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Editorial: Air pollution and climate change: Interactions and co-mitigation

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Editorial on the Research Topic
Air pollution and climate change: Interactions and co-mitigation

Introduction

Air pollution and climate change are two important environmental factors that are tightly interconnected. Climate change can impact the physical, chemical, and biological processes associated with air pollution. On the other hand, emissions of air pollutants can also affect climate through their direct and indirect radiative forcing. However, significant uncertainties exist regarding their interactions, and additional insights are needed to better understand the mechanisms and outcomes associated with both. Moreover, greenhouse gases (GHGs) are often co-emitted with air pollutants; thus, synergistic or combined mitigation efforts could be designed to achieve optimized co-benefits. However, the current literature lacks an understanding of these co-benefits.

In this Research Topic, we aim to present a collection of original articles and reviews that address the interconnections between these two environmental factors. We also included original research that improves our understanding of air pollutant formation and removal, air pollution space-time patterns, and source attribution. This Research Topic collected a total of 17 papers, which can be largely divided into the following Four areas.

1) Feedback between climate change and air pollution, a total of four papers, including interactions between meteorology, emissions, pollutant formation, and emissions mitigation.

2) Interactions between air quality and other confronting factors, a total of five papers, including urbanization, emissions control, biogenic emissions, celestial phenomenon, and regional transport.
3) Air pollution characteristics and source attribution, a total of six papers, including space-time patterns, chemical composition, optical characteristics, and source classification.
4) Mechanisms behind pollutant formation and removal, a total of two papers, including new particle formation mechanisms and a new air purification technique.

Feedback between climate change and air pollution

Im et al. provided a detailed literature review on the interactions between climate change and air pollution in Europe. They concluded that ozone concentrations in Europe would likely increase by up to 9 ppb [−4 + 9.3], in the second half of the century, much higher than the first century (±1.5 ppb). The feedback between climate change and surface ozone are mainly dominated by increased temperatures and biogenic volatile organic emissions (VOC), while the feedback from surface particular matter is lesser and more uncertain. Similar to ozone, larger changes in particular matter concentrations are projected in the second half of the century. Zhu et al. provided an estimation of reactive ammonia uptake by secondary organic aerosol (SOA) under changing climate, and they found that including the NH3-SOA feedback could affect the meteorological conditions.

Moreover, the changing climate could also affect air quality predictions. Hu et al. provided a novel methodology for studying the impacts of climate change on meteorology and air stagnation through dynamic downscaling methods. By using dynamic downscaling, they can make realistic predictions of future climate in China with high resolution. They concluded that the occurrence of wintertime air stagnation would reduce slightly by the mid-century over China, with the largest reduction projected under the business-as-usual scenario. However, they also found that long-lasting air stagnation events are projected to increase in the future. These changes also show distinct spatial variations. Wang et al. provided us with novel findings about the previously neglected methane emissions from older fishing vessels in China. They adopted a real-world measurement technique and discussed the emission factors from these vessels. Their study calls for urgency on methane emission inventory in shipping.

Interactions between air quality and other confronting factors

Fine particulate matter ($PM_{2.5}$) and ground-level ozone (O_3) are two of the most important ambient air pollutants. Their concentrations are known to be impacted by many factors, particularly emissions of precursor gases such as NO_x (nitrogen oxides) and VOC, meteorology, and associated physical and chemical processes. An in-depth understanding of the different factors contributing to pollution is the key to design effective mitigation strategies.

In this article collection, Zhang et al. applied the MEGAN (model of emissions of gases and aerosols from nature) model and estimated BVOC (biogenic volatile organic compounds) emissions over the Sichuan Basin, China. The significant impacts of BVOC emissions on regional O_3 pollution were subsequently quantified through CMAQ simulations. Liang et al. analyzed the trend of O_3 pollution in Jinan China, between 2013 and 2020 and investigated the impact of synoptic weather patterns on O_3 pollution. Features such as low sea level pressure, high temperature, and strong UV radiation were found to be the most prevalent synoptic patterns that likely favor O_3 formation. He et al. applied the WRF-CMAQ model and analyzed the evolution of $PM_{2.5}$ pollution during stable synoptic conditions in Shanghai, China. The development of $PM_{2.5}$ pollution was divided into four stages. The contributions from factors such as meteorology, emissions, and regional transport were found to vary significantly among stages.

Wang et al. simulated how land use and land cover change as the results of urbanization affect the dynamics of urban air quality. In this study, urban expansion was found to significantly impact meteorology near the surface, which consequently altered physical and chemical processes associated with $PM_{2.5}$ and O_3 pollution. Interestingly, urbanization was found to generally decrease $PM_{2.5}$ pollution due to enhanced vertical mixing and weakened aerosol production, but increase O_3 pollution around 8 p.m. as the result of reduction in horizontal advection. Finally, Tian et al. examined the impact of solar eclipse event on O_3 pollution in Yunnan, China. Substantially decreased O_3 pollution (up to 40%) were observed during the solar eclipse, likely due to drastically reduced solar radiation, and different meteorological conditions during the event. O_3 in severely polluted cities was also found to be more sensitive to nitrogen dioxide (NO_2) and carbon monoxide (CO) during the eclipse.

These articles provided valuable insights into the different factors impacting ambient $PM_{2.5}$ and O_3 pollution. The diversity of topics also highlights the complexity of this problem.

Air pollution characteristics and source attribution

Air pollutant species could have distinct space-time patterns and chemical compositions due to their emission sources, driving meteorology, and surrounding topography. Understanding those characteristics is crucial in advancing our knowledge of pollution formation and source attribution, which in term helps the design of pollution control and mitigation policies. Based on a state-of-the-art chemical transport model (WRF-CMAQ), Mao et al. simulated the long-term $PM_{2.5}$ and O_3 distribution in China at a 36 × 36 km scale between 2013 and 2019. In general, they found an increasing trend of O_3 and decreasing trend of $PM_{2.5}$, and a negative correlation is found between O_3 and $PM_{2.5}$ for most regions except for the Pearl River Delta and Yangtze River Delta. Another modeling work conducted by Yan et al., applied the advanced Source Apportionment Method (ISAM) to investigate the evolution mechanism and conduct source attribution of an extreme O_3 episode in the Sichuan Basin, southwestern China. The inadequate ventilation, in combination with stagnant conditions, is found to be the trigger of the episode, and the emissions from industrial and transportation sectors have the largest impacts on elevated O_3 concentrations. However, natural sources could also be a major player in pollution formation. As pointed out in the study of Liu et al., soil dust and fugitive dust are the top two sources of coarse particulate matter (PM_{10}) pollution in the Arid Region of Northwest China based on field measurement and backward trajectories calculated using the HYSPLIT model. Similar work is conducted by Zeb et al. for the Semiarid region in Pakistan. The average PM_{10} concentration in industrial locations (505.1 μg m^{-3}) is about twice that in urban and suburban locations. Their results showed that the pollution originated from local sources like cement industries, brick kiln industries, and others. Acuña Askar et al. Explored the detailed chemical composition and optical properties of $PM_{2.5}$ and water-soluble organic carbon (WSOC) of these particles in Northeastern Mexico. Where a close connection is found between WSOC compounds and brown carbon chromophores, and the terrestrial and microbial origin of WSOC. Finally, Lee et al.investigated the temporal variability of five air pollutants in megacities of South Korea between 2002 and 2020 based on monitoring data. Similar to the observation by Mao et al. for China, they also found O_3 to be the only pollutant with increasing trends in South Korea. The interconnections between human activities and seasonal and weekly patterns of major pollutants are also investigated, which provides valuable insights for air quality control.

Mechanisms behind pollutant formation and removal

Understanding chemical mechanisms behind pollutant formation and removal is not only important scientific knowledge but also provides critical insights into control and mitigation. Quantum chemistry calculations provide a useful tool to probe these mechanisms from the first principle. Liu et al. investigated new particle formation from the methanesulfonic acid–methylamine–ammonia system under acid-rich conditions using quantum chemistry calculations. Their calculations revealed stable cluster structures formed in this system. They found that methylamine and ammonia have a synergistic effect on new particle formation, and the role of ammonia increases with cluster sizes. Also using quantum chemistry calculations, Yang et al., applied the technique to study air pollutant adsorption on Pt-decorated N3-carbon-nanotubes, as a potential pollutant control technology. Their calculation showed that a suite of air pollutants could be removed by the adsorbent with adsorption energies ranging from -0.81~-4.28 eV, driven by the overlaps between the Pt 5d orbitals and the outmost p orbitals of the coordination atoms (C, N, O, and S atoms) in the gas molecules. These findings from quantum chemistry calculations provide microscopic insights into the pollution formation and removal processes that are valuable for developing policy and technology.

The 17 papers in this Research Topic use field observations, laboratory measurements, and numerical models and provide in-depth and detailed discussions on air pollution characteristics and source attribution, mechanisms between formation and removal, interactions with climate and other confronting factors, and obtained very interesting and meaningful results. We thank the authors and reviewers who contributed to this Research Topic. Together these papers provide valuable insight into the discussion of air pollution and climate interactions, and open up exciting avenues for future research.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

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