Overview: *Recent advances on the understanding of the Northern Eurasian environments and of the urban air quality in China - Pan Eurasian Experiment (PEEX) program perspective*

RC1: 'Comment on acp-2021-341', Anonymous Referee #1, 22 Jun 2021 reply

General Comments

This paper summarizes the results of a number of projects under the PEEX program, and pulls them into a single overview manuscript. The paper explores linkages between the various results and their connection to impacts, for example on human health. Overall, the paper contains a lot of potentially useful information with many associated references. However, I had a hard time understanding who the intended audience was. The paper could be a useful reference for scientists looking for information and related papers on environmental parameters in the Russian Arctic. However, in order to achieve this, some reorganization would be needed to help the reader find what they are looking for. Furthermore, some of the descriptions of the work lack detail. The specific comments below give examples of this, for the introduction, atmospheric composition, and synthesis sections.

We thank the reviewer for the apropos remarks. This paper, as the PEEX program (2012 -), is a multi-disciplinary research framework. This type of a framework is a relevant baseline if we, as a scientific community, aim to understand and find new feedbacks and interactions in the land-ocean-atmosphere continuum. For the future it is important to make perspective papers, where results from different disciplines are introduced to a wider scientific audience also with attempts to provide more holistic views on large-scale environmental challenges. The section structure of the paper follows the research agenda structure (land / atmosphere / aquatic / society systems and feedback & interactions) of the PEEX Science Plan. The result are reflected to this structure.

The geographical region discussed in this paper covers the Northern Eurasian region, in this case the boreal (taiga) forest zone, the Eurasian Arctic and China. China is identified as a relevant source area of the atmospheric pollution effecting the Arctic – boreal region, but also as one of a region of interest when discussing the global-scale environmental challenges and large-scale feedbacks. Referring to the so-called "Valeriepieris circle" map (2013) demonstrating that more people is "living inside a circle that outside it" (Danny Quah, London School of Economics and Political Science) concretizes the importance of China for the global climate change and air pollution challenge.

In addition to our responses to the specific comments, we have re-edited the abstract, added "table of contents" and a short description of our literature strategy to help the reader to understand better the chosen structure of the paper and our approach reporting the recent research results of the PEEX program. We frame our overview of the resent results by the PEEX community (including our co-authors), by the papers published in the ACP PEEX Part I special issue and by other relevant sources such as PEEX collaborating projects.

Specific comments

Line 87 (abstract): Include a clear statement of why a review paper is needed. Consolotation/linkages between datasets collected over large spatial area across multiple research themes?

We edited the abstract so that it will better describe the scope and context of the paper. We also added a "table of content together" with several cross-references.

Line 87 (abstract) and Line 106 (introduction): Why are urban megacities in China included in the paper? Would this fit better in a separate accompanying paper?

Chinese megacities and air quality have been identified as major environmental challenges in the PEEX Science Plan / program. We added the following text to clarify this aspect: "*The Pan-Eurasian Experiment (PEEX) Science Plan, released in 2015, addressed a need for a holistic system understanding and outlining the most urgent research needs for fast chancing in the Arctic-boreal region. Air quality in China together*

with long-range transport of the atmospheric pollutants were also indicated as one of the most crucial topics of the research agenda. These two geographical regions, the Northern Eurasian arctic–boreal region and China, especially the megacities, were identified as a "PEEX region". It is also important to recognize that the PEEX region science-based policy actions will have significant impacts in a global scale."

Line 128: What is the Silk Road Economic Belt Program?

We added the following text and reference:" *initiated by the President XI Jinping in 2013*" (Dave and Kobayashi 2018)

Line 152: I am a bit confused about the study area. Can a map be produced that summarizes the region of interest?

We added the following text and references: "*The PEEX study region consists of the Northern Eurasian Arctic and boreal (taiga) environments, thus the major geographical part of the environments is located in the Russian territory. China was added to the study area in 2013 as it was seen as locally and globally consequential region for climate change, air quality and long-term transport of atmospheric pollutants (Kulmala et al., 2015b; Lappalainen et al., 2016, 2018).*"

Line 533: In a number of places, more information/context is needed. For example, the discussion around line 533 indicates that wildfires caused CO2 increases. However, no information is provided on wildfire activity. Furthermore, it is not clear what methods are being used to detect increases over what averaging period.

We added the following text to clarify the situation: "*There are tendencies of a significant growth or suppression of soil CO_2 fluxes across different types of human impacts, such as forest fires, trampling, settlements, reindeer grazing and clearcuts on cryogenic ecosystems in Russia (Karelin et al., 2017). For example Ivanhov et al. (2019) analyzed CO_2 measurements during 2010-2017 and reported CO_2 concentration increases of 20 ppm in Tiksi at a coast of Laptev Sea and of 15 ppm at the Cape Baranov station. They also detected that wildfires in Siberia can lead to a parallel increase of the CO_2 concentration at the Russian Arctic. Furthermore, the measurements showed that the atmospheric CO_2 concentration increased on average by 2.0 ppm yr^{-1} during 2006-2013 in central Siberia, with a large inter-annual variations.*"

Line 566: Did wildfires impact CO concentrations?

Ratikin et al. (2018) concluded in their paper "Such pattern of changes in atmospheric composition especially in CO trends cannot be explained by growth of anthropogenic and/or wild-fires emissions. Possible reason of beginning of CO growth may be the change in the ratio of the natural sources and sinks with a significant role of atmospheric photochemical mechanisms."

Line 567: Why are CO and CH4 being compared and across different time periods? I'm having a hard time interpreting the results.

To avoid confusion, we removed information on CH_4 from this paragraph.

Line 574: What does 0.9-1.7% per year refer to? Background concentrations only? What about urban concentrations?

We added the urban concentration (Moscow) "*3.73%±0.39% per year*".

Line 581: What method was use to determine that monoterpenes are major contributors to O3 formation?

Berezina et al. (2019) evaluated the relative importance of VOCs in ground-level ozone formation by using ozone-forming potential (OFP) equation by Carter W. P. L. (1994). Development of ozone reactivity scales for volatile organic compounds. J. Air Waste Manage. Assoc., 44, 881–899.

Line 589: Discussion of stratospheric ozone should be in a separate paragraph and clearly identified as stratospheric to avoid confusion. Or perhaps in can be moved to the "UV variations" section?

We added cross-references between "2.2.1 Atmospheric composition and chemistry (Q4) / ozone" and "2.4.3 Natural hazards (Q12) / UV variation".

Line 598: Define threshold for NFP event days.

This is probably slightly too detailed information for this paper. We removed the two sentences related to this issue from the paper.

Line 627: Should the discussion on wildfire trends be included as a standalone section? I imagine that this is information that readers might be interested in (and want to find easily) for a variety of applications. Furthermore, this could then be cross-referenced from all sections discussing impact of wildfire trends on air quality.

We agree that the results / aspects related to "wildfires" or "fires" are included in several sections: "Black carbon and dust in the atmosphere and snow", "Anthropogenic emissions and environmental pollution in Russia", "Examples of air pollution episodes and related health effects" and "Future research needs from the system perspectives". The chosen approach builds on the PEEX research program structure. To avoid confusion, we added several cross-references between the relevant sections. In addition, we discuss the various perspectives and importance of fires in the section "*Future research needs from the system perspectives*"

Line 718: I feel like the section **"methodologies and model developments"** could be split up and moved into the relevant section. For example, readers interested in NFP may not think to read this part of the paper.

We would prefer to keep this section as it is. However, we understand the critics so, to make it easier for a reader to find relevant information, we added the "table of content" and cross-references between the sections "*Methodological and model developments related to atmospheric chemistry and physics*" and "*2.2.2 Urban air quality and megacities*".

Line 853: Is there trend information for NOx and SO2 emissions in the area?

We added information on NO_2 and SO_2 trends based on Wang et al. (2019).

Line 859: "relative frequent occurance" -- compared to what?

We modified this part of the text into the following form: "*Compared with most other urban environments investigated so far, measurements in urban China demonstrated a relatively frequent occurrence of atmospheric new particle formation (NPF), and the observed NPF events were typically characterized by high particle formation rates and strongly size-dependent growth of newly-formed particles (Kulmala et al., 2016b; Wang et al., 2017b; Chu et al., 2019).*"

Line 883: "... were analyzed for North China..." what method/data were used?

The data based on "monthly satellite and ground observed atmospheric constituents" were used.

Line 936: This paragraph and the ones after it contains a lot of information about air quality that is outside urban environments, as well as information on deposition and emissions. If a reader was seeking this information, they would not think to look under "**2.2.2 Urban air quality and megacities**" Reorganization of content is needed.

We added cross- references to clarify the content between these two sections.

Line 975: "... emissions of PM were observed..." what method was used?

The paragraph was updated as the following: "The annual yearbook "The State of Atmospheric Pollution in Cities on the Territory of Russia" for 2018 (Roshydromet and GGO, 2019) sates the highest atmospheric emissions of PM were observed in Siberian and Ural cities. In Novokuznetsk and Omsk, the observed PM was the highest (> 30 000 tons per year) while emissions from other cities such as Angarsk and Chelyabinsk were lower (< 20 000 tons per year). Note that in the 2015-2019 yearbooks, emissions from only stationary sources were provided due to revisions (approved and implemented in November 2019 by the Russian Ministry of Natural Resources and Ecology, MNRE) of methods applied for estimation of emissions into the atmosphere from mobile sources. Depending on a source type, different methods to calculate emissions are applied (MNRE, 2019). For the gaseous compounds, such as SO_2, the maximum emissions included very high from Siberian cities (e.g. Norilsk, Novosibirsk, Novokuznetsk, Omsk, Ufa, Irkutsk, Angarsk) and from North-West Russia cities (Zapolyarny, Nickel, Monchegorsk). High NO_2 emissions were observed in Novosibirsk, Omsk, Angarsk and Chelyabinsk. The CO integral urban emissions depend on a city size. These varied from less than 10 Gg yr^{-1} (for small regional centers like Vladimir, Kursk, Samara) to 406 and 804 Gg yr^{-1} for large metropolitan areas such as St. Petersburg and Moscow. As a whole, an analysis of spatio-temporal variation of trace gases in the boundary layer over Russian cities indicated significant emission variations between the urban environments and remote sites (Elansky et al., 2016)."

& 2 references were added:

Roshydromet and GGO (2019): The State of Atmospheric Pollution in Cities on the Territory of Russia for 2018. Yearbook. Federal Service on Hydrometeorology and Monitoring Environment, Roshydromet & A.I. Voeikov Main Geophisical Observatory, ISBN 978-5-9500883-8-4, St.Petersburg, 250 p., In Russian (http://voeikovmgo.ru/images/stories/publications/2019/ejegodnik_zagr_atm_2018+.pdf)

MNRE (2019): Methods for calculating emissions of pollutants into the atmosphe from stationary sources. Ministry of Natural Resources and Ecology. In Russian (https://www.mnr.gov.ru/docs/metodiki_rascheta_vybrosov_vrednykh_zagryaznyayushchikh_veshchestv_v_atmosfernyy_vozdukh_statsionarn/perechen)

Line 980: CO emissions are discussed. Why isn't this included (or cross-referenced) in the section describing ambient CO?

This paragraph discusses cities that are emission hot spots for different pollutants, including CO. Emission hotspots are a very different topic from ambient concentrations trends of the same pollutants (as discussed earlier in the paper in case of CO).

Line 1653: Should "UV variations" be linked to the discussion of stratospheric O3 (line 589)

We added cross- references between these sections.

Line 1665: "Air pollution and related health effects" - the discussion of air pollution in Bergen is very specific and also does not have any direct ties to human health. Perhaps this discussion should be moved into the section about atmospheric composition so that a reader interested in meteorological impacts can find it easily?

To clarify this, we modified the title of the paragraph as following "*Examples of air pollution episodes…*".

Line 1665: "Air pollution and related health effects" - the scope of this section seems vary narrow and focused on some example studies. What about the broad picture including all the species/locations monitored through the project? For example, there is no mention of urban air quality in megacities in this section.

Unfortunately, it has not yet been possible to carry out this type of a wide systematic approach under the PEEX framework. There is still a way to go towards a more coordinated observation system, which would allow us this type of reporting.

Line 1757: Why is BC highlighted as the most important air quality pollutant here for future study in relation to human health?

We fully agree. We removed "black carbon" from the text.

Line 1760: "... was found to vary from serious effects on population health..." I didn't see this evidence of health studies in the paper. Perhaps rephrase to something like "Air pollution was at concentrations that can be harmful to human health"?

We removed "population health" and edited the text according to this recommendation.

Technical comments

- Quite a few grammatical errors (recommend copy-editing).

  We have carefully checked the language and grammar of the latest version of the manuscript.

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