Response to Reviewer #2

We thank the reviewer for the evaluation of our work. Below we give a detailed response to each of the concerns raised by the reviewer. Reviewer's comments are in regular font and our replies are in bold font.

This manuscript examines black carbon (BC) aerosol concentration in South Asia and contributions from different sectors during the three-month ICARB campaign period. They find that anthropogenic and biomass burning emissions contribute to 70% and 28% of the BC surface concentration on average, and the residential and industrial sectors are major anthropogenic sources in most of the region. In addition, the long range transport contributes up to 30% of BC in eastern and western India. The model experiment is well designed and the model results are evaluated with observations available. The manuscript is organized in a clear structure and reads well.

We appreciate the summary evaluation

However, overall it does not offer much new insights. The authors may attempt to provide a more quantitative breakdown of contributions by different emission sectors to BC surface concentrations over this region. With only three-month simulations, as noted by the authors, I am not sure that it is very useful for that matter, because there are large temporal variations in aerosol emissions and regional meteorology that could affect the distribution and transport of aerosols in this region. I strongly recommend for longer-term simulations for at least a year, and seasonal analysis is needed. In particular for insights on developing mitigation strategies, multiple –year trend analysis of emission sector changes and meteorology changes may be needed.

This study offers three new insights. First, the performance of WRF-Chem model in reproducing the observed distribution of BC over the Bay of Bengal and the Arabian Sea has been validated and thus provides confidence in using the model for future studies over this region, where some of the earlier models have under-performed. Second, it provides answer to the question of why aerosol loading in the Bay of Bengal is much higher compared to the Arabian Sea as we have shown that the Bay of Bengal is affected by outflow from regions with stronger anthropogenic emissions. It is important to address this aspect because the stronger aerosol radiative forcing over the Bay of Bengal has been suggested to potentially perturb the monsoonal circulation and rainfall over South Asia [*Bollasina et al.,* 2013]. Third, we have quantified the contribution of different emission sources to BC mass concentrations over South Asian region and have shown that BC mass concentrations in different regions of South Asia cannot be inferred directly from only the emission inventories, as regional transport can significantly perturb the relationship between BC emissions and surface BC mass concentration. These objectives are now highlighted in the revised manuscript.

We agree with the reviewer that we need long-term simulations to account for seasonal changes of aerosol emissions and meteorology for source contribution analysis and we have noted this requirement in summary of the revised manuscript. However, to understand the effect of seasonal changes in BC emissions and meteorology on the source contribution analysis, we recently conducted a high resolution (10 km) year-long simulation of BC for the year 2011. We performed a detailed evaluation of the model's ability in simulating the seasonal cycle of BC over South Asia, examined relative importance of seasonal changes in emissions and meteorology in controlling BC seasonality and analyzed seasonal changes in the source contributions and regional transport of BC over this region. However, including the year-long analysis would be too much to be added to the current paper but instead is presented in a separate paper (Kumar et al., 2015). The main conclusions of that paper are: (i) WRF-Chem is able to reproduce seasonal cycle of BC over most parts of India; (ii) seasonal cycle of BC in India is controlled mainly by seasonal changes in meteorology; (iii) anthropogenic sources provide most of the BC over India throughout the year and (iv) regional transport remains a key process throughout the year, however, source-receptor relationships change with season.

Another concern is that all the attribution analysis seems to be done for the surface concentrations of BC only. The importance of understanding surface BC distribution is not discussed. Radiative effects of BC are important, but they depend on other BC properties as well, such as vertical distribution, particle size, mixing state, which are not discussed in the paper. It looks like a solid evaluation of BC surface concentrations simulated by WRF-Chem but falls short of scientific focus.

The analysis was restricted to the surface concentrations, to put our results in context of the air quality. We agree that it is important to examine radiative effects of BC, for which the vertical distribution, mixing state etc are also important; however, we did not want to jump straight to such calculations without further evaluating the model's ability to simulate aerosol chemical composition and optical properties. To this end, another study is in progress, which is using ICARB observations and aerosol optical depth retrievals from AERONET and different satellites (MODIS, MISR and SeaWiFS) to evaluate WRF-Chem simulated aerosol chemical composition and optical properties. After building sufficient confidence in the model's representation of aerosol optical properties, we will examine the radiative effects of BC as well as other aerosols.

Minor comments:

1. Page 30729, Line 7: first-time use of SD. It needs to be spelt out;

We have spelled it out.

2. Line 13: "70%";

Changed.

3. Line 18: "the southern Peninsula";

Changed.

4. Line 19: “contributes”

Changed.

5. Page 30730, lines 6-7: “wet or dry deposition at the surface” reads like wet deposition at the surface?

The sentence has been split into the following two sentences. “BC has very low chemical reactivity in the atmosphere and is removed primarily by the wet and dry depositions at the surface. However, the wet deposition represents 70-85% of the global total loss”.

6. Line 10: “variations”

Changed.

7. Line 13: “emissions”

Changed.

8. Line 19: do you mean, atmospheric heating over the elevated Himalayas?

Yes. The sentence has been revised.

9. Page 30731, Line 17: first-time use of “BoB”, and “AS”. It needs to be spelt out;

Changed.

10. Page 30732, line 2: ad “geographical” before “distribution”

Added.

11. Page 30735, line 13: why “20 January 2011”

Sorry about this. We meant 18 March 2006, the start date of the campaign. This is changed now.

12. Page 30736, line 6: “SD” of observation or model results?

We meant SD of measurements. This line has been rewritten now.

13. Line 7: add “of model results” after SD

Added.

14. Page 30737, line 8: “distributions”

Changed.

15. Line 9: add “at” before “high altitude cleaner sites”

Added.

16. Line 10: replace “like right” with “reasonable”

Changed.

References

Bollasina, M. A., Ming, Y., and Ramaswamy, V.: Earlier onset of the Indian monsoon in the late twentieth century: The role of anthropogenic aerosols, Geophys. Res. Lett., 40, 3715–3720, doi:10.1002/grl.50719, 2013.

Kumar, R., Barth, M. C., Pfister, G. G., Nair, V. S., Ghude, S. D. and Ojha, N.: What controls the seasonal cycle of BC in India?, J. Geophys. Res., submitted manuscript, 2015.