**Authors' comments on Review #2**

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**"Russia's black carbon emissions: focus on diesel sources" by N. Kholod et al.**

We thank the referee for the helpful comments.

**Comment 1:** Lines 181-184: authors claim "Russia does not have large-scale production of diesel passenger cars", but also say 98% of diesel cars were either imported or produced in Russia by foreign companies. Not sure how this affects the overall emissions, but what fraction of on-road diesel cars are made in Russia by Russian or non-Russian companies? (Also, since this paper focuses on diesel cars, the line about "foreign-make cars, both gasoline and diesel" is superfluous.)

**Answer:** The Russian vehicle registry shows the following data about registered cars: vehicle type, manufacturer, year of manufacturing, fuel type, emission (Euro) class, and ownership type. The registry data do not allow for distinguishing between imported vehicles and those produced in Russia by foreign companies.

Changes to the text:
We have deleted the phrase "Russia does not have large-scale production of diesel passenger cars" to avoid confusion.

Thank you for pointing out that the line about "foreign-make cars, both gasoline and diesel" is superfluous. We have deleted the line.

**Comment 2:** Lines 203-204: what higher emissions standards do imported diesel vehicles meet? Euro 6? Or were imported vehicles always produced to meet a higher standard than necessary for Russia?

**Answer:** Russian mainly imports diesel vehicles from Japan, the European Union, and the United States, with a smaller number of vehicles from South Korea and China. The imported vehicles might meet the emissions standards of the manufacturing countries. Russia adopted European emissions standards about 10 years after the EU, Japan, and the US. As a result, vehicles produced abroad and imported to Russia might meet higher emission standards. However, there is a chance that vehicles produced in foreign countries for the Russian market can only meet the Russian standards. Imported USED vehicles do meet higher emissions standards than necessary in Russia. For example, the EU implemented the Euro 5 standard in 2005 and Euro 6 in 2014 while Russia implemented the Euro 5 standard only in 2016. Among all imported used cars to Russia in 2015, over 70% were vehicles made by Toyota, Nissan, Volkswagen, and Renault.

As a result, when analyzing the distribution by emission standard we rely on the data from the registry.

**Correction to the text:**
“In addition, a significant number of diesel vehicles were imported in Russia, and as a result they might meet higher emission standards.”

**Comment 3:** Lines 240-251: The authors rely on the Bond et al. (2004) assumption of super-emitter fraction as 10%, even though they cite several more recent studies that show superemitters can be as high as 13-15% of the fleet, even in California. Given the lack of studies in Russia, and the authors’ literature survey of the Russian fleet (36% of trucks and 23% of buses older than 20 years), using the old Bond et al. (2004) assumption will likely bias their emissions inventory low as the authors acknowledge at the end. The authors should investigate the sensitivity of their results to this fraction, and perhaps try higher values (15-30%) for the super-emitter fraction.

Answer:
We have modified the text to assume that the share of superemitters is 15%. In the sensitivity analysis, we assume that the share of superemitters in the diesel fleet ranges between 10% and 20%.

Changes to the text: please see answer to Comment 7.

**Comment 4:** Lines 286-287: What is the basis for their assumption of 40-20-40 on urban roads, rural roads, and highways?

Answer:
Thank you for pointing this out. The first reviewer also asked the same question. We updated our assumptions on the distribution of vehicle-kilometers traveled on urban roads, rural roads, and highways. The share of vehicle-kilometers traveled on urban roads is taken from the ICCT Roadmap model (http://www.theicct.org/global-transportation-roadmap-model), and the rest is divided by 40:60 between rural roads and highways (our assumption based on expert judgement).

Changes to the text:
“The share of vehicle-kilometers traveled (vkt) on urban roads is taken from the ICCT Roadmap model. The share of vkt on urban roads is 75% for cars, light commercial vehicles, and buses and 50% for trucks. The rest of VKT the rest is divided by 40:60 between rural roads and highways.”

**Comment 5:** The authors use NIIAT data for on-road emission factors, but the actual source of that data is not clear – are these based on measurements or on estimates based on emissions standards? The authors present the data used; a brief explanation of the source methodology will be helpful, since these NIIAT publications do not appear to be easily accessible online.

Answer:
The NIIAT data on emission factors for Russian models are based on measurement. NIIAT has been working on emission methodologies since the 1980s, and tests for vehicles without emission controls (Euro 0), Euro 1 , and Euro 2 were conducted together with the Environmental Department of the Scientific and Research Vehicle Testing Center located in the Moscow region (Donchenko, V., Kunin, Y., Ruzski, A., Vizhenski, V., 2014. Evaluation of road transport effect on atmospheric air: method of emission computations and use of results. Transport Research Arena, Paris. Available at http://tra2014.traconference.eu/papers/pdfs/TRA2014_Fpaper_19875.pdf).
For foreign models, NIIAT uses emission factors from the European EMEP/CORINAIR guidebook. For its emission calculation methodologies, NIIAT blended emission factors for Russian and European vehicles to reflect the composition of the Russian on-road fleet.

The NIIAT methodologies are not available in English. We worked directly with NIIAT experts and received methodological explanations during multiple meetings. We also presented the results of our emission calculations at a meeting in the NIIAT office in Moscow.

Changes to the text:
"Based on vehicle driving tests conducted with Scientific and Research Vehicle Testing Center, NIIAT has developed emission factors for Russian models. For foreign-made vehicles, NIIAT relies on data from the European EMEP/CORINAIR guidebook. Thus, Russian-specific emission factors for $PM_{2.5}$ in the NIIAT methodologies are based on the average for every vehicle type and emission class on Russian roads."

**Comment 6:** The conclusions should note that the results exclude military diesel usage emissions; in particular, these could be large sources of sulfate PM, and possibly also BC.

Answer: we updated the text in conclusion as follows:
"These results do not include emissions from military diesel usage. Military vehicles can be a large source of BC emissions given that they use high-sulfur diesel."

**Comment 7:** While the authors present a comprehensive list of potential uncertainties with their emissions inventory estimate, they don't propagate the uncertainties through, which would be helpful. From their list, it appears the emission factors could produce uncertainties of +/-30% or so, while the bias due to low super-emitter fraction (10% when 15-20% might be more appropriate) could increase the overall BC estimate by as much as 40%!

Answer: For sensitivity analysis we assume that the share of superemitters in the total diesel fleet is in the range of 10%-20% with the central estimate of 15%. We also propagated the uncertainties for on-road vehicles and off-road diesel sources.

Changes to the text:
"For on-road vehicles, three major sources of uncertainty were considered: the share of superemitters in the fleet, average annual distance traveled, and emissions factors for normal vehicles and superemitters. Supplement Table S10 shows the assumption for uncertainty calculations for on-road vehicles.

The central value of BC emissions from on-road vehicles in 2014 is 20.7 Gg with an uncertainty range of -10.2 Gg and + 7.3 Gg. The central value of OC emissions is 10.5 Gg with an uncertainty range of -4.2 Gg and + 3.2 Gg.

Supplement Table S10. Uncertainty estimates for BC and OC emissions from on-road vehicles

| | Central | Minimum | Maximum |
|---|---|---|---|
| Share of superemitters | 15% | 10% | 20% |
| Annual distance traveled, km | Avtostat | NIIAT | Avtostat |
| Cars | 15 000 | 15 000 | 15 000 |
| LCVs | 55 000 | 30 000 | 55 000 |
| Trucks | 63 000 | 45 000 | 63 000 |
| Buses | 65 000 | 50 000 | 65 000 |
| PM emissions factor | COPERT | COPERT -20% | COPERT +20% |
| BC/PM speciation ratio | COPERT | COPERT -10% | COPERT +10% |
| Emissions, Gg | | | |
| BC normal | 11.8 | 7.1 | 12.3 |
| BC superemitters | 8.9 | 3.4 | 15.7 |
| **BC total** | **20.7** | **10.5** | **28.0** |
| OC normal | 5.6 | 4.3 | 5.0 |
| OC superemitters | 4.9 | 2.1 | 8.7 |
| **OC total** | **10.5** | **6.4** | **13.7** |

The uncertainty in BC emissions from off-road sources is estimated in the range from 19.2 Gg to 42.1 Gg (or -33%/+48%) with the central value of 20.7 Gg. OC emissions from off-road engines are in the range from 4.5 Gg to 9.8 Gg with the central value of 6.7 Gg.

The total emissions from diesel sources in Russia are estimated to be 49.2 Gg of BC and 17.2 Gg of OC in 2014."

**Comment 8:** One final concern is that the current submission has no explanation of differences between this paper, and the on-road BC emissions estimate published earlier by the first author (Kholod and Evans, http://dx.doi.org/10.1016/j.envsci.2015.10.017 ) While the current paper is more detailed, the bottom line figure appears the same - in 2015, Figure 1 of Kholod and Evans shows 20,000 tons of BC from on-road Russian sources similar to the current paper. Maybe the complicated model of the current submission is not needed?!

Answer:
There several important differences between this article and Kholod and Evans (2016).

- Kholod and Evans (2016) use the Global Change Assessment Model (GCAM) to build a forecast for BC emissions from on-road transport (Figure 1). The model calculates emissions in 5-year time intervals. Though the model is a powerful tool to project BC emissions, the model does not distinguish between diesel and gasoline vehicles and does not show the BC distribution by emission standards.
- The current study uses activity-based emissions factors (g/kg fuel). As we show in the article, large uncertainty exists in the fuel consumption by on-road vehicles (in the range from 11 million tons to 22 million tons). In the current study, the emission calculations for on-road vehicles do not use fuel data. Instead we use data on annual distance traveled and activity-based emission factors (g/km). This approach allows us to calculate emissions by vehicle type and emission standard. We also account for superemitters.

Changes to the text:
"Similarly, Kholod and Evans (2016) use the Global Change Assessment Model (GCAM) to build a forecast for BC emissions from on-road transport in Russia. Total BC emissions from on-road transport were estimated to be about 20.0 Gg in 2015. The model, however, does not calculate emissions from vehicles by emission standard, which is important for developing emission reduction strategies."