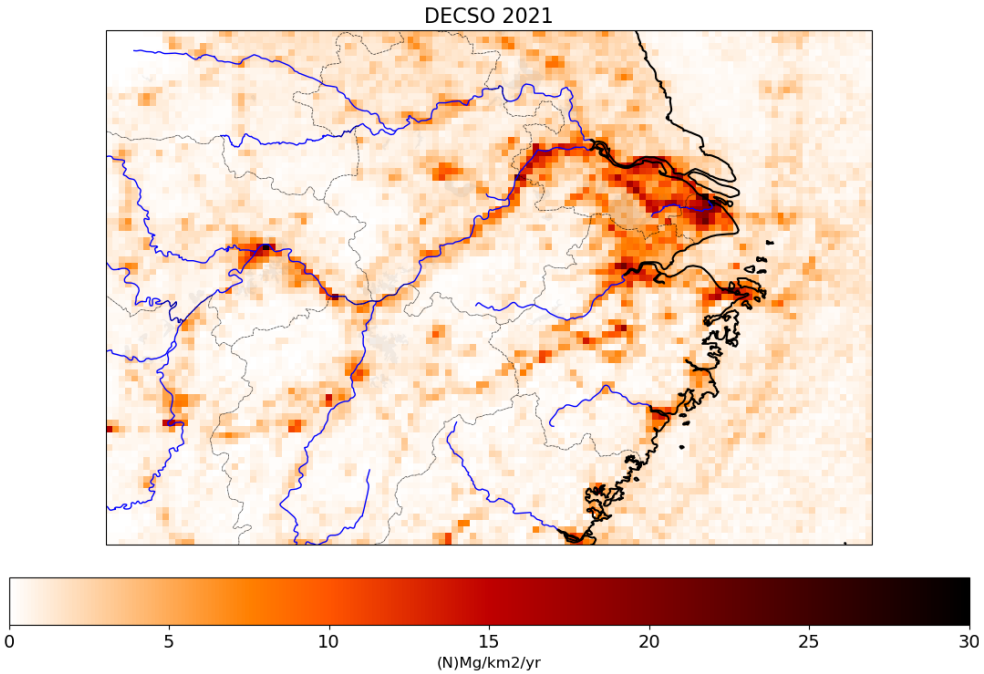
The results are shown on the next two slides

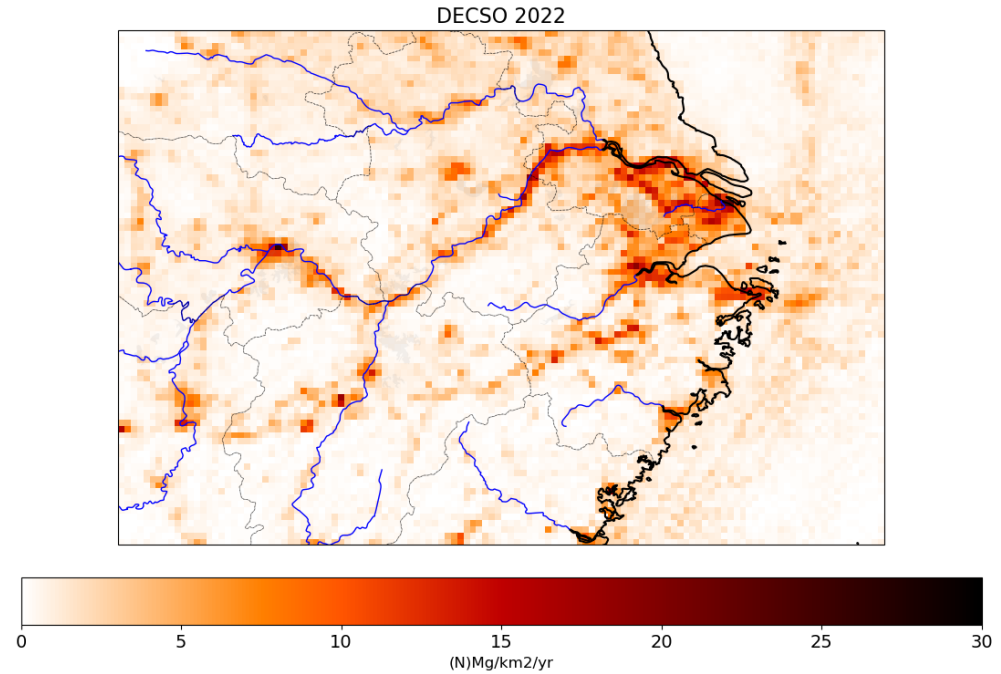
Annual NOx emissions: 2019-2022

decreasing trend





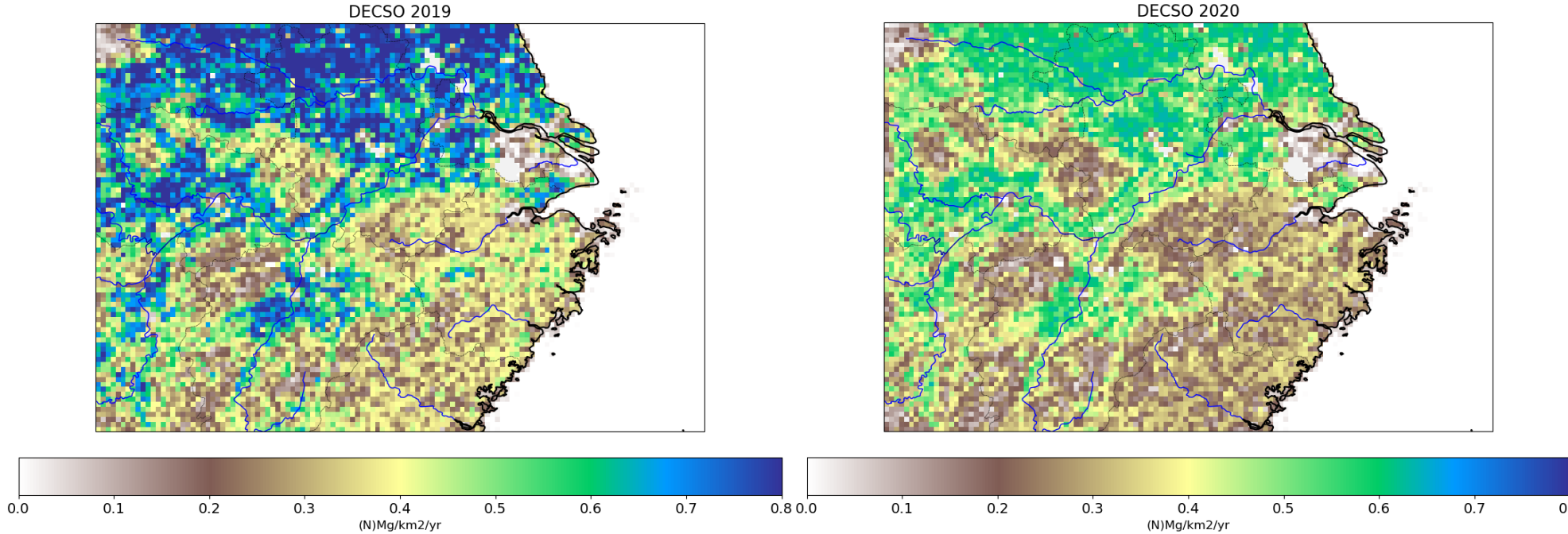


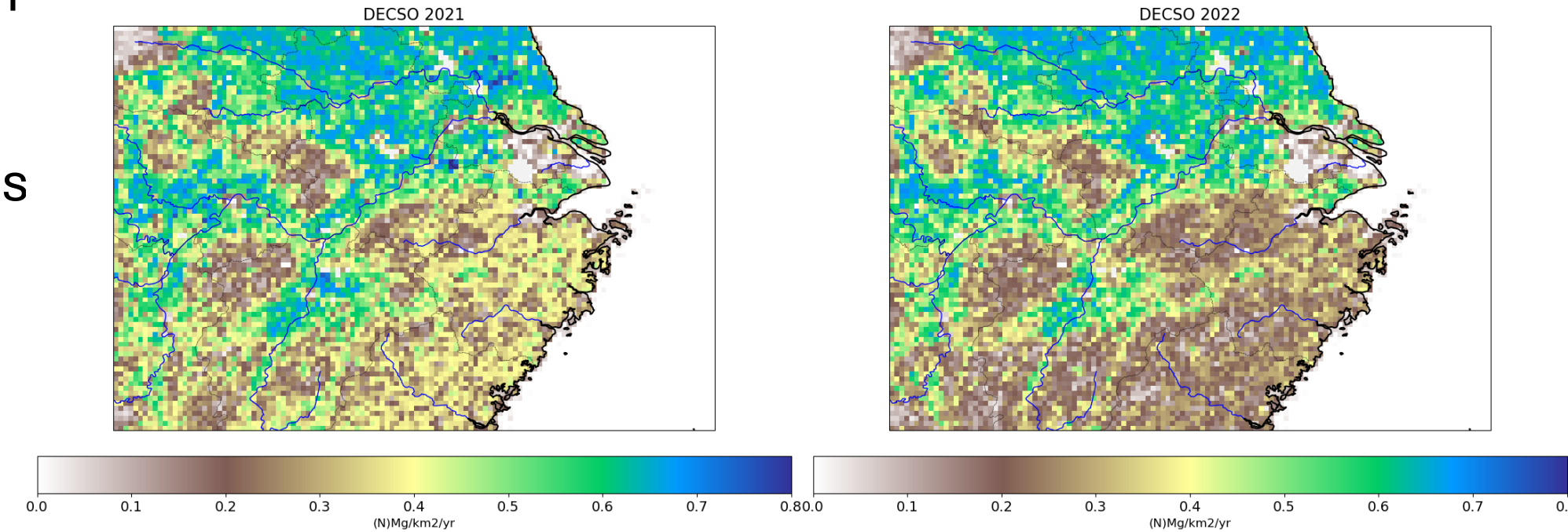


Soil NOx emissions 2019-2022

- 2019 was exceptional warm in China

- Lower emissions from forest

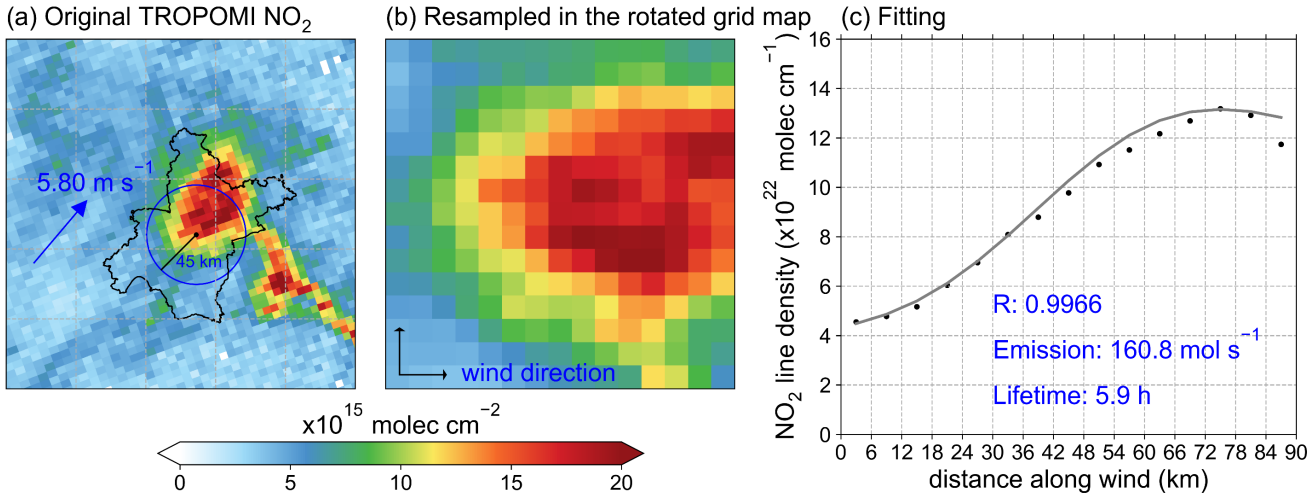




Estimating the variability in NO_x emissions from Wuhan with TROPOMI NO_2 data using the superposition column model

NSMC: Qianqian Zhang

Analysis steps:



a) Take the Wuhan urban area as the target domain, construct a grid map centered at the city center toward the mean wind direction.
b) The TROPOMI NO_2 columns in the cells perpendicular to the wind direction are integrated to form the so-called
c) NO_2 'line densities'.

the NO_2 line density is fitted with the superposition column model:

$$N_i(x) = \frac{E_i}{k}\left(1 - e^{-kL/u}\right) \cdot e^{-k(x-x_i)/u} \cdot \frac{1}{[NO_x]/[NO_2]} \quad for\ x > x_i \quad , \qquad (1)$$

$$N_i(x) = 0 \qquad for\ x \le x_i \quad , \qquad (2)$$

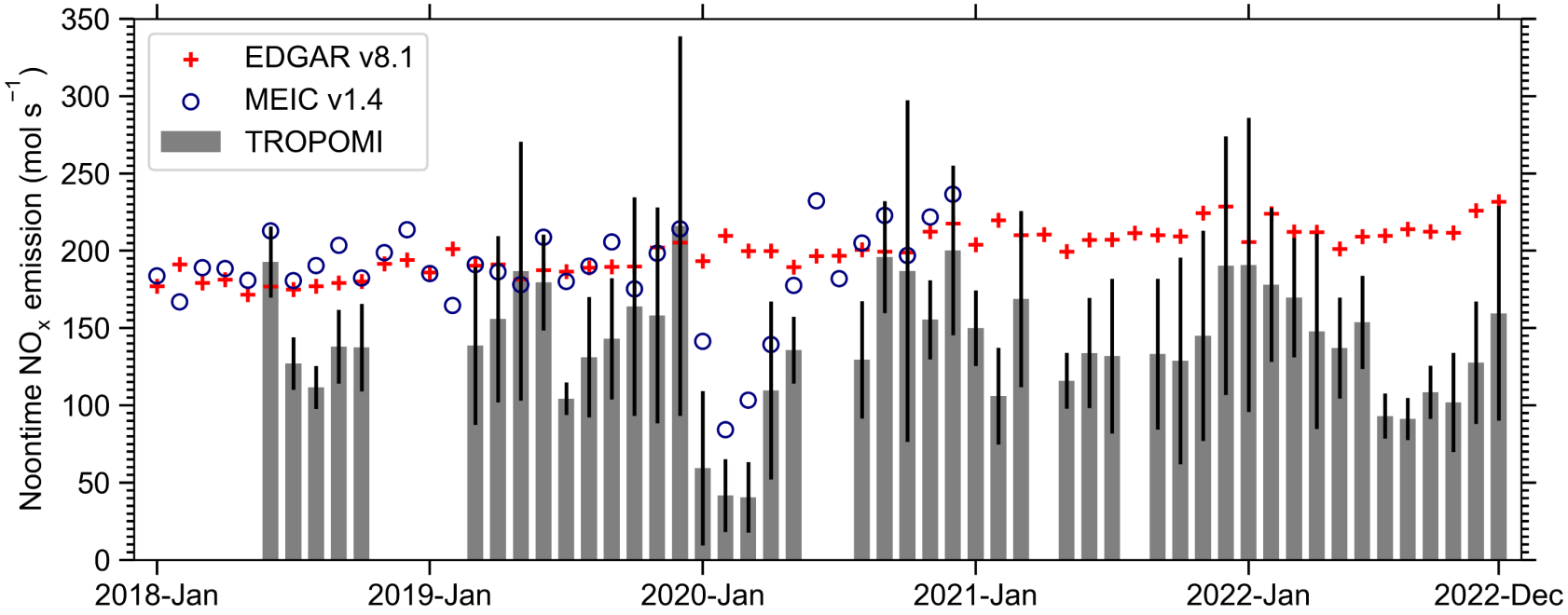
$$N(x) = \sum_{i=1}^{n} N_i(x) + b + \alpha x \qquad (3)$$

$$\text{func} = \left(\frac{N(x) - N_{TROPOMI}(x)}{N_{TROPOMI}(x)}\right)^2 + fac * \left(\frac{E_i - E_{ABACAS,i}}{E_{ABACAS,i}}\right)^2 \qquad (4)$$

- Compared to previous work, we use an initial guess for the NOx lifetime in cold months (4 h) and warm months (2 h) instead of the chemical loss rated simulated in the chemical transport model.
- To reduce the dependence of fitted NO_x chemical lifetimes and emissions on the $\tau_{[NO_2]}$, the bottom-up emission inventory is used in the cost function, but with a We exert a scale factor changing between 0.1 and 0.2 to make sure the cost function is dominated by the NO_2 line density term.

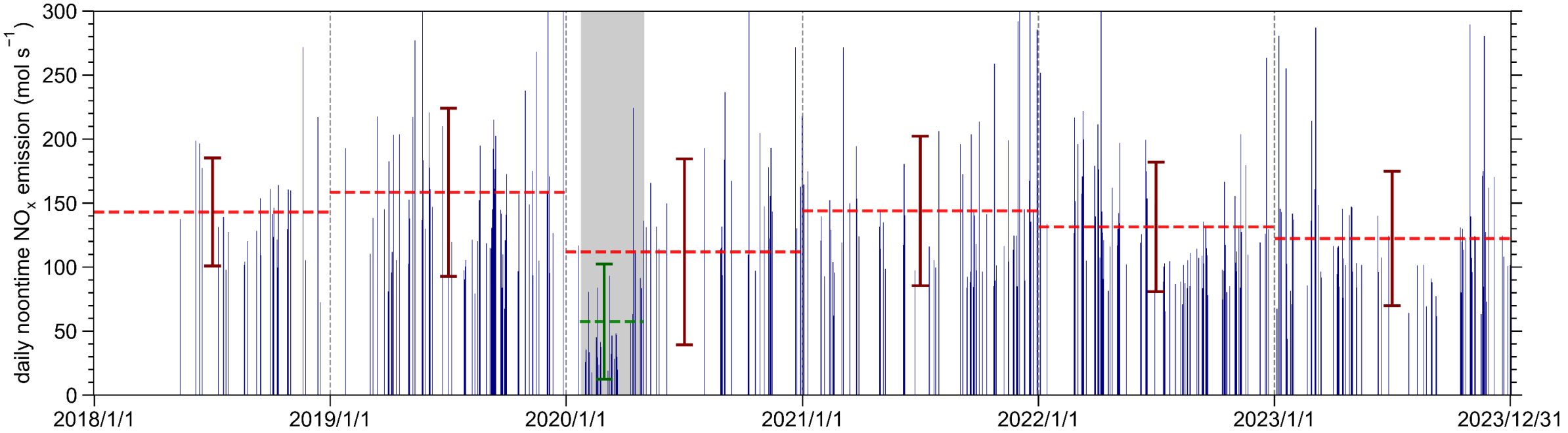
Estimating the variability in NO_x emissions from Wuhan with TROPOMI NO_2 data using the superposition column model

Compare the results with bottom up emission inventories:



- The difference between TROPOMI and MEIC v1.4 is within 35%, and both of them capture the NO_x emission reduction in early 2020 due to COVID-19 lockdown.
- TROPOMI and EDGAR v8.1 are close to each other (within 30% difference) in 2018 and 2019, but the discrepancy is larger since 2020. EDGAR v8.1 is > 50% higher than TROPOMI from 2020 to 2022

Estimating the variability in NO_x emissions from Wuhan with TROPOMI NO_2 data using the superposition column model



- Stringent emission control strategies have been implemented in China to control NOx emissions to combat air pollution since as early as 2010, and a nationwide NOx emission reduction has been seen since 2012. We find a similar trend over Wuhan from 2018 to 2023.
- Our calculation shows an increase in NO_x emissions over Wuhan from 2018 to 2019
- We calculated the mean NO_x emissions during 2020 lockdown are 49% lower than the same period in 2019.
- Emissions in 2021 and 2022 are close to each other and about 10% lower than 2019. A significant decrease (13.6%) is seen in 2023 compared to 2022.

Estimating the variability in NO_x emissions from Wuhan with TROPOMI NO_2 data using the superposition column model

Discussion on the uncertainty

parameters	Influence on NOx emissions	Influence on NOx lifetime
The systematic error in TROPOMI NO_2 data	20%	20%
Upwind emissions	15%	8%
Bottom-up NO_x emissions	10%	30%
The NO_x/NO_2 ratio	10%	10%
Wind fields	4%	8%
Overall uncertainty	35%	44%

Zhang, Q., Boersma, K.F., van der Laan, C., Mols, A., Zhao, B., Li, S., Pan, Y.: Estimating the variability in NOx emissions from Wuhan with TROPOMI NO2 data during 2018 to 2023. Atmos. Chem. Phys., 25, 3313-3326, https://doi.org/10.5194/acp-25-3313-2025, 2025*

Trends from IASI observations over 2008-2024

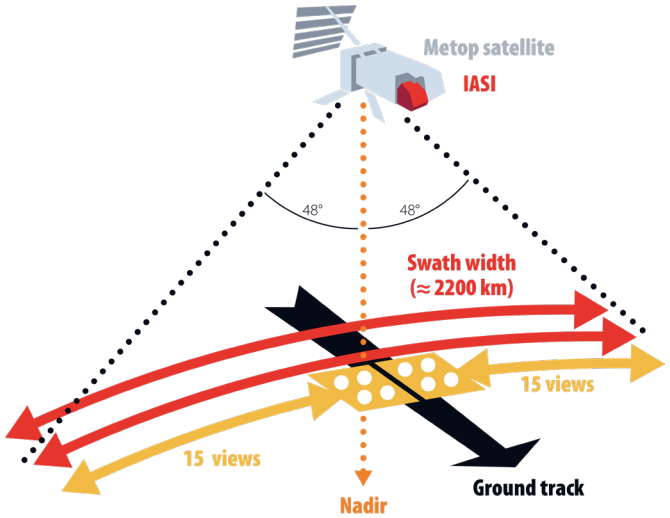
Clerbaux et al., (2009)

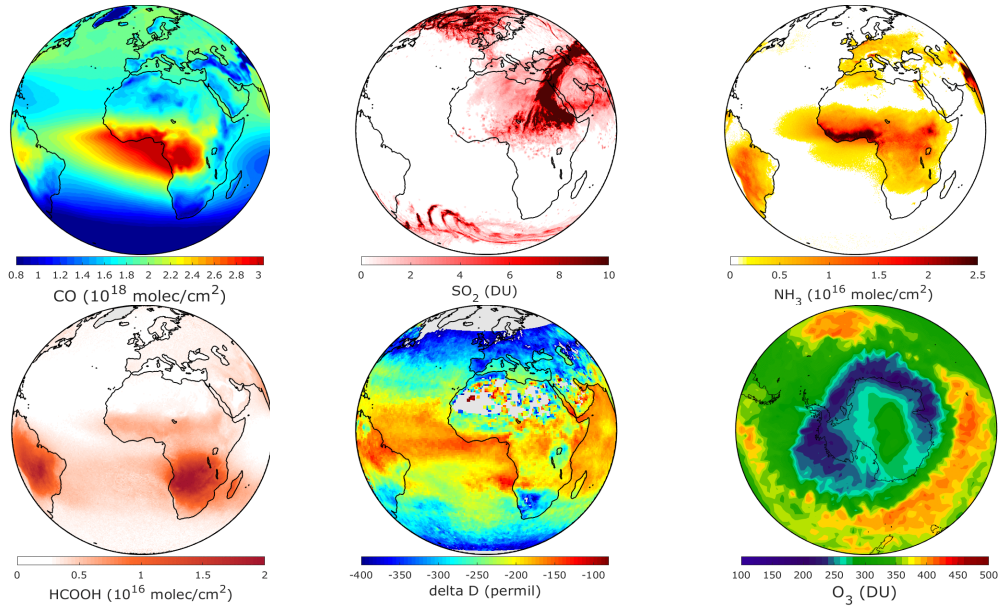
IASI **(Infrared Atmospheric Sounding Interferometer)**

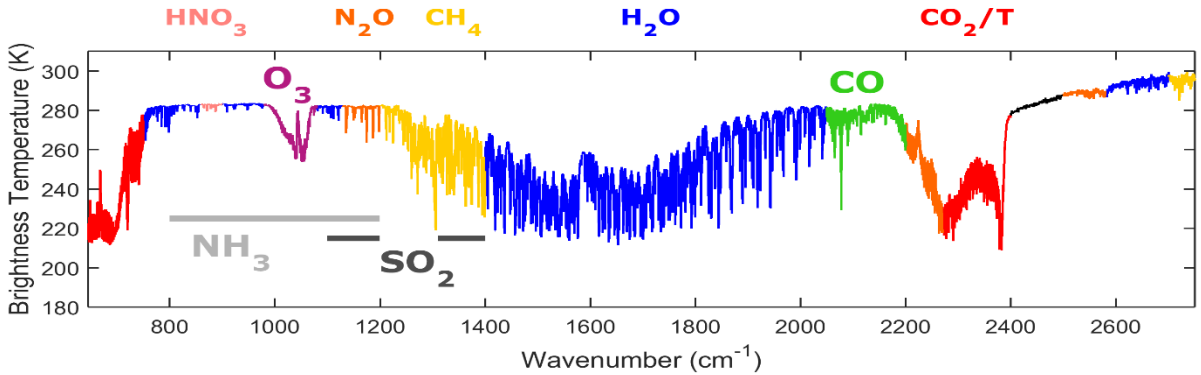
nadir-looking Fourier-Transform Spectrometer that measures Earth's radiance in the thermal infrared range.

- **Spectral range:**
  645 cm^{-1} to 2760 cm^{-1}
  (3.6 µm to 15.5 µm)

- Crossing time @ 9:30 AM and PM local time





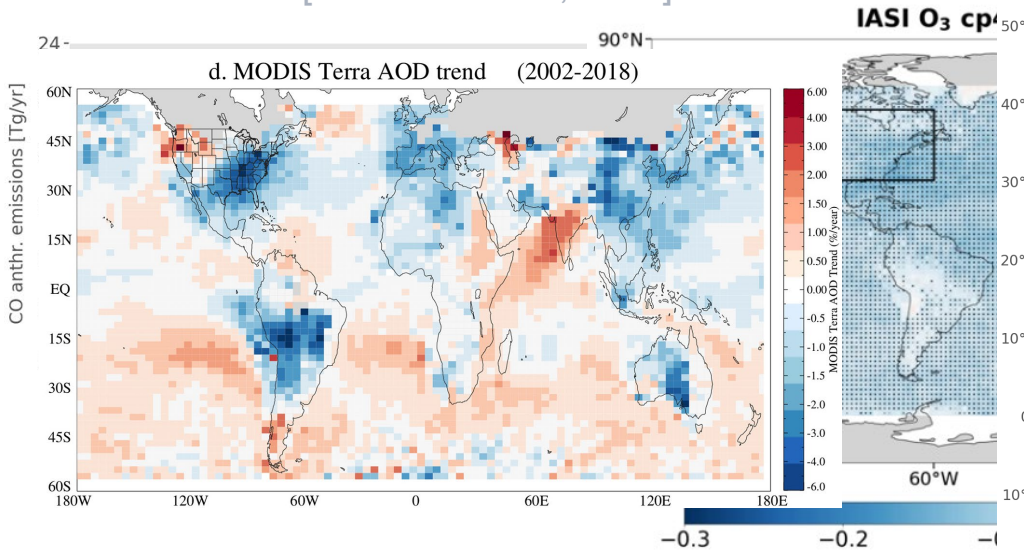


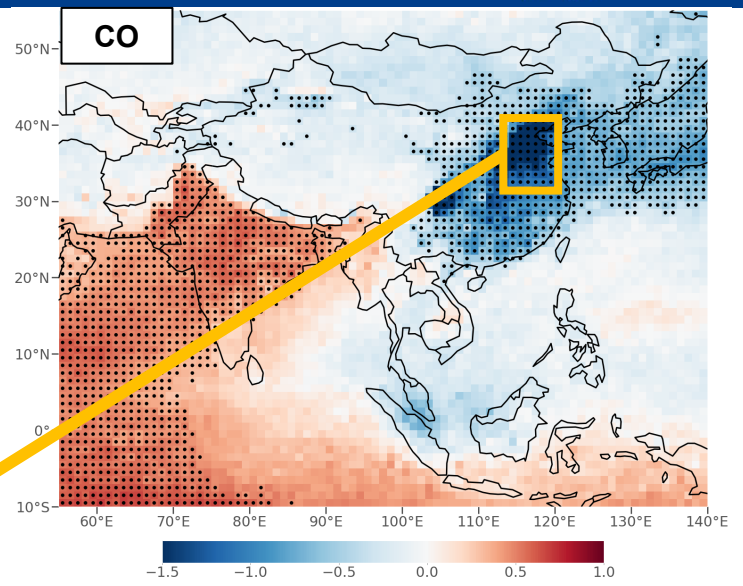
https://iasi.aeris-data.fr/

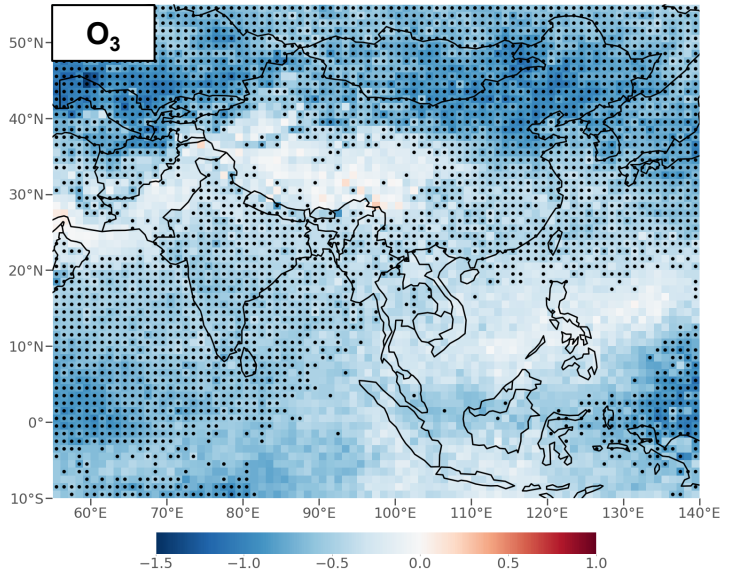
Selviga Sinnathamby, Sarah Safieddine from LATMOS

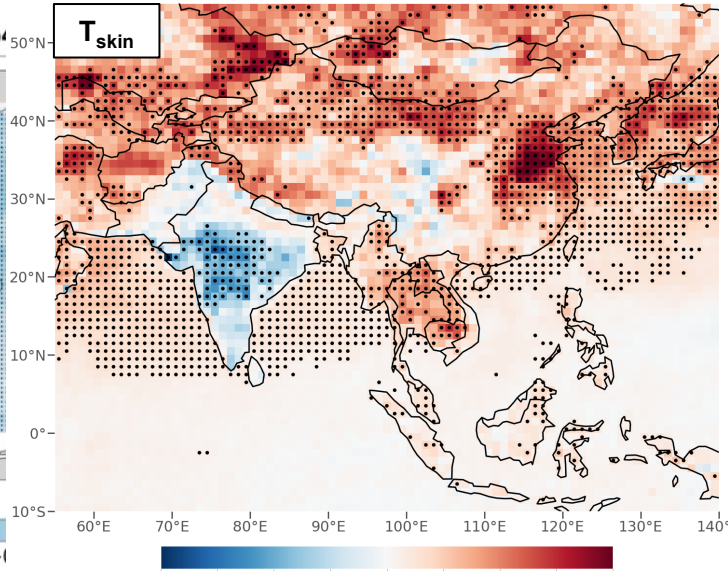
IASI Trends from IASI observations over 2008-2024

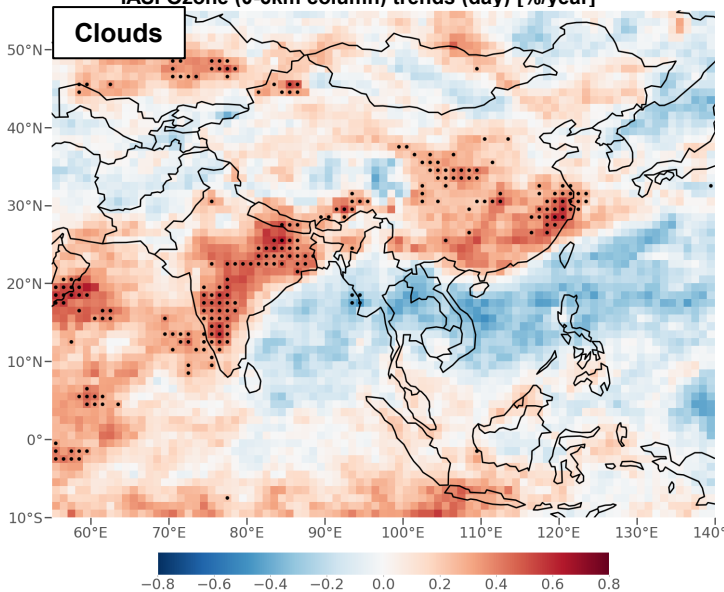
- Trends are estimated using the Theil-Sen method [Theil, 1950; Sen, 1968] on yearly averages. Significant trends (p-value < 0.05) are stippled.
- Decrease of local anthropogenic CO emissions in China (China Air Quality Action Plan, 2012) but South Asia ?
- Decreasing trend of lower tropospheric O_3 in Asia (and globally [Boynard et al., 2025])
- Decreasing trend of skin temperature in South Asia explained by the increase of cloud cover or/and aeorsol loads [Buchholz et al., 2021] ?











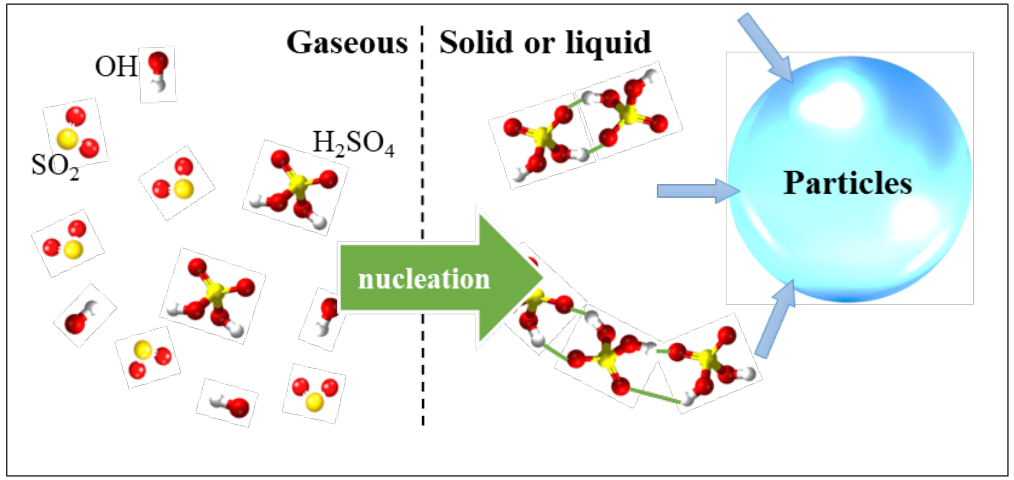
WP 2 results

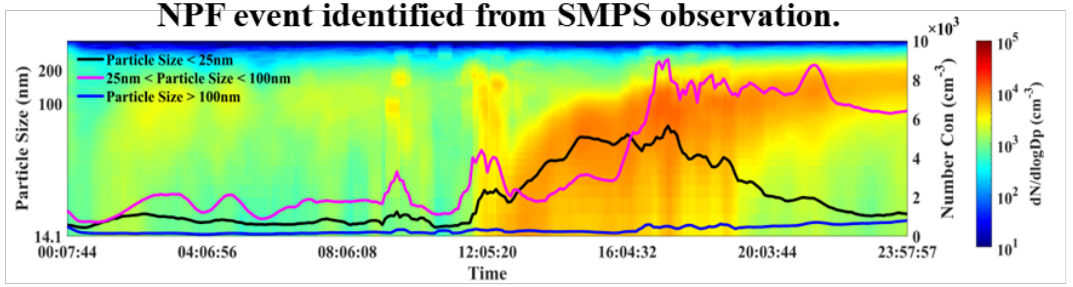
NPF identified by remote sensing

(WP2: AIRCAS & KNMI)

We find that:

- We successfully identified 84% of the NPF days compared with SMPS observations.
- The duration of the HCHO-induced NPF events was longer than for SO_2 .
- Our method may have the opportunity to identify the dominant chemical reactions that determine NPF events.



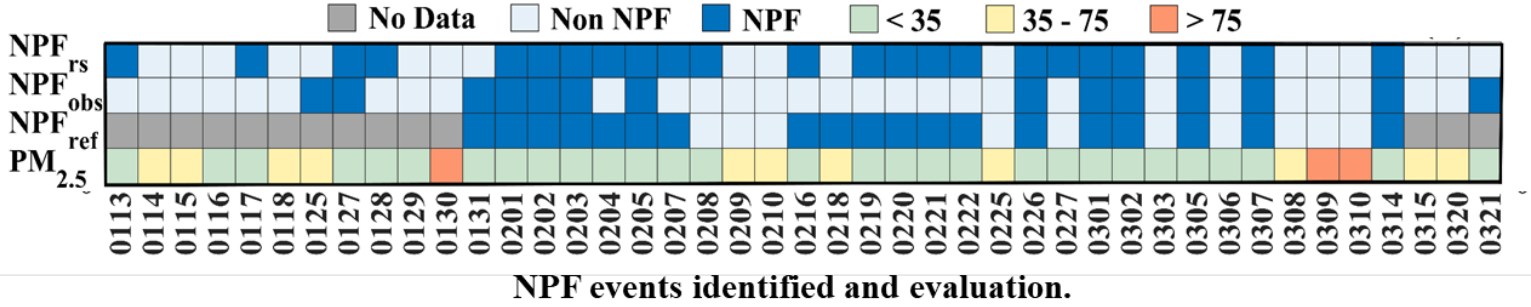


Obtain the thresholds for identifying regional nucleation of NPF events

Positive identification of 84% of the NPF events from RS obs.







NPF events identified and evaluation.

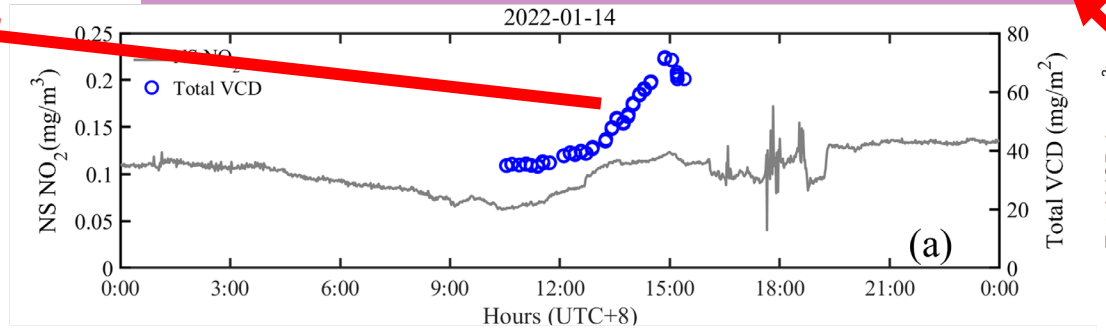
- **Zhang Y.**, Dai L., Zhang P., de Leeuw G., Li Z., Fan C., Exploring the use of ground-based remote sensing to identify new particle formation events: A case study in the Beijing area, Science of The Total Environment, 954, 176693, https://doi.org/10.1016/j.scitotenv.2024.176693, 2024.

Relation between total-column (TC) and near-surface(NS) NO_2

- Before and after 13:00, TC and NS concentrations are well correlated with linear correlation coefficients R of 0.94 and 0.85, respectively, but with significantly different slopes.

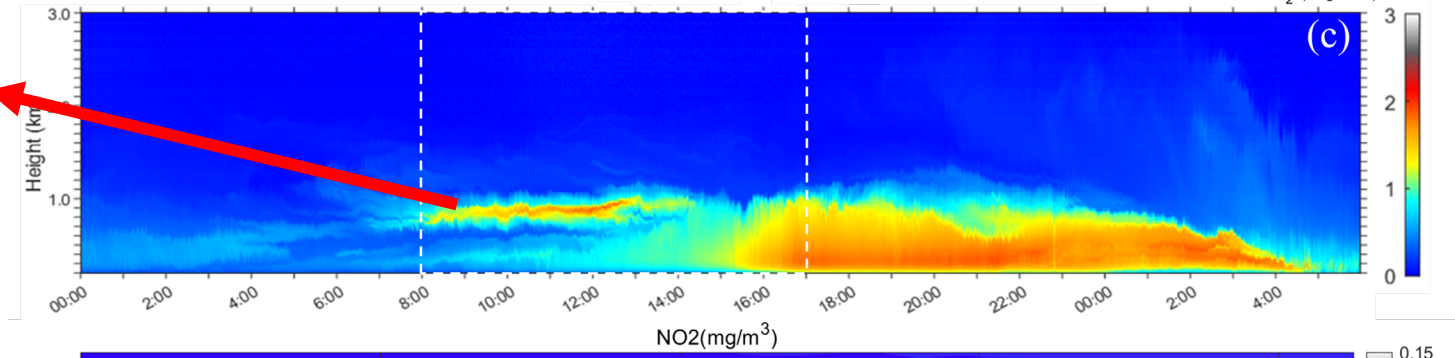
PANDORA VS In situ

- both VCD and NS concentrations initially showed similar behavior with minimal variation.
- their temporal patterns diverged after 13:00 while NS concentrations plateaued, VCD exhibited rapid, nearly doubling before declining slightly.



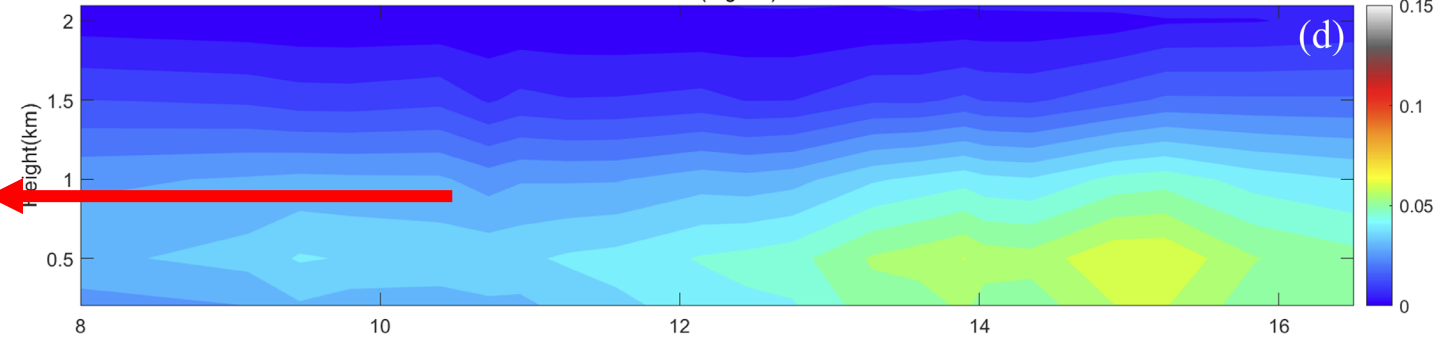
LIDAR

- The internal boundary layer rises gradually until about 11:00 (up to about 400 m), with the clean layer above (between 400 and 500 m), and a new layer (at heights of approximately 800 to 900 m) appears around 07:00, probably due to advection.

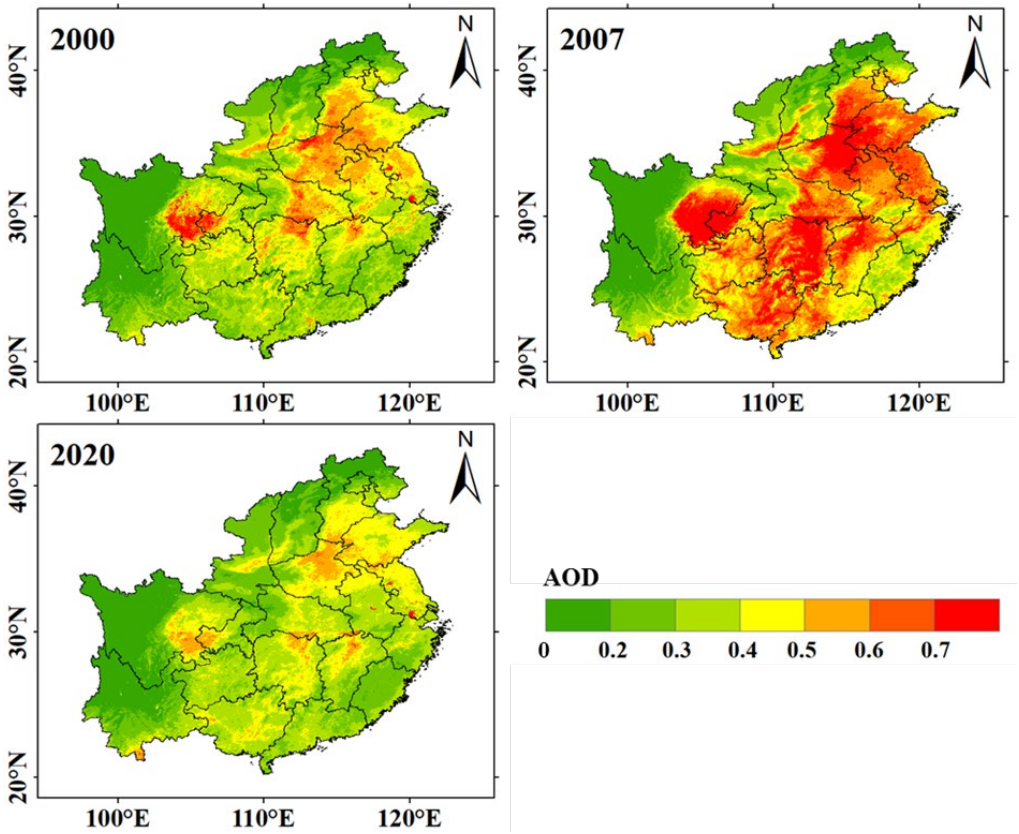


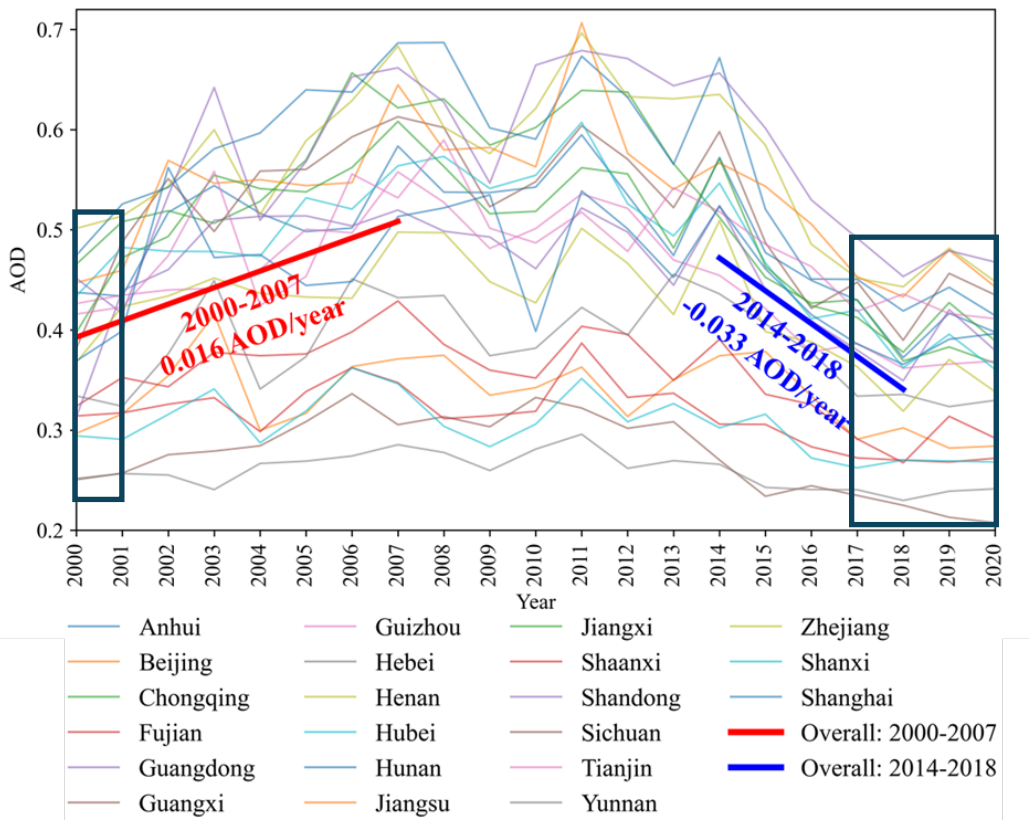
PANDORA

- The Pandora observations do not show the occurrence of disconnected boundary layers in the morning.
- The fine stratified structure within 1000 m cannot be identified with the available PANDORA data.



Satellites tell you:
How China's Air Pollution Has Changed in the Past Two Decades:
(WP2: KNMI & AIRCAS)



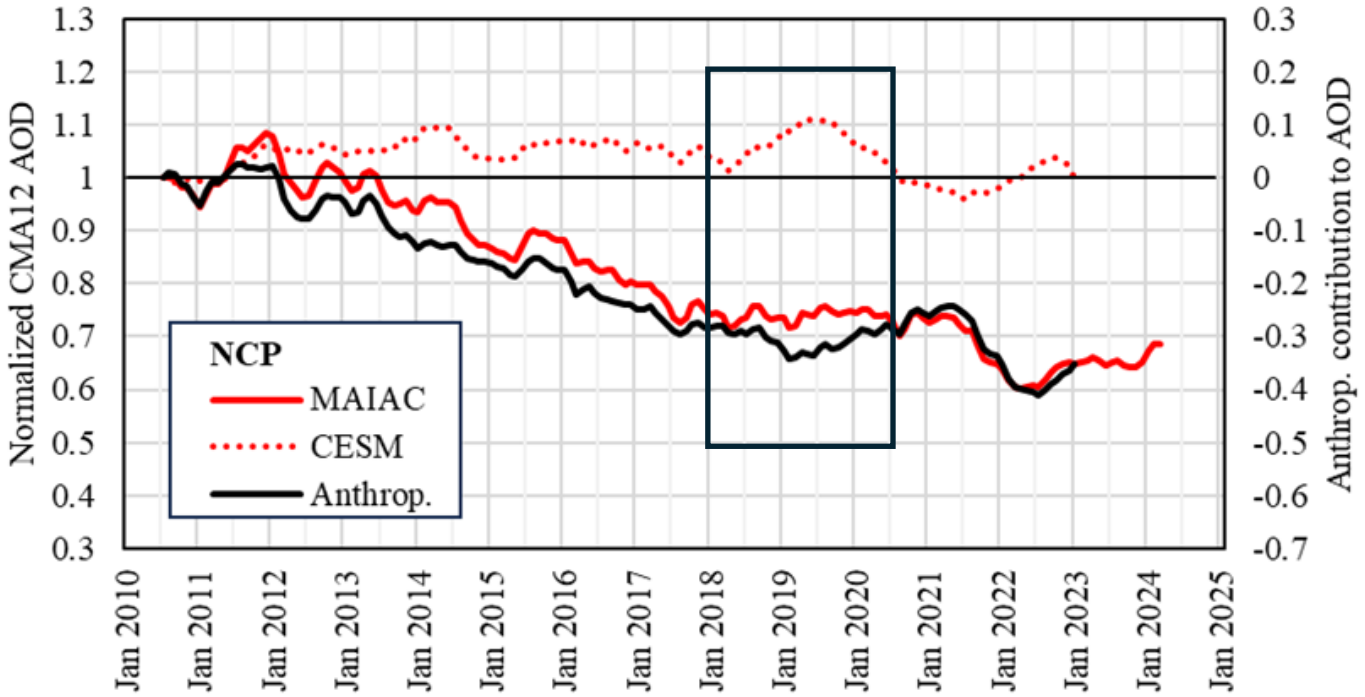


Annually averaged Satellite-derived AOD maps over SE China and provincial scale time series show the increase of AOD between 2000 and 2007.

- The strong decrease after 2014 shows the effectiveness of emission reduction policy, resulting in overall lower AOD in 2020 than in 2000!
- The comparison with model data shows the substantial effect of meteorological influences.

de Leeuw et al., Atm. Env., 2023; Z. Li, G. de Leeuw, X. Yan, C. Fan, Y. Zhang: China Focus, Sept. 2023

NCP (2019):
Meteorological effects offset emission reductions



Normalized AOD

Model runs with monthly mean emissions fixed at those in 2010 and meteorological conditions nudged to MERRA-2:

Anthropogenic contributions (emission) reduced in early 2019

Meteorological contributions to AOD large in 2019

Meteo offsets emission reduction

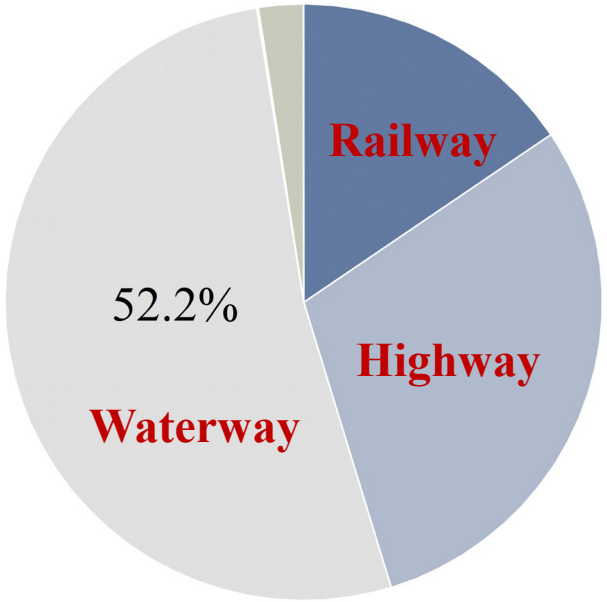
Observed AOD values hardly change

Fan et al., under review

WP 3 results

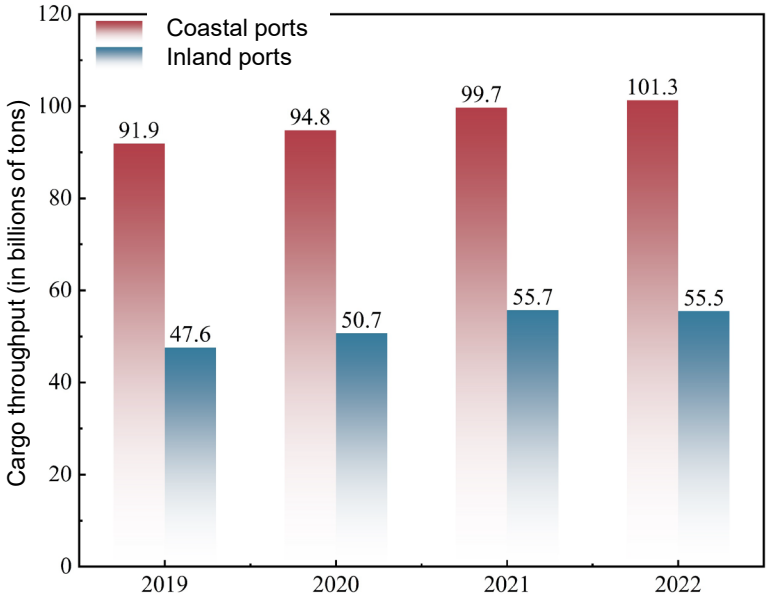
Research Background

Freight Turnovers in 2022



(China Statistical Yearbook, National Bureau of Statistics, 2023)

Changes in Port Cargo Throughput from 2019 to 2022



(Statistical Bulletin on the Development of the Transportation Industry, Ministry of Transport of the People's Republic of China, 2023)

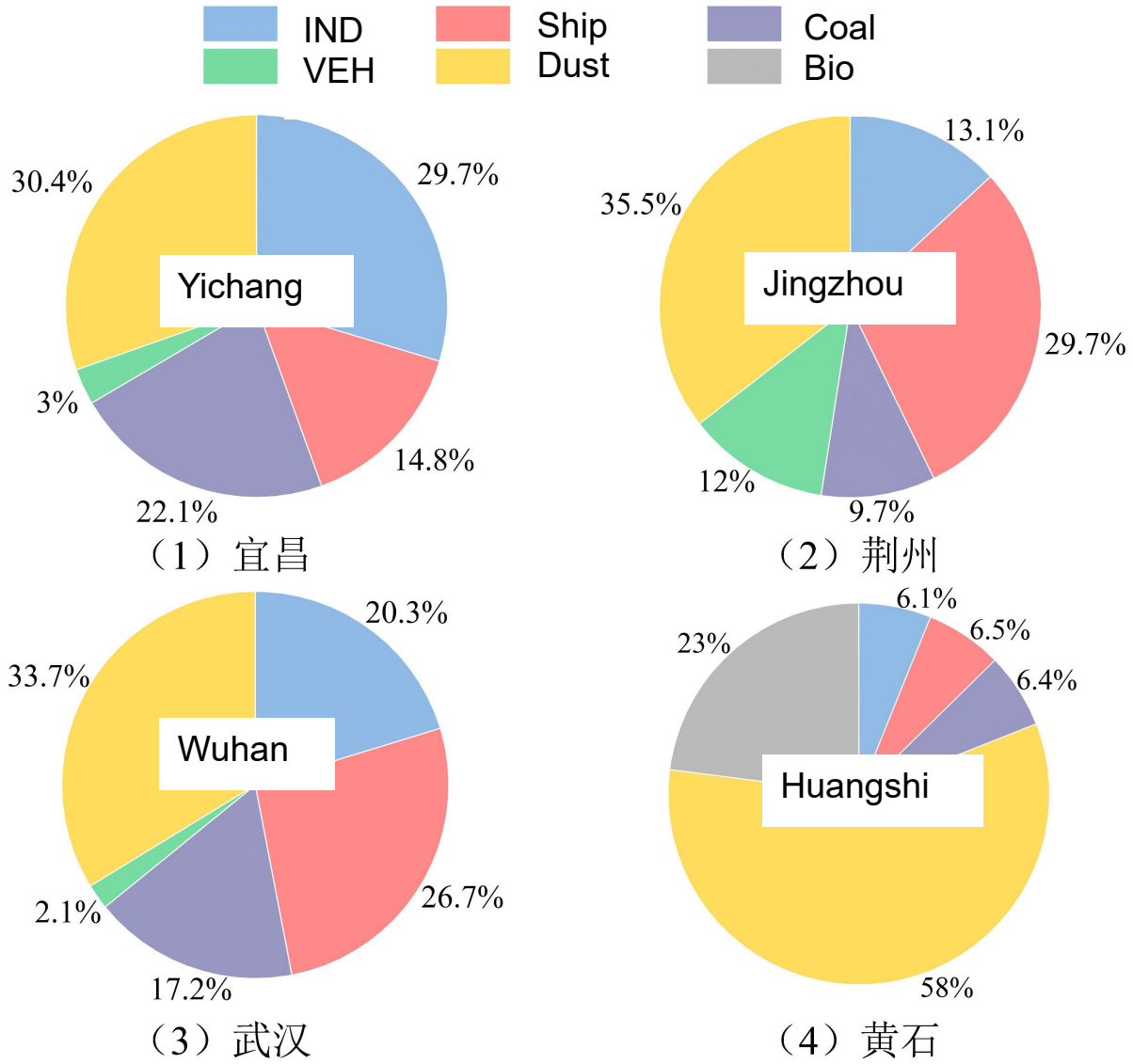
Emission standards

	2018	2019	2020	2021	2022
Gasoline car	National V		National VI		
Ship	—	National I			National II

(China Mobile Source Environment Management Annual Report, Ministry of Ecology and Environment of the People's Republic of China, 2023)

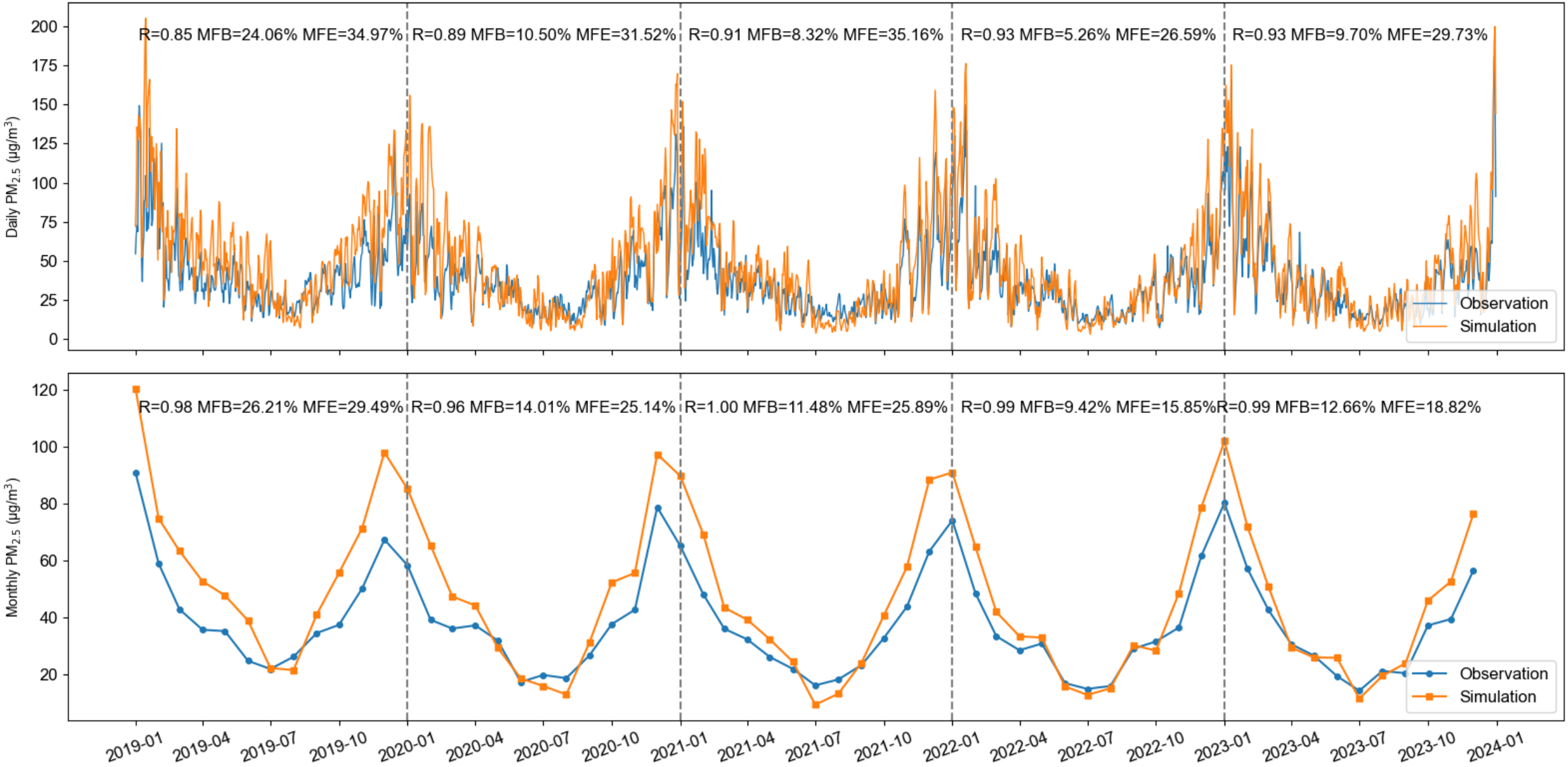
- **Waterway is gradually becoming the dominant transportation method**
- **The cargo throughputs are increasing year by year**
- **The outdated emission standards for ships and the increased supervision of land sources have led to an increase in the weight of ship sources in the total emissions**

PMF source identification based on metallic elements of PM2.5

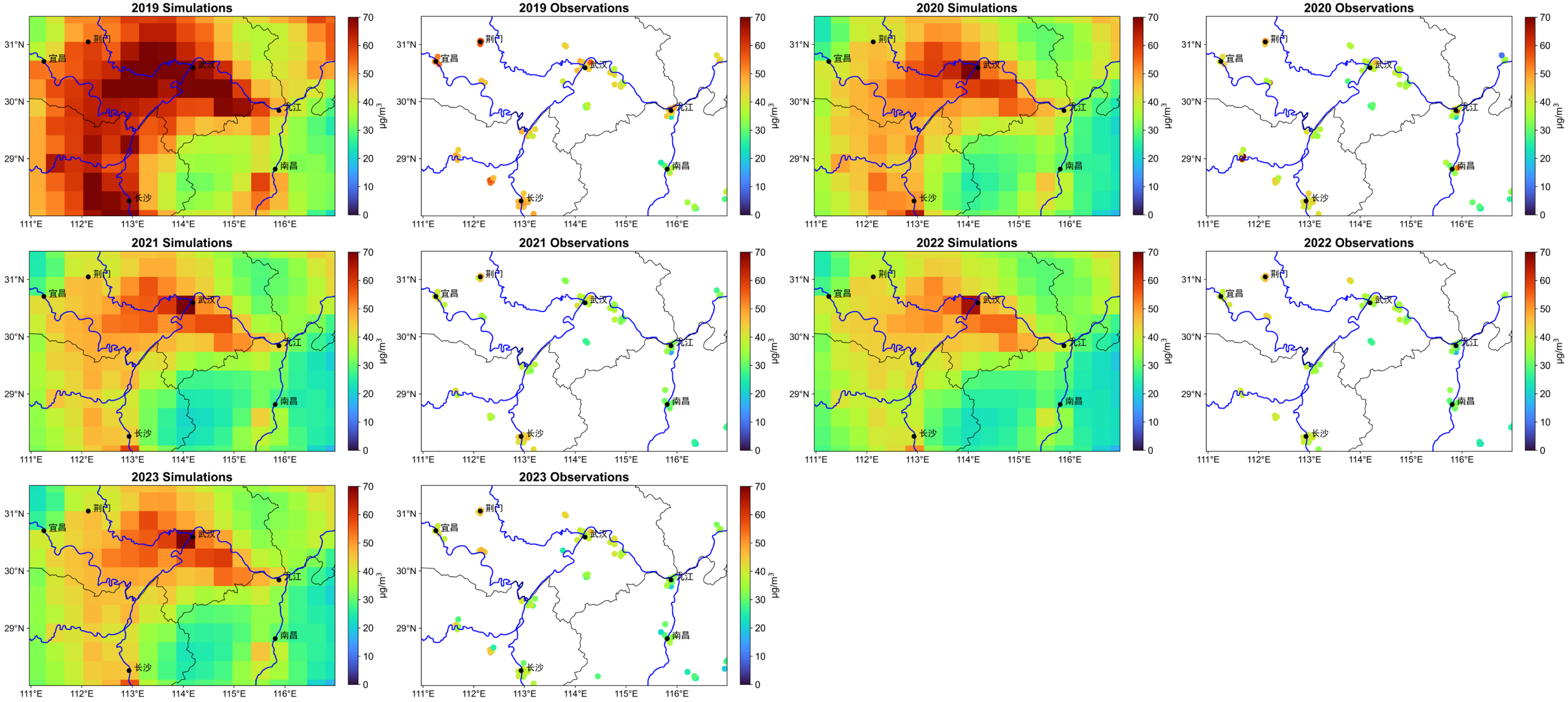


- **The contribution rates of ship emissions to the four port stations (Yichang, Jingzhou, Wuhan, and Huangshi) are relatively high at 14.8%, 29.7%, 26.7%, and 6.5%, respectively**

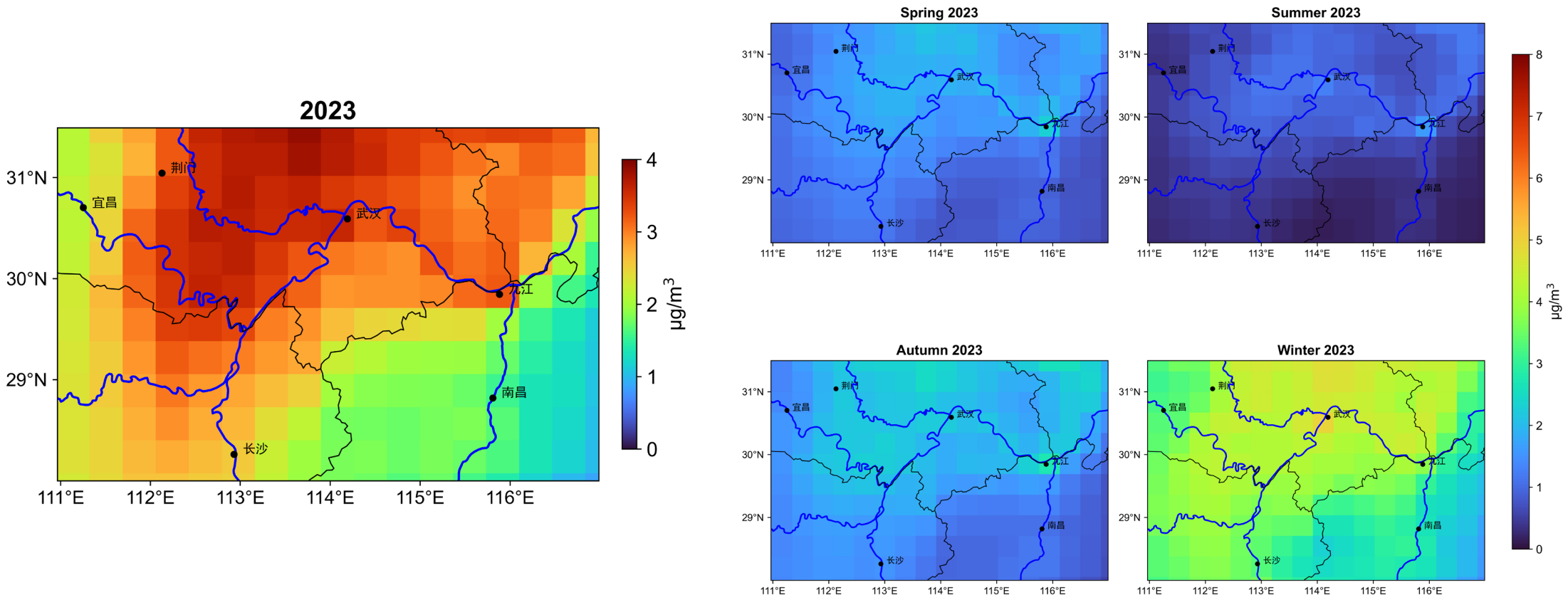
Comparison between base simulations and PM2.5 observations



Comparison between base simulations and PM2.5 observations

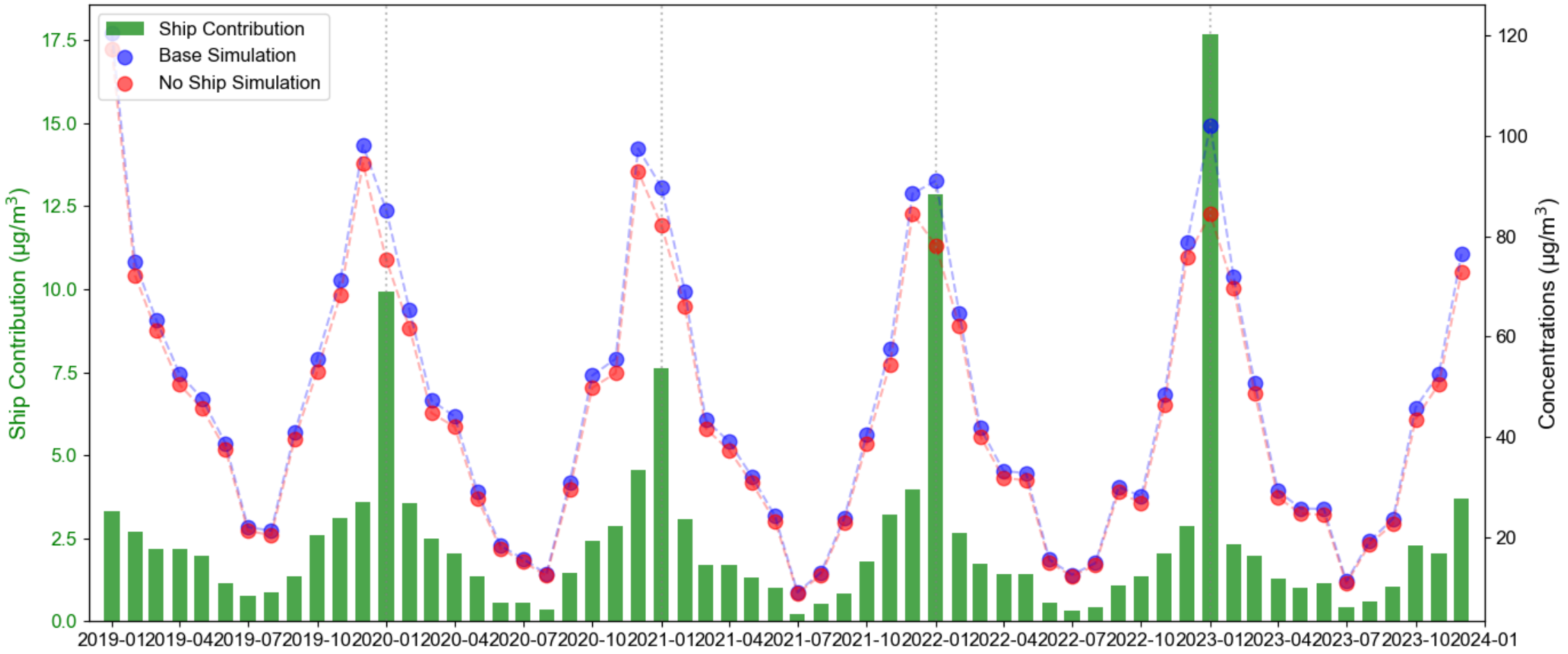


Annual and seasonal PM2.5 caused by ship emissions



- **Ship emissions contribute an average annual PM2.5 concentration of 1-4 μg/m3 to the urban agglomeration in the middle reaches of the Yangtze River, with the heaviest pollution in winter.**

Monthly PM2.5 concentrations caused by ship emissions



WP 4 results

Nocturnal Ozone Enhancement (NOE) events in Wuhan

CUG

Ozone Production during daytime

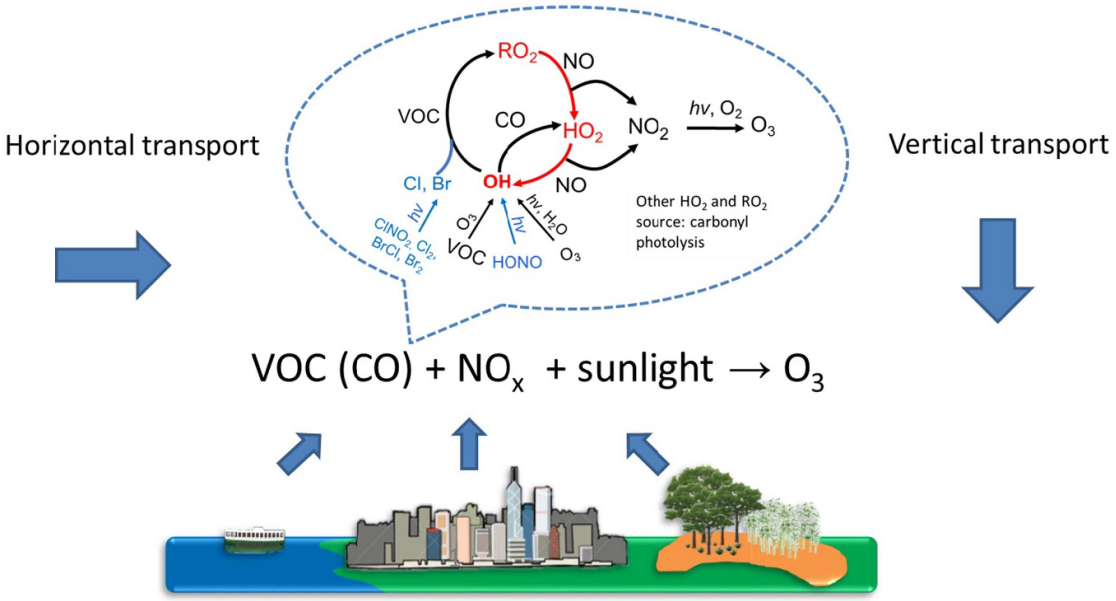


Figure 2. Illustration depicting the sources of ground-level ozone (O_3) and radicals that initiate oxidation of VOC and CO in polluted regions. The 'conventional' radicals are labelled in red, and understudied halogen radicals and HONO (an OH source) are shown in blue. The O_3 loss pathways, radical termination steps and their depositions are not shown.

Wang et al., *ERL*, 2022

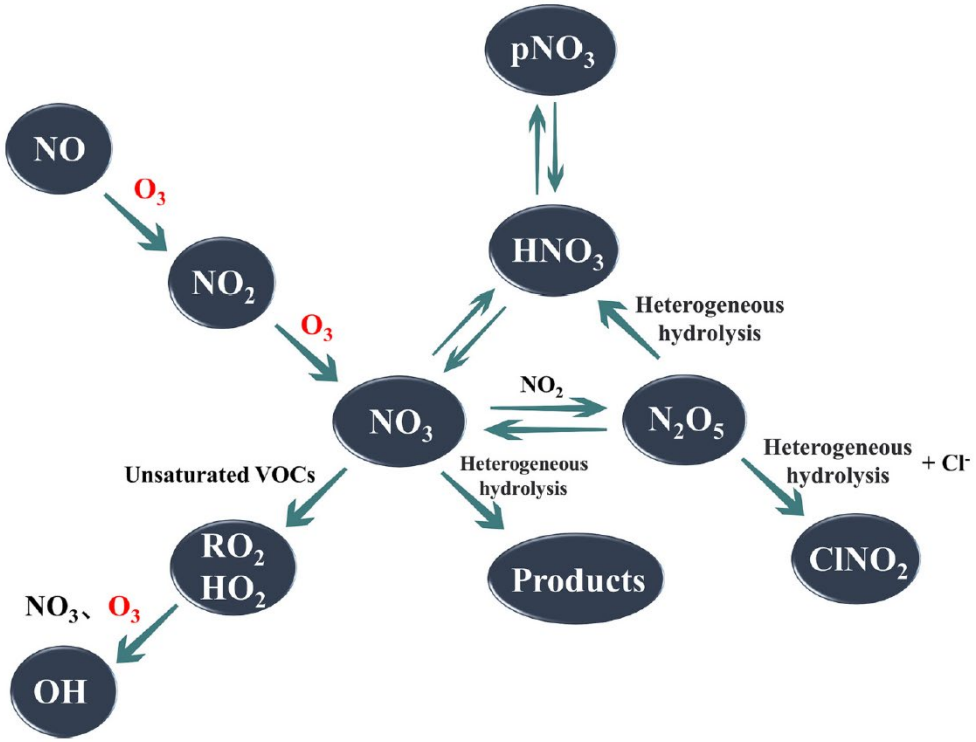


Fig. 5. The main chemical processes in which ozone is involved at night.

Zhu et al., *STE*, 2024

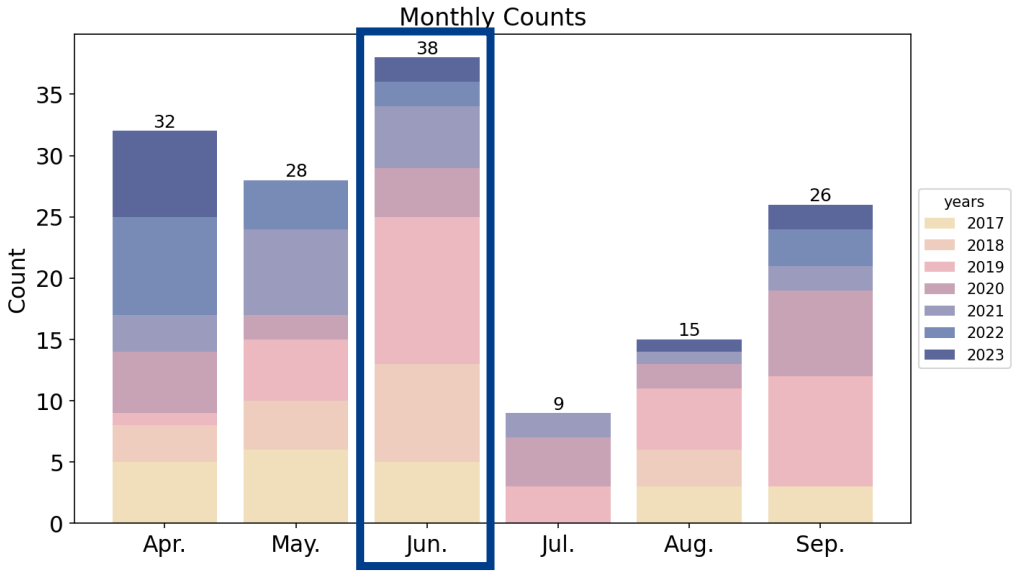
Ozone depletion at night

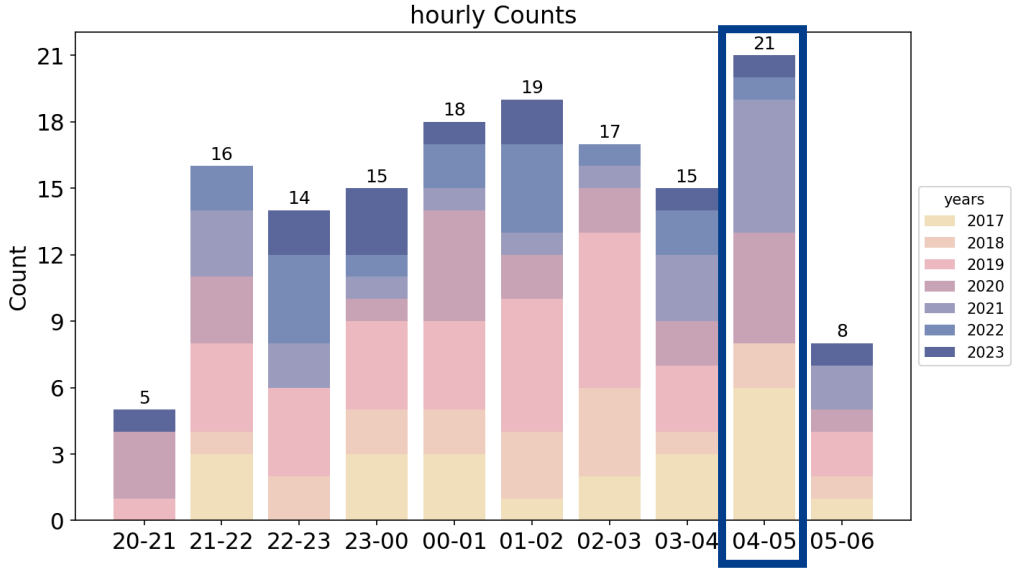
Nocturnal Ozone Enhancement events occur frequently

Nocturnal Ozone Enhancement (NOE) events in Wuhan

Screening of NOE Events in Wuhan

Year	NOE Events
2017	20
2018	13
2019	25
2020	20
2021	15
2022	13
2023	10
2017-2023	116





Definition of NOE: ozone increase by 5 ppbv or more within 1 h at night

116 NOE events from 2017 to 2023

Highest frequency in June, during 4:00-5:00

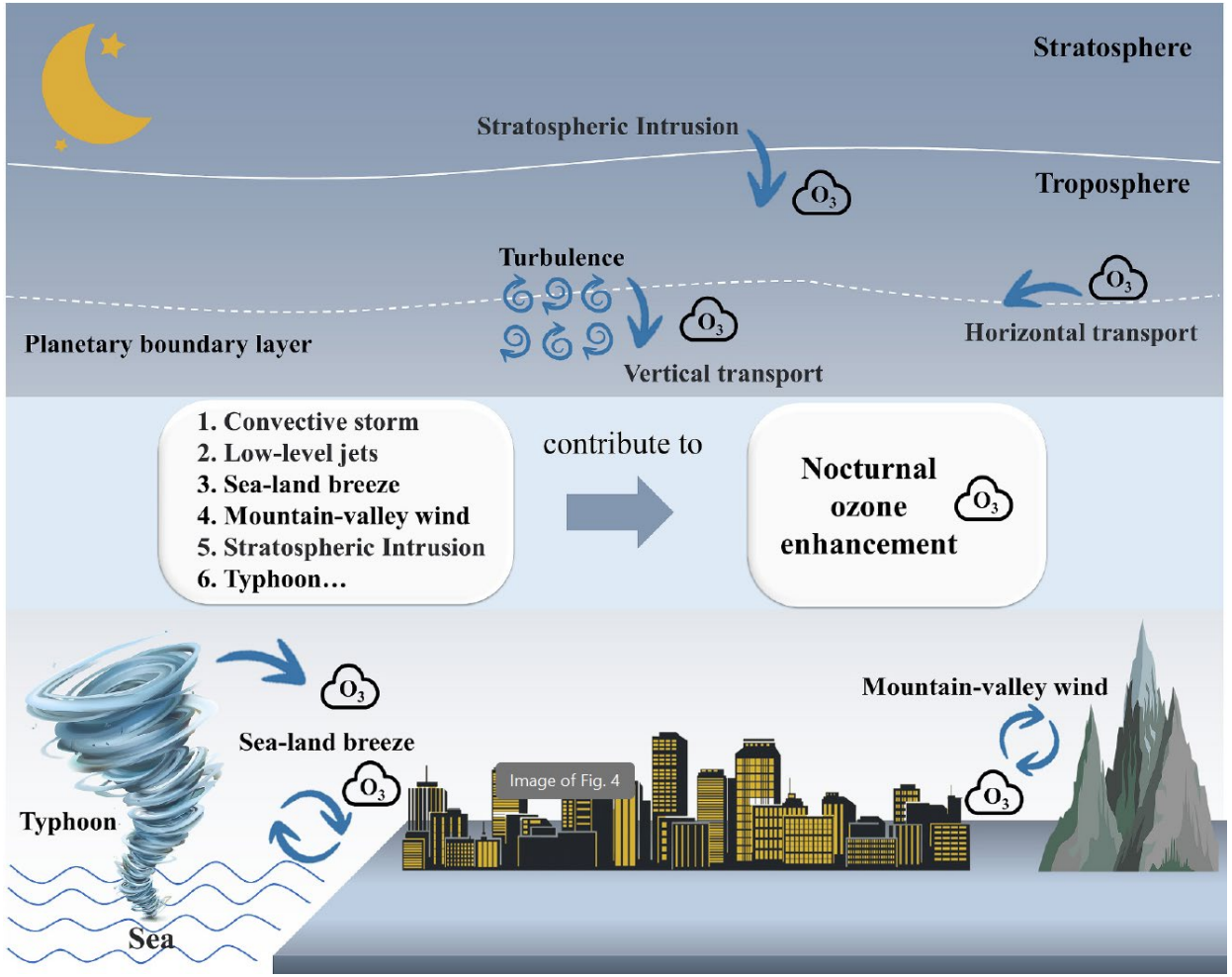
Nocturnal Ozone Enhancement (NOE) events in Wuhan

analysis of contributing factors

- ✓ **Stratosphere intrusion**
- ✓ **Vertical transport & mixing**
- ✓ **Horizontal transport**

No clear sea-land breeze or mountain-valley wind in Wuhan

Cases with typhoon removed

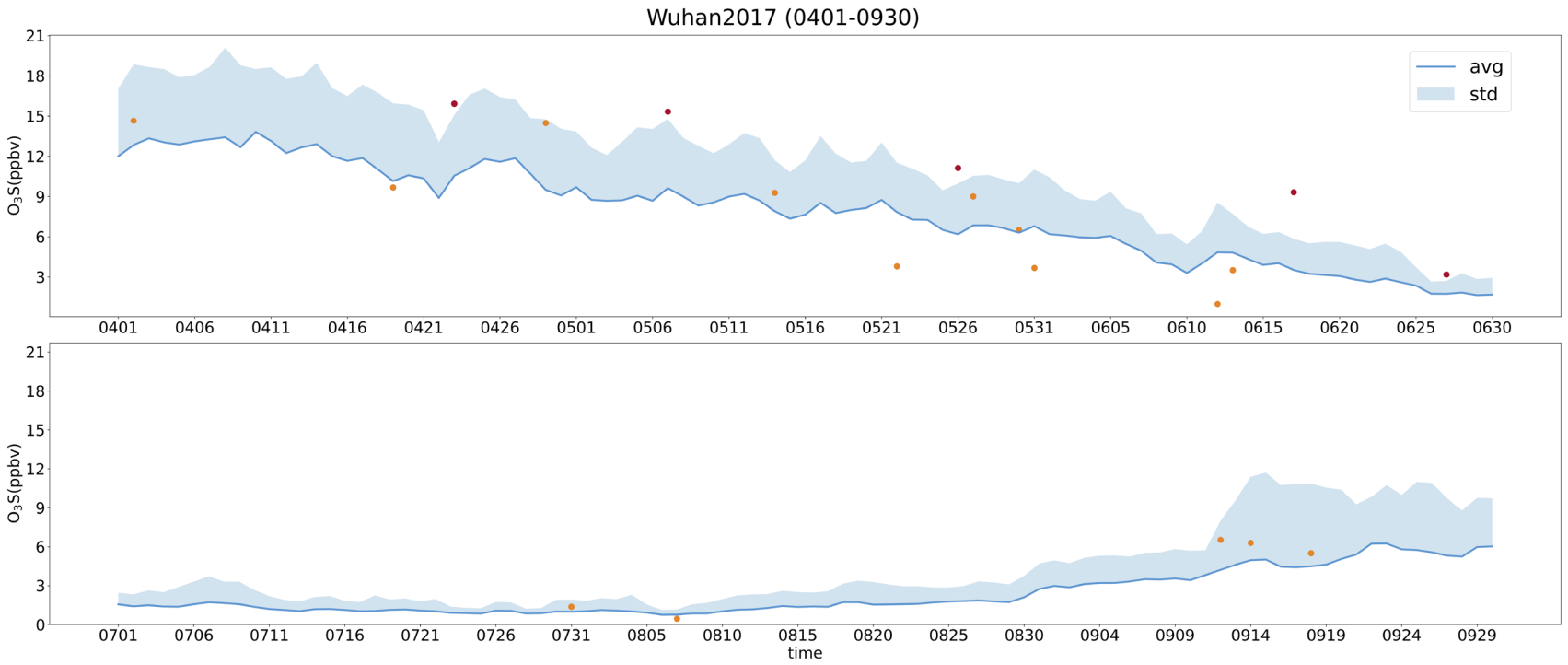


Zhu et al., *STE*, 2024

Nocturnal Ozone Enhancement (NOE) events in Wuhan

Stratosphere intrusion

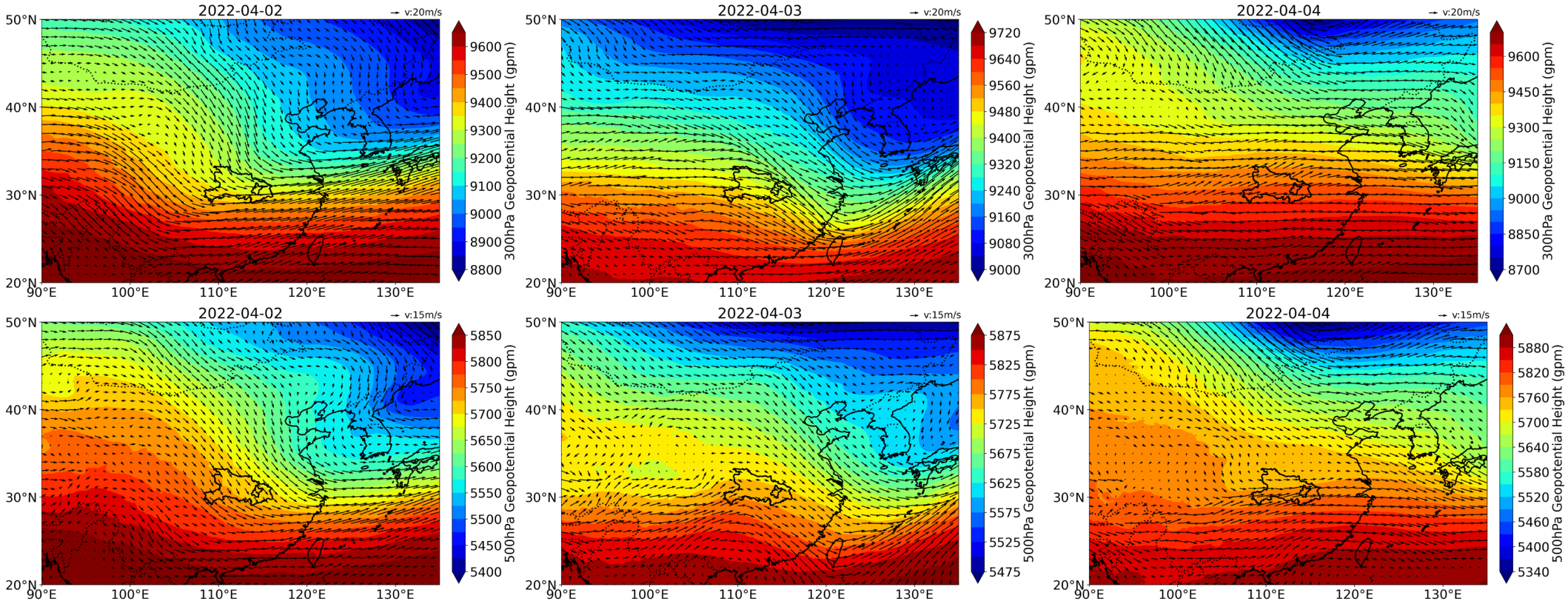
Year	High O_3S Days during NOE Events
2017	5
2018	1
2019	2
2020	4
2021	2
2022	4
2023	0
2017-2023	18



Selection criterion: daily O_3S (a tracer for stratospheric ozone from the CAM-Chem model) concentration exceeds the climatological average plus one standard deviation. The average is the daily mean from 1995 to 2023.

Nocturnal Ozone Enhancement (NOE) events in Wuhan

Stratosphere intrusion



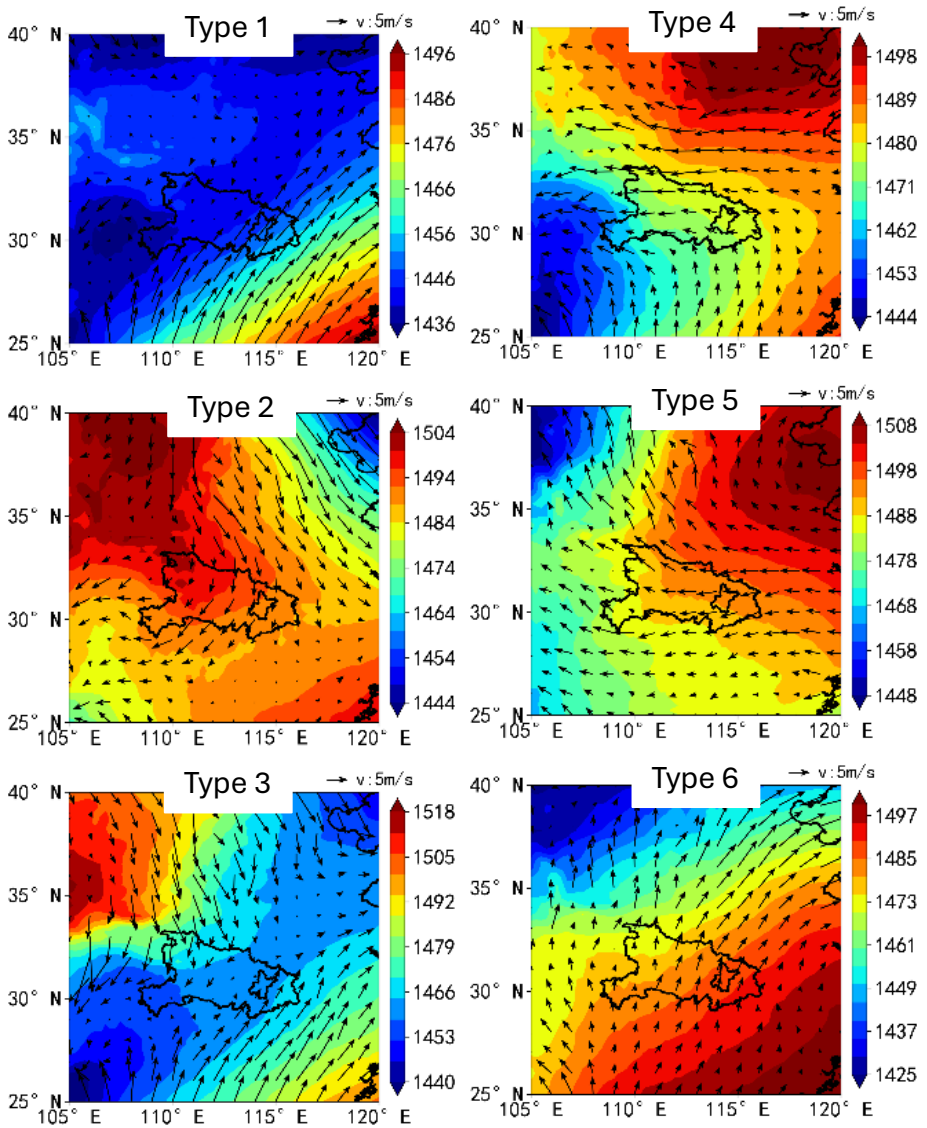
The figure shows NOE events occurring on three consecutive nights. During this period, an **upper-level trough** passed over Wuhan. According to synoptic meteorology, Wuhan was situated in the **post-trough region**, where negative vorticity advection induced **subsidence**, facilitating the intrusion of ozone-rich stratospheric air into the troposphere over central China.

Nocturnal Ozone Enhancement (NOE) events in Wuhan

Vertical transport & mixing or Horizontal transport?

Self-organizing map (SOM):
an unsupervised artificial neural network that employs a competitive learning strategy, in which neurons compete with each other to progressively optimize the network

6 types of weather conditions detected by SOM.



The figure shows the composite fields obtained by averaging all cases within each category after classification using SOM.

Work done by YS: Liwen Tian



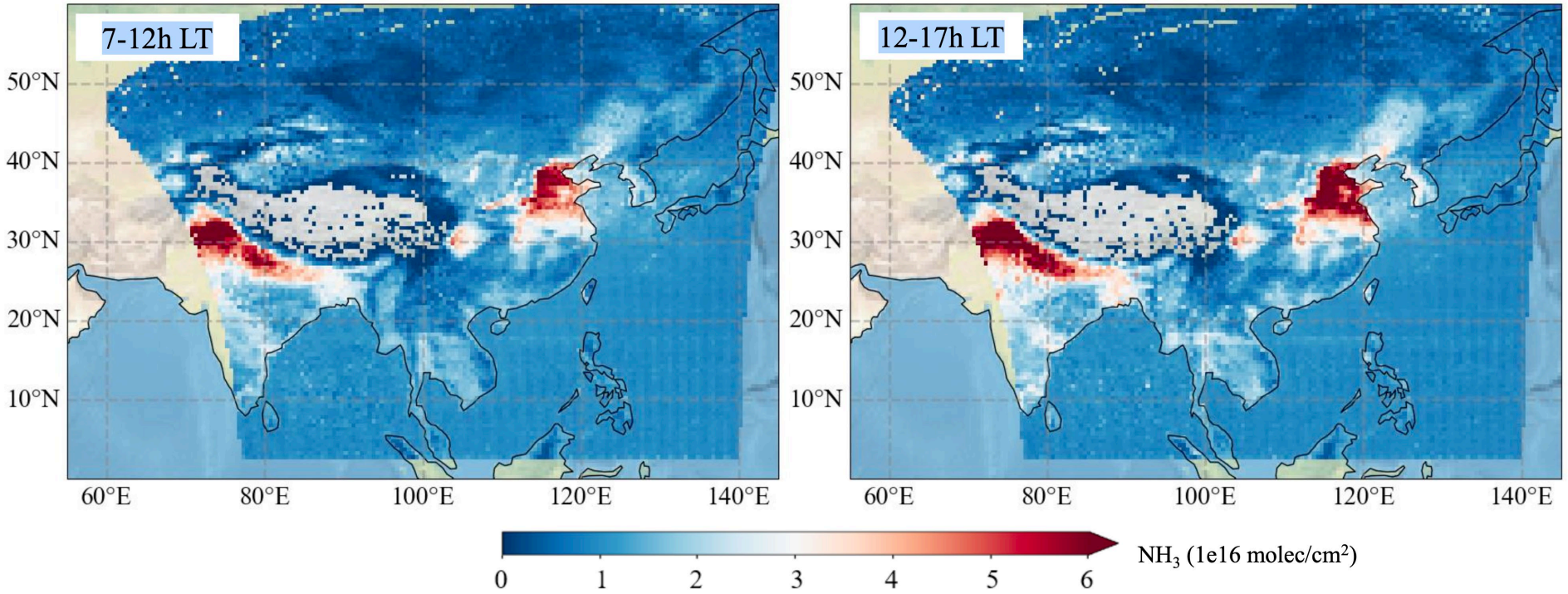
CSTEC
中国科学技术交流中心
China Science and Technology Exchange Center

esa
THE EUROPEAN SPACE AGENCY

Discussion

Using GIIRS data for studying NH3 emissions

■ **FY-4B/GIIRS NH_3 retrievals from 2022-07 to 2024-06** [1]



2 Two-year averaged NH_3 columns derived from GIIRS (DOFS>0.1, 0.5°×0.5° grid).

[1] Zeng, Z.-C., et al., 2023. *Atmos. Meas. Tech.*, 16, 3693–3713.

GIIRS NH3 Data from Z.-C Zeng from Peking University