Experiment reveals 3D structural image of atmospheric boundary layer during haze pollution in the North China Plain

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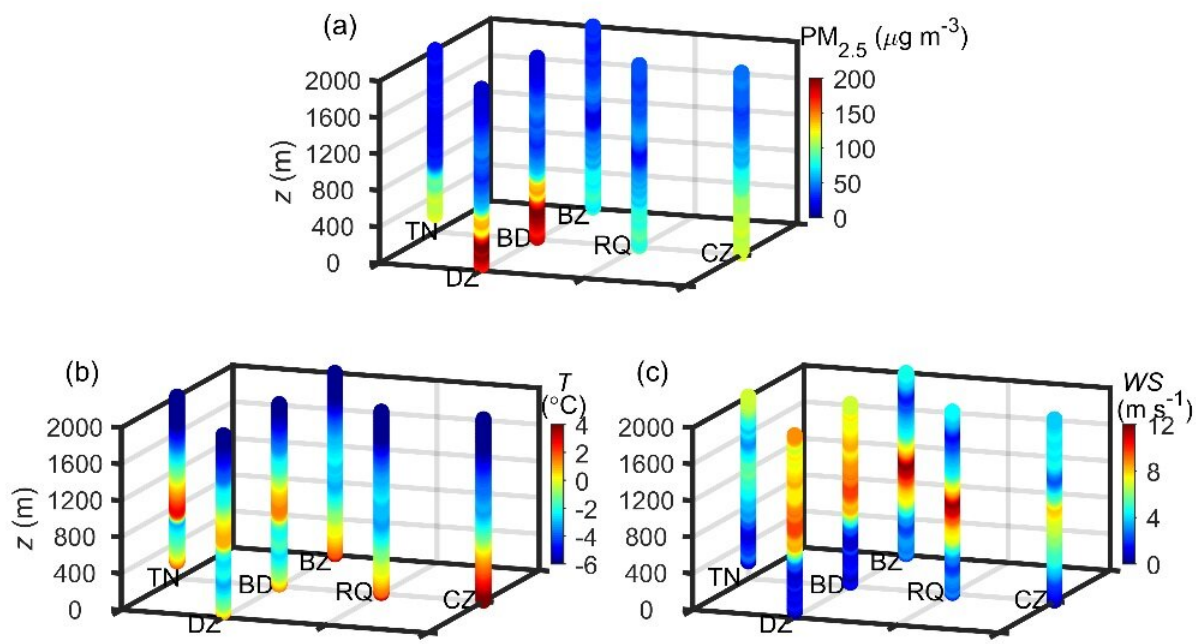
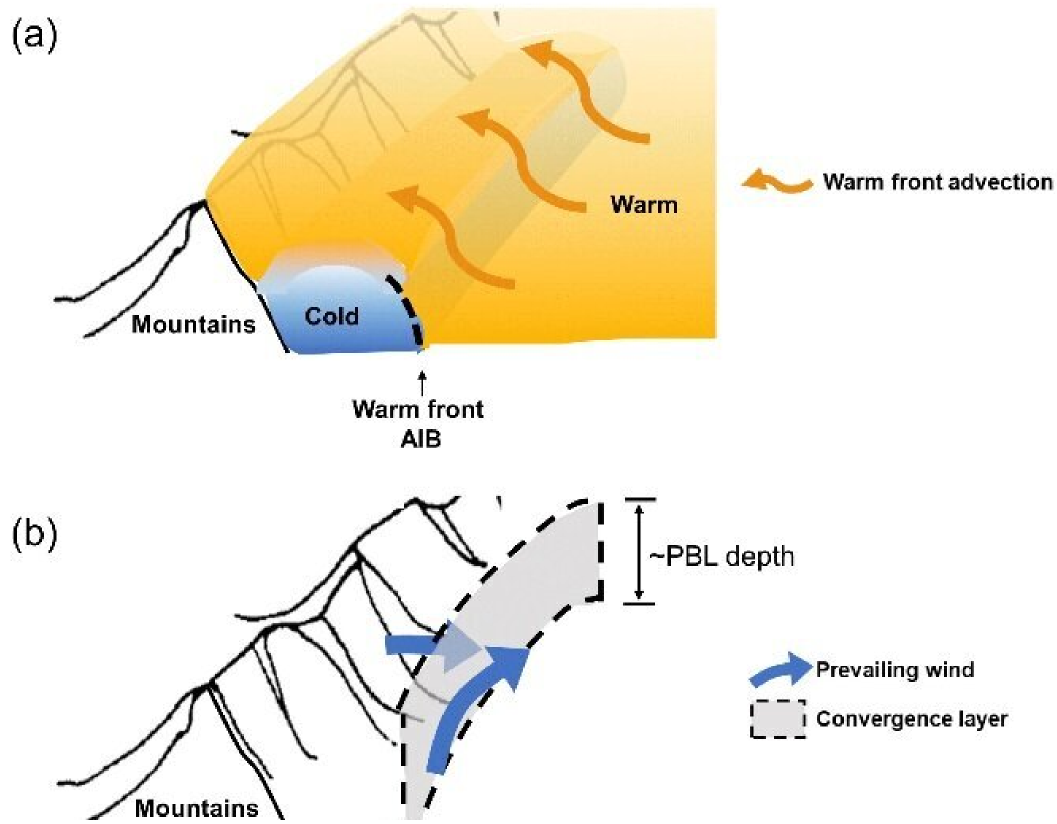


The Taihang Mountains have an adjusting effect on the meteorological conditions of the atmospheric boundary layer (ABL) in the North China Plain (NCP). For the thermal structure (figure b), the western part of the NCP near the mountains is significantly affected by drainage flow and subsidence warming, resulting in lower surface temperature, stronger elevated inversion layer, more stable atmospheric stratification, and worse conditions for vertical diffusion of pollutants. For the dynamic structure (figure c), the blocking effect of mountains causes frictional loss of kinetic energy and leads to airflow diversion. As a consequence, the calm wind layer in the western part of the NCP near the mountains is relatively thicker, which is not conducive to the horizontal transport of pollutants. Therefore, PM2.5 concentrations are higher in the western area (figure a). Credit: Science China Press

The results of the experiment "Comprehensive Observation on the Atmospheric boundary layer Three-dimensional Structure" (COATS) were recently published online in *Science China Earth Sciences*. This study enriches the understanding of the physical mechanism and spatial structure of the atmospheric boundary layer (ABL) during haze pollution.

From 2016 to 2020, Peking University, together with the Chinese Academy of Meteorological Sciences and the Institute of Atmospheric Physics, Chinese Academy of Sciences, conducted the COATS experiment in the North China Plain (NCP). The COATS experiment adopted a "point-line-surface" spatial layout, obtaining both spatial-temporal profiles of the meteorological and environmental elements in the ABL and the turbulent transport data of fine particulate matter ($PM_{2.5}$) in winter and summer.



According to the atmospheric internal boundary conditions, haze pollution in front of the Taihang Mountains can be divided into three types. Frontal type pollution (figure a) arises under the mountain thermal effects and the warm front. The cold polluted air mass at the mountain front is covered by a dome-like warm cap, which restricted the diffusion of polluted air both in horizontal and vertical directions. Wind shear type pollution is characterized by airflow convergence, mainly in two modes, the westerly-southwesterly wind shear (figure b) and southerly-northerly wind shear, which provide dynamic conditions for pollutant transport and accumulation. For topographic obstruction type pollution (figure c), the cold air mass is dammed at the windward side in front of the mountains; the warm southerly advection is obstructed by the mountains and adjusted into cold easterly advection; air masses ascend after converging at the mountain front and then cool down, showing significant inversion at the boundary of the cold air zone. Credit: Science China Press

The COATS experiment made new discoveries regarding the spatial structure heterogeneity of the ABL and its influence on the spatial distribution of pollutants. Three-dimensional structural images of the ABL during haze pollution in the NCP were obtained. It was determined that the spatial structure of the ABL adjusted by the Taihang Mountains is responsible for the heterogeneous distribution of haze pollution in the NCP, and that mountain-induced vertical circulations can promote the formation of elevated pollution layers. The restraints of the atmospheric internal boundaries on horizontal diffusion of pollutants were emphasized.

Futhermore, the typical thermal structure of persistent heavy haze events and the pollutant removal mechanism by low-level jets were revealed. The quantitative contribution of the ABL processes to pollutant transport and diffusion in different seasons was evaluated. The concept of "aerosol accumulation layer" was defined, and the applicability of the material method in determining the atmospheric boundary layer height was clarified. A measurement system for obtaining the turbulent flux of $PM_{2.5}$ concentrations was developed and the understanding of the turbulent transport of $PM_{2.5}$ between the ground and the atmosphere was expanded.

More information: Qianhui Li et al, COATS: Comprehensive observation on the atmospheric boundary layer three-dimensional structure during haze pollution in the North China Plain, *Science China Earth Sciences* (2023). DOI: 10.1007/s11430-022-1092-y

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