The mushroom-like air pollutant formed by the strong anthropogenic heat island over typical coal-burning plants

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INTRODUCTION

Background

- We found that there exist morning SO_2 peaks across a national scale in China.
- The increases of forenoon SO_2 and the synergistic SO_4^{2-} have been evidenced to originate from the downwash transport of nighttime residual layer by *Wang and Ma et al.*, [2023].
- The coal-burning plants are not only strong heat sources, but also severe pollution sources;
- The physico-chemical processes of the atmospheric boundary layer in the perturbation of local coal-burning plants remain unclear.

Objective

- To explore the boundary layer structure over a typical coal-burning plant using in-situ remote sensing measurements.
- To track the transport trajectories of air pollutants emitted from the coal-burning plant by driving a large-eddy simulation model coupling with customize chemistry mechanism.

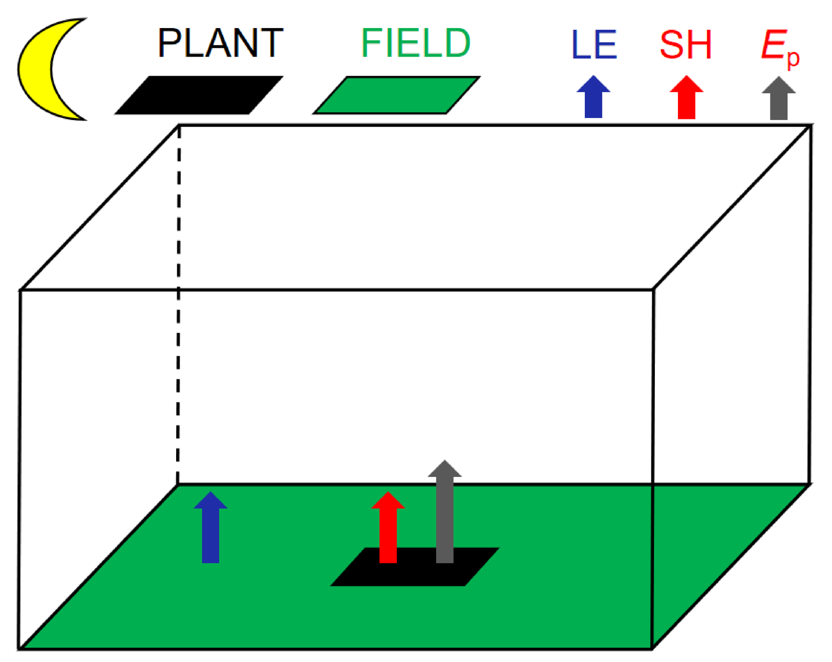
METHODOLOGY

1. In-situ remote-sensing instrumentations

a. RPG-HATPRO-G5 microwave radiometer for measuring the vertical temperature and humidity profiles.
b. Windcube-100S Doppler lidar for measuring the three dimensional wind profiles of (u, v, w).
c. CL-51 ceilometer lidar for measuring the vertical atmospheric back-scattering coefficients and the mixed layer height.

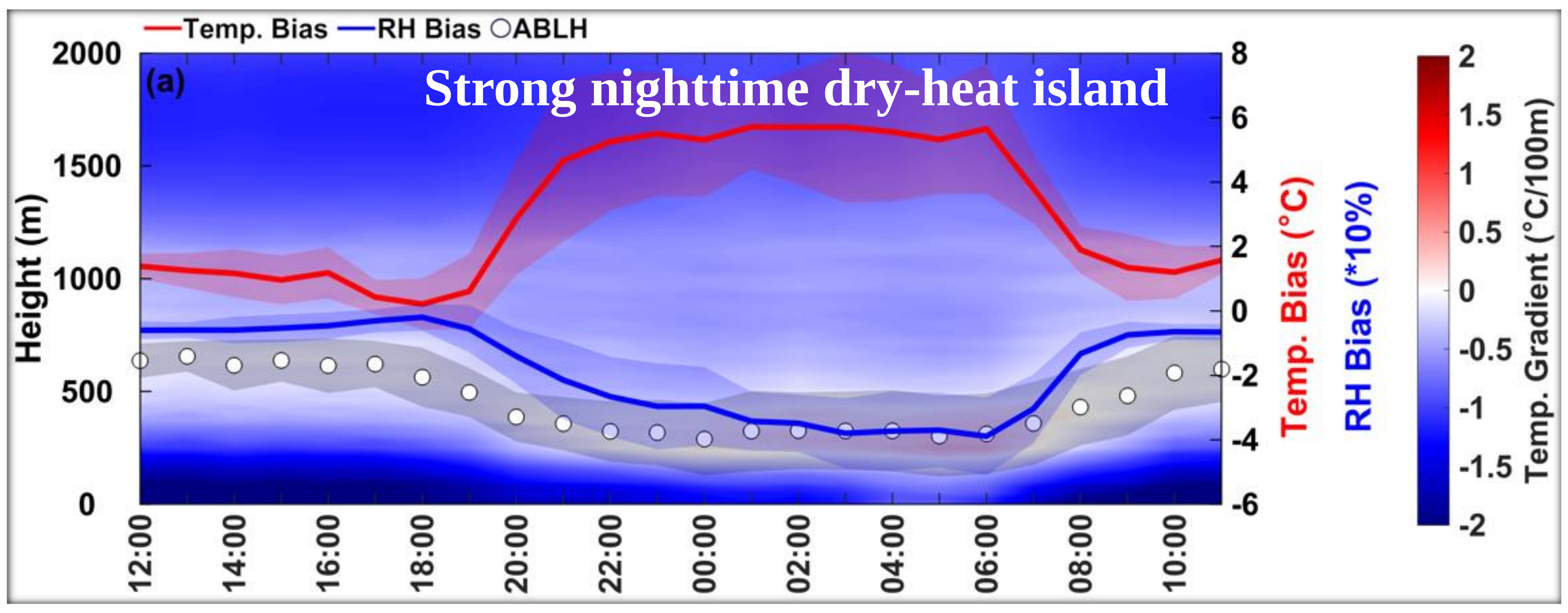
2. Large-eddy simulation modeling

a. PALM: Parallelized Large-eddy Simulation Model;
b. Simulation domain was set to 20 × 20 × 2.5 km³ with corresponding resolution of 20 × 20 × 20 m³ ($x \times y \times z$);
c. Calm wind was applied in the simulations unless otherwise stated;
d. Customize nighttime chemistry mechanism is embeded into PALM model.
e. Each simulation was run for 3 hr.



RESULTS AND DISCUSSIONS

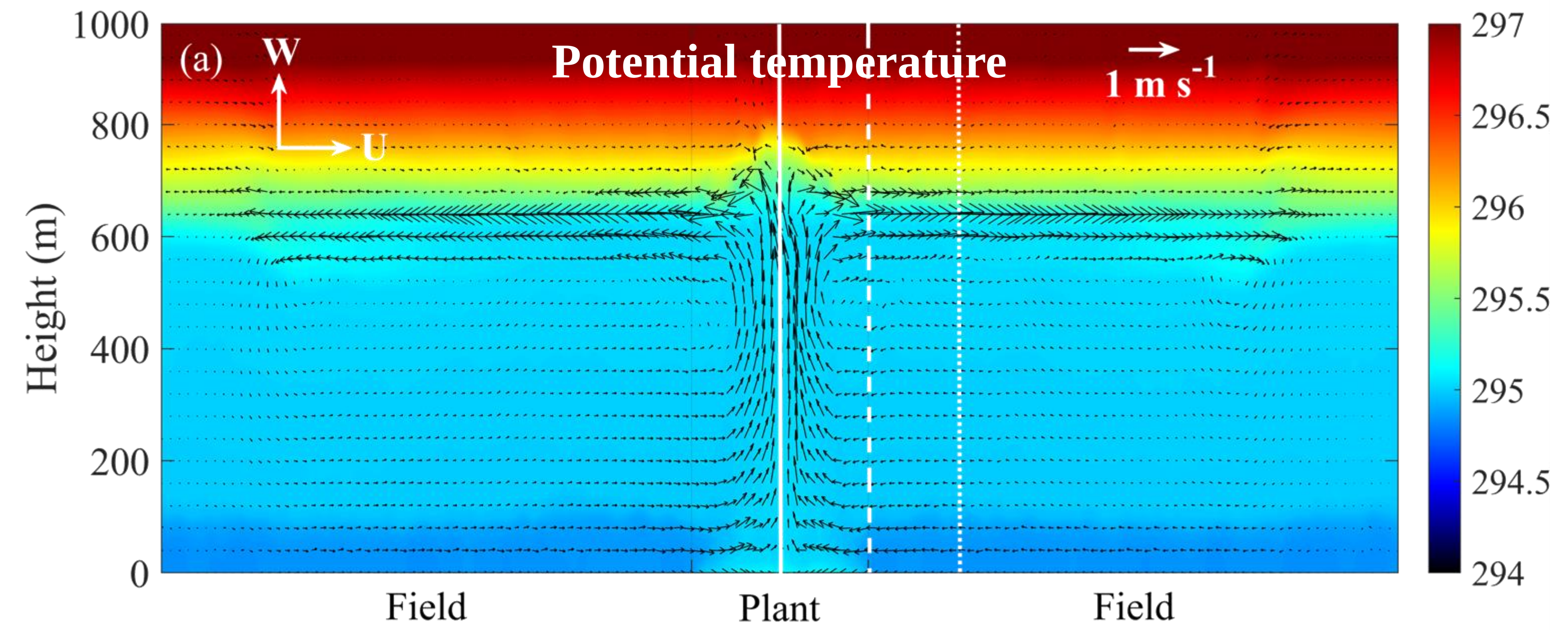
1. Diurnal remote-sensing mearuements in June 2021



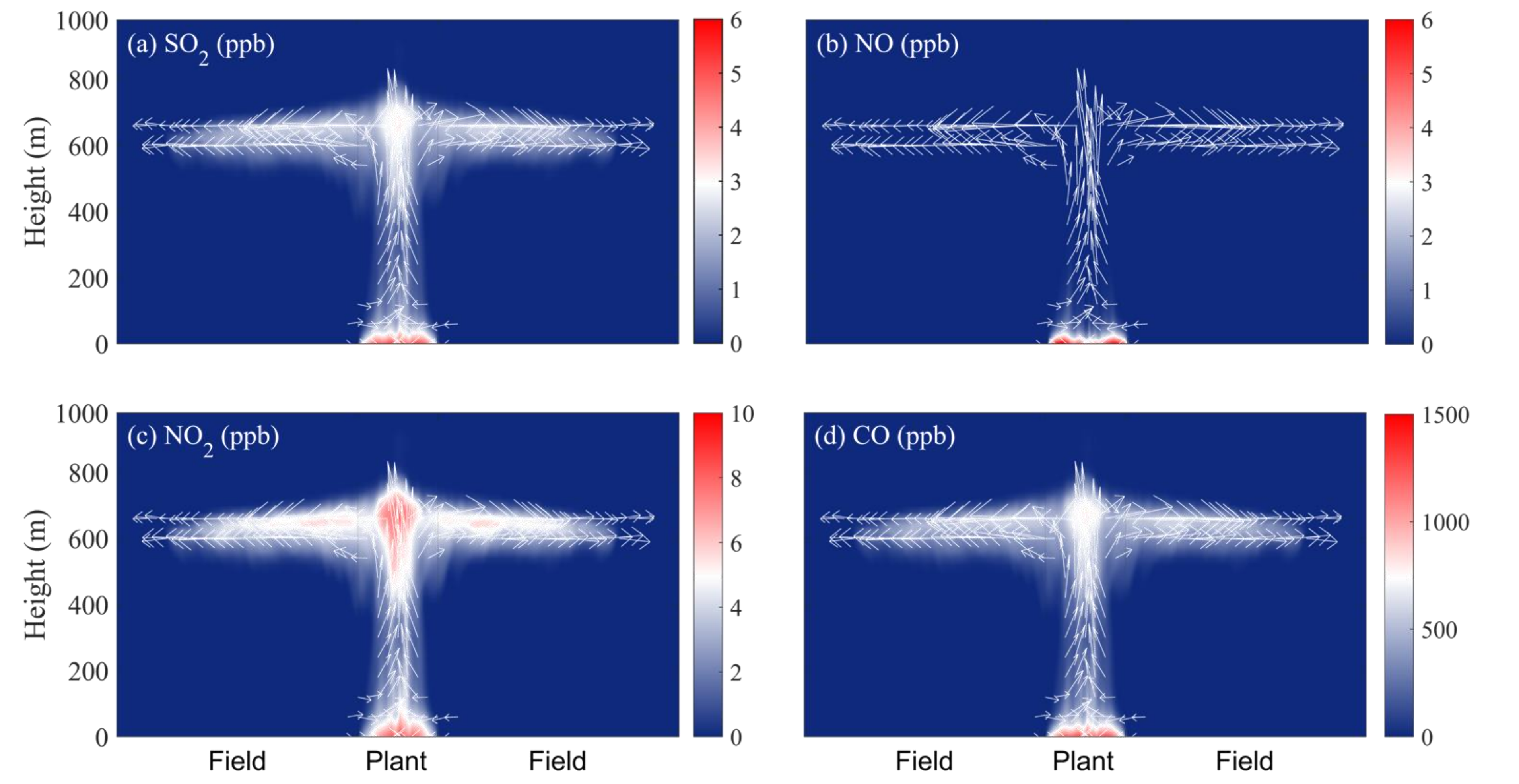
2. Large-eddy simulation modeling

	Plant domain (Grids in x,y)	Heat Flux (HF in W m^{-2}) Anthropogenic HF P	Anthropogenic HF F	Latent HF P	Latent HF F	Surface temperature (K) P	Surface temperature (K) F	Wind (m s^{-1}) u	Wind (m s^{-1}) v	Species	Emission(ppb m s^{-2})	Activity
REF	2 km ×2 km (40 ×40)	20	0	0	15	297.15	291.65	0	0	SO_2 NO NO_2 CO	0.4 0.9 0.1 100	Inert Active Active Inert
Aerodynamic trade windand Anthropogenic heat flux												
U05	2 km ×2 km (40 ×40)	20	0	0	15	297.15	291.65	0.5	0	SO_2 NO NO_2 CO	0.4 0.9 0.1 100	Inert Active Active Inert
U1	2 km ×2 km (40 ×40)	20	0	0	15	297.15	291.65	1	0	SO_2 NO NO_2 CO	0.4 0.9 0.1 100	Inert Active Active Inert
SH0	2 km ×2 km (40 ×40)	0	0	0	15	294.75	294.75	0	0	SO_2 NO NO_2 CO	0.4 0.9 0.1 100	Inert Active Active Inert
SH45	2 km ×2 km (40 ×40)	45	0	0	15	299.55	287.05	0	0	SO_2 NO NO_2 CO	0.4 0.9 0.1 100	Inert Active Active Inert
SH0U1	2 km ×2 km (40 ×40)	0	0	0	15	294.75	294.75	1	0	SO_2 NO NO_2 CO	0.4 0.9 0.1 100	Inert Active Active Inert

2.1 Strong heat island circulation



2.2 Mushroom-like air pollutants above the plant



CONCLUSION AND ACKNOWLEDEMENTS

Conclusions:

➢ There exists strong nighttime heat island effects above a coal-burning steel plant in summer, with an average temperature difference of 6.5 ℃ and an average humidity difference of 38%.

➢ Large-eddy simulations reveal significant heat island circulations with intense undraft transport the emitted air pollutants upward into the nighttime residual layer.

➢ The air pollutants stored in the nighttime residual layer will downward transport to the ground suface through convective motions after morning sunrise, accompanied by strong photochemical reaction processes, thereby leading to severe hazy episodes.

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