On assessing haze attribution and control measures in China

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ABSTRACT

This paper analyzes the air pollution situation in China, particularly the severe intensifying tendency in central North China. Five major comments on the air pollution issue in China are proposed, emphasizing the scientific understanding on the mechanisms of air pollution formation processes, the interannual variability, the relative roles of climate change and pollutant emissions, the interaction between climate change and atmospheric chemical processes, and the seasonal prediction of air pollution. The viewpoints have significance for air pollution management in China and around the world.

1. Introduction

Since the year 2000, haze has occurred more frequently in China, with coarse and fine particulate matter (PM$_{10}$ and PM$_{2.5}$) concentrations increasing substantially in regions including the Beijing–Tianjin–Hebei area, the Yangtze River Delta, the Pearl River Delta, the Sichuan Basin, and the Central Shaanxi area. Severe haze can greatly influence people's health on a regional level and damage China's international reputation, and has become a major challenge to social and economic development. At the beginning of the year 2017, the World Health Organization (WHO) Director General, Dr. Margaret CHAN, the World Meteorological Organization (WMO) Secretary General, Petteri TAALAS, and the United Nations Environment Programme (UNEP) Executive Director, Eric SOLHEIM, published a report in the WHO Bulletin in January 2017 entitled ‘Working as one UN to address the root environmental causes of ill health’, pointing out ‘There are many compelling reasons why we need to clean up the global environment. One of the most pressing is that a polluted environment is a deadly one. Every year, almost 12.6 million people die from diseases associated with environmental hazards, such as air, water or soil pollution, and climate change. That is one in four deaths worldwide’ (Chan, Solheim, and Taalas 2017). Thus, air pollution is a worldwide challenge, but especially in China.

China has invested enormous financial, human, and material resources in reducing the emissions of pollutants, and to promote scientific research and technological development to support the protection of the atmospheric environment. From the research perspective, there have been special research plans supported by the Ministry of Science and Technology, China Environment Protection Agency, and the National Natural Science Foundation of China, Chinese Academy of Sciences. However, so far, the actual effect is still very limited. Serious air pollution has occurred more frequently in recent years. For example, Tianjin and the surrounding area has suffered from a continuous outbreak of a wide-ranging and persistent haze pollution event since 17 December 2016, with two long-term severe haze pollution processes within 20 days. This serious air pollution situation arouses much fear in eastern China and has led to discussion on the haze immigration issue.

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At present, the haze pollution situation and governance in China is in a critical period, but the public and government departments often misunderstand air pollution in terms of its formation, scientific attribution, and reasonable methods of management. This may result in serious problems with respect to the formulation and implementation of policies and measures for the prevention and control of atmospheric pollution. Thus, the motivation of this paper is to offer some clarification on the key issues related to haze attribution and control measures.

2. Quantifying the roles of anthropogenic emissions and climate change is a precondition of reasonable management of air pollution

There is no doubt that the increase in anthropogenic pollutants is the basic cause of air pollution. If the emissions were zero, the concentration of air pollutants would not exceed the standard. The problem is that even developed countries and regions in Europe and the United States cannot realize zero emissions. The current situation in China in terms of our stage of development with respect to energy means that we have to strike a balance between socioeconomic development and emissions reduction policies, and seek to solve the pollution problem under a process of development and transition towards green development. Thus, the reality for China is that economic construction and environmental protection must be coordinated and balanced.

On the other hand, it is necessary to recognize that global warming plays an important role in China’s air pollution. It is estimated that nearly 20% of the 30-year long-term increasing trend of air pollution in China is caused by the impact of global warming. However, because this estimation is carried out based on climate–environment coupled earth system modeling, which itself contains much uncertainty, this kind of evaluation is by no means a foregone conclusion. For example, Wang, Chen, and Liu (2015) showed that only the Arctic sea-ice variability may account for more than 40% of the total air pollution variability on interannual to interdecadal scales. Meanwhile, Yin, Wang, and Yuan (2015) demonstrated that East Asian monsoon variability and change can have a significant influence on air quality. In addition, Arctic and Northern Hemisphere high-latitude warming, atmospheric vertical temperature stratification effects, increased water vapor content, reduction in wind speed, and changes in other climatic factors, can considerably intensify air pollution. Scientific and quantitative assessment of the impact of climate change and variability on air pollution calls for further research.

3. Understanding the mechanisms governing the interannual variability of air quality from the perspectives of climate variability and emissions control

Scientific research institutions, governmental departments, or other organizations often try to carry out assessments on the effects of emissions reduction by comparing the air pollution between two specific years. However, this is not a reasonable approach, and the conclusions are extremely unreliable and often misleading. This is because the large interannual variability of the climate can lead to a large interannual variability of atmospheric pollution, even if the emissions do not change. Moreover, the impact of climate variability on air pollution may even exceed that of the changes in anthropogenic emissions. As a result, the interannual variation of air pollution could be largely or even mainly caused by the climate variability. Therefore, to quantitatively assess the relative contribution of climate variability and changes in emission sources is a complex and urgent task for research.

4. Recognizing the formation processes of severe air pollution and formulating prevention and control regulations in advance

Regional meteorological conditions and local topography are closely related to the formation of heavy air pollution, and the former feature large seasonal, interannual, and interdecadal variability. Since Beijing city is located in a unique region insofar as it is surrounded by mountains and the Bohai Sea, pollutants do not diffuse easily and pollutants may be transported to and converge in Beijing. Thus, there are normally one or two days of accumulative processes before the formation of a heavy pollution event. Therefore, based on reliable weather forecasting, we should take control measures at least one or two days ahead of the air pollution occurrence, and then maintain them until the end of the pollution process.

Therefore, to alleviate moderate and severe urban air pollution, several measures should be undertaken. First, meteorological/environmental protection departments should try to produce reliable and high spatial resolution weather and air pollution forecast, at least 48 h in advance. Second, relevant government departments should take measures to control pollutant emissions in Beijing city and surrounding areas, at least 24 h in advance, or even 48 h in advance if possible. Third, when the pollution weather has formed, the above control measures should be maintained, until the unfavorable meteorological conditions are destroyed.

In addition, it is very important to make scientific and quantitative assessments of the relative contributions of various sources of atmospheric pollution in Beijing city in different seasons, in different years, and under different
meteorological conditions. However, it is an extremely complex and difficult scientific question, and many uncertainties exist in this regard. Nonetheless, such assessments must be made to provide a scientific basis for reasonable and effective prevention and control measures.

5. Promoting the seasonal prediction of air pollution

Weather forecasts for air pollution are very important in the context of, for example, people’s travel, social outdoor activities, and even some activities for the defense sector. Therefore, it is necessary to consider the interaction between atmospheric circulation and atmospheric chemical processes (such as the impact of particles on radiation and cloud and its feedback mechanism) besides traditional weather forecasts. This can be beneficial to both the weather forecast and the prediction of air pollution. In addition, current forecasts are valid mainly for 24 h to 10 days, with reliable prediction amounting to less than a week. In fact, another forecasting at another timescale is also very important; namely, seasonal forecasts of air pollution (similar to seasonal climate prediction). This kind of prediction offers great value for the government and public in terms of long-term planning and pollution control measures; however, such a prediction service has yet to be established due to an insufficient scientific basis. Recently, such predictions have begun to be carried out at Nanjing University of Information Science and Technology (Yin and Wang 2016). The preliminary prediction approach and model have been developed, by considering several predictors. These predictors could on the one hand be observation-based predictors such as the preceding sea surface temperature in particular ocean areas, the sea-ice extent in the Arctic, or the snow and vegetation cover in Eurasia; whilst on the other hand they could be GCM-based predictors such as atmospheric circulation factors (Yin and Wang 2016). Preliminary test results for real-time seasonal prediction are encouraging. Indeed, in the near future, a real-time seasonal forecasting system will be set up and applied operationally. However, given the limitations of such prediction in terms of its scientific complexity and level of accuracy, the prediction should be cautiously applied.

6. Implementing stricter air pollution prevention and control policies in key areas

At present, air pollution in Beijing–Tianjin–Hebei is the most prominent and needs to be solved as early as possible. However, the air pollution in the Yangtze River Delta, Pearl River Delta, Sichuan Basin, and central Shaanxi region is also quite severe. According to recent research results (Wang, Chen, and Liu 2015; Wang and Chen 2016; Cai et al. 2017), future global warming will very likely further exacerbate the air pollution in eastern China. The reason is that global climate warming will result in a more stable atmosphere and weakening of the lower-level cold-air activity, which is not conducive to pollutant diffusion. Therefore, the development of regional air pollution prevention measures and control plans and enforcement is an important and urgent task, in order to limit the air pollution in China.

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