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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Introduction to Special Issue – In-depth study of air pollution sources and processes within Beijing and its surrounding region (APHH-Beijing)" *by* Zongbo Shi et al.

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Response to reviewer comments:

General response:

We thank both reviewers for providing constructive comments.

We have carefully considered every single comment and revised the manuscript accordingly. We also provided a point by point response to all the comments made below.

One point we would like to make is that this is an Introduction to special issue paper, not an overview or research paper. ACP editorial policy states that "Special issues may

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include an introduction article or an overview article or both. Introduction articles outline the motivation and background, and overview articles synthesize and summarize the findings of the special issue papers. The manuscript title must clearly reflect the relation to the special issue and should start with "Introduction:" or "Overview".

To make this clearer, we have added a paragraph at the end of the introduction.

“This introduction paper describes the motivation and background of APHH-Beijing programme, and presents some of the background air quality and meteorology observations that lay the basis of data interpretation for the whole programme, particularly during the two intensive field campaigns. These campaigns form one of the core research activities within APHH-Beijing integrating the different themes / projects. We did not intend to present the key scientific results of APHH-Beijing here as much of the research activities are still ongoing and unpublished. Such information is more suitable to go to an overview paper.”

We also would like to emphasize that scientific work on the impact of synoptic scale meteorology on air quality and the air quality climatology add significant knowledge to our understanding of air pollution events in Beijing. Therefore, this introduction paper not only provides the motivation and background of the APHH-Beijing programme but also new science.

Many of the ACP special issues have introduction papers, such as:

Kulmala, M. et al., 2009. Introduction: European Integrated Project on Aerosol Cloud Climate and Air Quality interactions (EUCAARI) – integrating aerosol research from nano to global scales. Atmos. Chem. Phys., 9, 2825–2841. Cairo, F., et al., 2010. An introduction to the SCOUT-AMMA stratospheric aircraft, balloons and sondes campaign inWest Africa, August 2006: rationale and roadmap. Atmos. Chem. Phys., 10, 2237–2256 Kruger, K and Quack, B., 2013. Introduction to special issue: the TransBrom Sonne expedition in the tropical West Pacific. Atmos. Chem. Phys., 13, 9439–9446 Kulmala, M. et al., 2015. Introduction: The Pan-Eurasian Experiment (PEEX) –

multidisciplinary, multiscale and multicomponent research and capacity-building initiative. Atmos. Chem. Phys., 15, 13085–13096 Martin, S.T. et al., 2016. Introduction: Observations and Modeling of the Green Ocean Amazon (GoAmazon2014/5). Atmos. Chem. Phys., 16, 4785–4797.

âĂČ Reviewer 1

Comment 1: several giant projects on air pollution and health impacts funded in the volume of billions RMB yuan are processing currently or have been completed in Beijing and neighboring provinces in the last decade. These works should be summarized to make the literature review more complete. The authors are strongly encouraged to present a summary to highlight the importance of APHH-Beijing in comparison with others.

Response: We agree that a summary of past work in Beijing will be valuable to put the APHH-Beijing work into context and we have added a summary about the CARE-Beijing and other large programmes (see below). APHH-Beijing programme was designed in 2015 and started in 2016. The rationale of this programme in the introduction paper was based on work up to 2016. Thus, we feel that it is not totally appropriate to include ongoing and unpublished work in this introduction paper.

Changes in the texts: We have added texts in the Introduction

“Many research programmes were initiated in Beijing to study the air pollution processes since late 1990s. Earlier research programmes (e.g., early 2000) focused on primary emissions of SO2, NO2, CO, PM10, volatile organic compounds and then secondary pollutants such as ground-level ozone and secondary fine particles. These researches contributed to the development of air pollution mitigation strategies by the Beijing Municipal government.

Beijing Olympic Games (2008) offered additional incentives to improve air quality and this led to the funding of CAREBEIJING (Campaigns of Air Pollution Research

in Megacity Beijing and Surrounding Region) and other major programmes. CARE-BEIJING was initiated and organized by Professor Tong Zhu of Peking University, with participation of hundreds of scientist and students from China, USA, Germany, Italy, Japan, and South Korea. The field campaigns were conducted in the summer of 2006, 2007, and 2008, with the objectives to learn the environmental conditions of the region, to identify the processes (transport and transformation) that lead to the impact of the surrounding area on air quality in Beijing, to quantify the impact of the surrounding area on air quality in Beijing, and to formulate policy suggestion for the air quality attainment during the 2008 Beijing Olympic Games. Other major research programmes, initiated since early 2000, aimed to provide scientific basis to deliver air pollution mitigation measures for ensuring a good air quality during the Olympics Games. Measures developed as a result of these programmes successfully reduced the air pollution during the Olympics Games, and provided valuable examples for air pollution control policy-making in other cities (Wang et al., 2010). CARE-BEIJING latter on was extended to CAREBEIJING-NCP (Campaigns of Air Pollution Research in Megacity Beijing and North China Plain), where field campaigns were carried out in the summer of 2013 and 2014 to investigate the transport and transformation processes of air pollutants in megacity Beijing and North China Plain. The results of CAREBEIJING and CAREBEIJIN-NCP have been published in three special issues of Atmospheric Chemistry and Physics (https://www.atmos-chem-phys.net/special_issue198.html) and Journal of Geophysical Research-Atmospheres (https://agupubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)2169-8996.CARBS1). These large research programmes and numerous discovery science projects significantly enhanced our understanding on the emission, sources and processes of air pollutants in Beijing (Chan and Yao, 2008; Zhu et al., 2012). However, our understanding of sources and emissions of key air pollutants such as PM2.5 and ozone and the role of the interactions between physical and chemical processes in the formation of pollution events in the Beijing megacities is still far from being accurate or complete. In addition, none of the abovementioned large programmes are directly

linked heath effect studies. ”

In addition, we have added a section at the end of the paper to summerize this introduction paper and highlight the novel aspects of the APHH-Beijing. “The APHH-Beijing is an integrated and multidisciplinary research programme by leading UK and China researchers to (1) quantify sources and emissions of urban atmospheric pollutants; (2) elucidate processes affecting urban atmospheric pollution events; (3) estimate the personal exposure and impacts of air pollution on human health, and (4) develop intervention strategies to improve air quality and reduce health impacts in the Beijing megacity. This introduction paper outlines the motivation of the APHH-Beijing programme as well as provides the background air quality and meteorological conditions that form the basis of data interpretation for the whole programme, particularly during the two intensive field campaigns as a core research activity within the programme.

APHH-Beijing has measured the fluxes of key air pollutants, including NOx, CO, BC, VOCs and speciated particulate matter, applied a suite of traditional and modern techniques to apportion the sources of particulate matter, determined a wide range of pulmonary and cardiovascular biomarkers linking to direct personal exposure and extensive fixed-station monitoring as well as source apportionment results, and evaluated the effectiveness of Beijing’s air pollution control policies using both chemical transport models and novel machine learning techniques. A number of papers have already been published under the APHH-China programme including those in APHH-Beijing special issue (Wang et al., 2019; Pan et al., 2019; Xia et al., 2018; Zhou et al., 2018; Wang et al., 2018; Lyu et al., 2019; Hollaway et al., 2019; Du et al., 2018; Liu et al., 2018a,b; Smith et al., 2018). More papers are being prepared for publication in this special issue and elsewhere, which will cover (but not limited to) emission fluxes of air pollutants, chemical composition and source apportionment of fine particles, satellite observations of trace gases and aerosols, sources and processes leading to haze events and photochemical smogs, physical and optical properties of aerosol particles, formation processes of secondary aerosols, urban meteorology, feedbacks between

haze, photochemistry and meteorology, integrated regional and urban scale modelling, personal exposure to air pollutants and human health effects of air pollution."

Comment 2: Section 2 is too ambitious to be practical for two short-term campaigns

Response: It appears that there is a misunderstanding here. The whole programme is more than the two campaigns. We have introduced the two campaigns because they are one of the core activities that integrate research across the themes and the information provided in this introduction paper provided a background for a number of in-preparation papers for this special issue.

Section 2 is extracted from the five funded proposals that were awarded on a competitive basis and assessed by international expert reviewers and a panel of UK/China top scientists. Now look back at these set objectives, we have indeed make progresses in all areas.

Comment 3: Lines76-80 "The winter campaign was characterized by high PM2.5 pollution events whereas the summer experienced high ozone pollution events. Air quality was poor during the winter campaign, but less severe than in the same period in 2015 when there were a number of major pollution episodes. PM2.5 levels were relatively low during the summer period, matching the cleanest periods over the previous ïňĄve years." The statement looks like the report issued by local EPD rather than a scientiïňĄc study. The reviewer gains almost nothing from it. It should be more speciïňĄc. Response: This is a very general introduction which sets our campaign periods in context. However, we recognise that it is very qualitative and have therefore modified it to include quantitative information which guides the reader more usefully. The revised text reads as follows:

Changes made: "The winter campaign was characterised by high PM2.5 pollution events with peak hourly concentrations at the urban site ranging up to 498 μg m-3, whereas the summer experienced events of high ozone concentrations with the highest hourly average up to 176 ppb. Air quality was generally poor during the winter cam-

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paign with an average PM2.5 concentration of 96 μg m-3, but less severe than in the same period in 2015. Synoptic scale meteorological analysis suggests that the greater stagnation and weak southerly circulation in November/December 2016 contributed to the poor air quality during all haze events detected. PM2.5 levels were relatively low during the summer campaign with the highest daily concentration of only 79 μg m-3, matching the cleanest periods over the previous five years."

Comment 4: Lines 80-82, "Synoptic scale meteorological analysis suggests that the greater stagnation and weak southerly circulation in November/December 2016 may have contributed to the poor air quality." Contributed to a few or all severe PM2.5 pollution events?

Response: We updated Figure 12 to include indication of haze events. This clearly demonstrates that CTs associated with stagnation (CT9, 11) dominate during all haze events of the winter campaign. The text and abstract have been updated accordingly.

The sentence in the abstract is now changed to "Synoptic scale meteorological analysis suggests that the greater stagnation and weak southerly circulation in November/December 2016 may have contributed to the poor air quality during all haze events detected."

Comment 5: Line 100, "particularly severe in developing megacities, such as Beijing, where rapid urbanisation has led to a fast increase in pollution emissions (Guan et al., 2014), on top of regional pollution from industrial and other anthropogenic activities." Can Beijing be called as developing megacities? The reviewer also cannot understand the statement, please consider to revise.

Response: We recognize that the definition of a "developing megacity" can sometimes be controversial. In this context, we argue that Beijing is a developing megacity because it is still transforming rapidly and its GDP growth is significantly faster than developed megacities. We have revised the sentence:

Changes made: The quoted sentence has now been changed to: “Air pollution is particularly severe in developing megacities, such as Beijing, where pollutants from traditional sources, such as solid fuel combustion are mixed with those from road traffic (Guan et al., 2014), on top of regional pollution from industrial and other anthropogenic activities.”

Comment 6: Lines 117-119 “This makes Beijing a particularly interesting place to study as it provides a new environment to test our understanding of urban pollution processes.” The reviewer feels very surprised that all Chinese co-authors agree with the statement.

Response: We have revised this sentence as following: “This makes Beijing a particularly interesting place to study as it provides an atmospheric environment very different to developed megacities such as London and Paris to investigate urban pollution processes.”

Comment 7: The objectives in Section 2 are ambitious. The reviewer has doubt how they can be achieved through two short-term campaigns at two sites. Response: see above response to comment 2.

Comment 8: Section. 3.1.1 does not sound scientiïňĄc to this reviewer. It makes more sense to use the data from the air quality monitoring network and the two additional sites together to evaluate the accuracy of emissions of air pollutants? Response: The air quality monitoring network is a valuable source of data but measures only a small suite of classical pollutants whereas our monitoring campaigns measured a much larger range of species, which are helpful in constraining the numerical models. We also made air pollutant flux measurements at the IAP site and that can only be done with a tower. We have also been analysing data from the monitoring network in Beijing and agree that this is a valuable resource in model validation studies. Consequently, we have modified the final paragraph of Section 3.1.1 to read as follows:

“Measured ground level concentrations both from our campaign sites and the Beijing

monitoring network, together with source apportionment results, are compared with the predictions of a chemistry-transport model and used to provide a clear distinction between advected regional pollution and the impact of local sources. . .".

Comment 9: Lines 243-246" Previous studies of pollution in Beijing have shown that it is often perturbation of the physicochemical and dynamic atmospheric conditions that modulate the most severe air quality events, rather than changes in emissions, for example during the development of stable inversions or periods of strong photochemistry." The references are missing. Please consider to revise. The statement is hard to follow

Response: we revised this sentence to :

"Previous studies of pollution in Beijing have shown that the interactions of physical conditions, such as the development of temperature inversion in the atmosphere, and chemical processes, e.g., formation of secondary pollutants, such as aerosol particles and ozone that modulate the most severe air quality events."

Comment: Lines 280-283, " AIRLESS aimed to advance air quality and health research in China by bringing together two ïňĄelds of research that have made rapid advancements in recent years: measurements of a wide range of pulmonary and cardiovascular biomarkers in a panel study and personal monitoring of multiple air pollutants with high spatio-temporal resolution by sensor technology" In China or In Beijing and Neighboring Provinces? Why are the two sites' measurements helpful for the targets? Response: All work is done at Beijing. We recognize that we could have been more specific. We have revised this sentence as below. We have identified the reasons why the site measurements are useful for AIRLESS (see below).

" AIRLESS aimed to advance air quality and health research in Beijing by bringing together two ïňĄelds of research that have made rapid advancements in recent years: measurements of a wide range of pulmonary and cardiovascular biomarkers in a panel study and personal monitoring of multiple air pollutants with high spatio-temporal res-

olution by sensor technology”

“AIRLESS is also benefiting from the use of an extensive range of pollution metrics and source apportionment results collected from in the Themes 1 and 2 projects. ”

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