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Editorial: Physical and chemical processes within the planetary boundary layer and their impacts on air pollution

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Editorial on the Research Topic
Physical and chemical processes within the planetary boundary layer and their impacts on air pollution

1 Introduction

Air pollution is a critical environmental problem that arises from diverse natural and anthropogenic emissions and poses significant threats to public health (Bu et al., 2021), ecosystems (Hu et al.), and climate change (Bellouin et al., 2020). Despite some progress in reducing emissions and improving air quality in certain regions, many parts of the world still experience dangerous levels of pollution (Sicard et al., 2023).

The planetary boundary layer (PBL) forms the lowest layer of the troposphere and is a key player in the complex dynamics of air pollution through various physical and chemical processes (Stull, 1988). A comprehensive understanding of these processes is critical to devising effective strategies to mitigate air pollution. This entails the optimization of emission reduction measures, as well as the development of accurate air quality forecasting models. Such knowledge can inform sound public policy decisions aimed at reducing air pollution levels and safeguarding public health.

2 Physical processes

The PBL is a highly intricate and multi-scale system, involving a variety of physical processes (Serafin et al., 2018; Miao et al., 2022), such as turbulence, convection, radiation, and advection. The exchange of heat, moisture, and momentum between the surface and the atmosphere is largely governed by the thermal stratification of the PBL and its underlying surface characteristics (Stull, 1988). This exchange strongly influences the transport and dispersion of air pollutants, including aerosols and trace gases, from the surface to the upper troposphere.

TABLE 1 Main findings from the published research papers within the Research Topic on "*Physical and Chemical Processes within the Planetary Boundary Layer and Their Impacts on Air Pollution*."

PBL processes	Main findings
Physical processes	Xiong et al. developed a new numerical method to isolate the direct and semi-direct effects of aerosols and compare their effects with the indirect effect and found that the effects of aerosols through clouds, especially the indirect effect, play the dominant role in their feedback processes on PBL structure and air quality under cloudy conditions.
	Wei et al. summarized the current state of low-level jet (LLJ)-pollutant interactions from the perspectives of observations, models, and mechanisms, and proposed to conduct high-resolution spatiotemporal observations of pollutants and turbulence to better understand their interactions.
	Li et al. combined the Kolmogorov-Zurbenko filter method and the multiple linear stepwise regression method to study the influence of meteorological parameters on ozone concentration in Zibo and found that the overall meteorological influence was variable.
Chemical processes	Guo et al. conducted an online measurement of VOCs in the urban area of the city of Lhasa for the first time in May 2019 and observed a total of 49 VOCs.
	Wang et al. conducted a field observation lasting approximately 5 months, from 25 October 2021 to 22 March 2022, and found that most of the $PM_{2.5}$ pollution events occurred under conditions of low wind speed, temperature inversion, and high humidity, which favored the accumulation and secondary transformation of pollutants.
	Du et al. numerically found that the O_3-sensitive regimes in the city of Chengdu were in a transition zone, while the other neighboring cities were in the NOx-limited zone.
	Hao et al. studied the interfacial partition constant of 2-chloroacetophenone by measuring the mass uptake vapor on various environmental water films of different thicknesses and found that the adsorption partitioning ability of 2-chloroacetophenone at the air/water interface was negatively correlated with the surface tension.
	Hu et al. applied a remote sensing-based method to assess the impact of O_3 on the net primary productivity (NPP) of China's terrestrial ecosystems by combining MODIS NPP and the latest ground-based observations of O_3 concentration.
	Ai et al. evaluated existing diesel pollution control policies in Beijing and proposed emission control measures taking into account air quality improvement, emission reduction needs, diesel consumption characteristics, and existing emission reduction problems.
	Wang et al. found that cloud cover can influence O_3 pollution in Beijing, Hangzhou, and Guangzhou.

Turbulence is the dominant feature of the PBL and is responsible for mixing and transporting heat, moisture, and pollutants (Wei et al.). Convection, on the other hand, is responsible for the vertical transport of heat and moisture (Margairaz et al., 2020). Radiation plays a significant role in determining the energy balance of the PBL (Lee, 2018) and its interaction with aerosols (Xiong et al.). Meanwhile, advection involves the transport of air masses horizontally (Miao et al., 2022), and certain synoptic conditions and PBL dynamics can result in the long-range transport of pollutants (Colarco et al., 2004; Xiao et al., 2020).

The height and stability of the PBL determine the concentration of pollutants at the surface (Miao and Liu, 2019) and regulate their vertical distribution (Bourgeois et al., 2018; Banerjee et al., 2022). Therefore, understanding the dynamics and physical processes of the PBL is crucial in predicting air pollutant concentrations and developing effective air pollution mitigation strategies. For example, the interaction between aerosols and the PBL (Wang et al., 2022) is a critical factor in air pollution formation and dispersion. High concentrations of aerosols can enhance the stability of the PBL, resulting in decreased PBL height and exacerbating pollution levels (Petäjä et al., 2016). Additionally, aerosols can affect cloud adjustments and microphysical processes, leading to changes in the PBL height and the concentration of pollutants (Xiong et al.).

3 Chemical processes

Chemical processes within the PBL are the critical drivers in affecting the composition and concentration of atmospheric pollutants (Wang et al., 2017). Reactions between pollutants (Ma et al., 2012), including nitrogen oxides (NO_x) and volatile organic compounds (VOCs), with the involvement of sunlight and other atmospheric compounds such as oxygen, can lead to the formation of secondary pollutants such as photo oxidants and aerosols. One of the most crucial processes is the photochemical production of ozone (O_3) (Wang et al.), which occurs during the VOCs degradation process with the presence of NO_x and sunlight (Du et al.). Additionally, the transformation of primary gaseous pollutants, including nitrogen monoxide (NO) and sulfur dioxide (SO_2), into secondary particle pollutants (Wang et al.) such as nitric acid (HNO_3) and sulfate aerosols (SO_4) is another critical process. The other category triggering this transformation is atmospheric oxidants, including hydroxyl radicals (OH), O_3, and nitrate radicals (NO_3), and heterogeneous reactions, which are generated through various photochemical reactions (Brown and Stutz, 2012; Wang et al., 2017; Ye et al., 2022).

Meteorological conditions such as air temperature, humidity, and wind speed influence these chemical processes (Li et al.; Wang et al.). For example, higher temperatures and stronger solar radiation accelerate the photochemical reactions, leading to a higher production rate of O_3 and other secondary pollutants, and finally causing photochemical pollution. In contrast, increased wind speed and turbulence can enhance the mixing and dispersion of pollutants within the PBL, leading to lower concentrations of these compounds distributed near the surface.

Thereby, understanding the mechanisms behind these PBL chemical processes and their links with meteorological conditions is crucial for predicting and mitigating air pollution.

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4 Summary

In short, the physical and chemical processes occurring within the PBL have profound effects on air pollution (Table 1), and it is essential to comprehend these processes thoroughly. To achieve this goal, it is necessary to conduct extensive research, including field measurements (e.g., Guo et al.), laboratory experiments (e.g., Hao et al.), and model simulations (e.g., Ai et al.). Such research will enable us to develop a comprehensive understanding of the sources, transformations, and transport of atmospheric pollutants, benefitting the development of future air pollution mitigation strategies and further reducing adverse effects on human and ecosystem health.

Author contributions

YM and GZ wrote the editorial with inputs from XL and CX. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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